

# **Analysis And Control Of Complex Dynamical Systems Robust Bifurcation Dynamic Attractors And Network Complexity Mathematics For Industry**

Analysis and Control of Complex Dynamical Systems Robust Bifurcation, Dynamic Attractors, and Network Complexity Springer

A new edition of a classic textbook on complex analysis with an emphasis on translating visual intuition to rigorous proof.

This book consists of lecture notes of a summer school named after the late Jacques Louis Lions. The summer school was designed to alert both Academia and Industry to the increasing role of multidisciplinary methods and tools for the design of complex products in various areas of socio-economic interest. This volume offers the reader a rare opportunity of being exposed to the presentation of real industrial and societal problems together with the relevant innovative methods used.

New statements of problems arose recently demanding thorough analysis. Notice, first of all, the statements of problems using adjoint equations which gradually became part of our life. Adjoint equations are capable to bring fresh

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ideas to various problems of new technology based on linear and nonlinear processes. They became part of golden fund of science through quantum mechanics, theory of nuclear reactors, optimal control, and finally helped in solving many problems on the basis of perturbation method and sensitivity theory. To emphasize the important role of adjoint problems in science one should mention four-dimensional analysis problem and solution of inverse problems. This range of problems includes first of all problems of global climate changes on our planet, state of environment and protection of environment against pollution, preservation of the biosphere in conditions of vigorous growth of population, intensive development of industry, and many others. All this required complex study of large systems: interaction between the atmosphere and oceans and continents in the theory of climate, cenoses in the biosphere affected by pollution of natural and anthropogenic origin. Problems of local and global perturbations and models sensitivity to input data join into common complex system.

This book provides a coherent framework for understanding the essence of complex systems and the nature of digital transformations, analyzes challenges of and patterns in innovative development, and shares a wealth of insights and best practices, resulting in the most extensive coverage of the topic available. In

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particular, the book's cutting-edge contributions, prepared by scientists, engineers, and field experts, focus on the design, implementation, and evaluation of practical interventions that promote the innovative and sustainable development of complex systems. In addition to sharing a rich collection of cases from around the world, they provide a broad interdisciplinary analysis of collaboration mechanisms, theories and approaches to support and accelerate the development of complex systems.

From foundations to state-of-the-art; the tools and philosophy you need to build network models.

This volume presents a theoretical framework and control methodology for a class of complex dynamical systems characterised by high state space dimension, multiple inputs and outputs, significant nonlinearity, parametric uncertainty, and unmodeled dynamics. A unique feature of the authors' approach is the combination of rigorous concepts and methods of nonlinear control (invariant and attracting submanifolds, Lyapunov functions, exact linearisation, passification) with approximate decomposition results based on singular perturbations and decentralisation. Some results published previously in the Russian literature and not well known in the West are brought to light. Basic concepts of modern nonlinear control and motivating examples are given.

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Audience: This book will be useful for researchers, engineers, university lecturers and postgraduate students specialising in the fields of applied mathematics and engineering, such as automatic control, robotics, and control of vibrations.

This book is the first to report on theoretical breakthroughs on control of complex dynamical systems developed by collaborative researchers in the two fields of dynamical systems theory and control theory. As well, its basic point of view is of three kinds of complexity: bifurcation phenomena subject to model uncertainty, complex behavior including periodic/quasi-periodic orbits as well as chaotic orbits, and network complexity emerging from dynamical interactions between subsystems. Analysis and Control of Complex Dynamical Systems offers a valuable resource for mathematicians, physicists, and biophysicists, as well as for researchers in nonlinear science and control engineering, allowing them to develop a better fundamental understanding of the analysis and control synthesis of such complex systems.

Complexity is emerging as a post-Newtonian paradigm for approaching a large body of phenomena of concern at the crossroads of physical, engineering, environmental, life and human sciences from a unifying point of view. This book outlines the foundations of modern complexity research as it arose from the cross-fertilization of ideas and tools from nonlinear science, statistical physics and

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numerical simulation. It is shown how these developments lead to an understanding, both qualitative and quantitative, of the complex systems encountered in nature and in everyday experience and, conversely, how natural complexity acts as a source of inspiration for progress at the fundamental level. Originally published: Boston: Academic Press, 1991. With new errata list. This elementary book provides some state-of-the-art research results on broad disciplinary sciences on complex networks. It presents an in-depth study with detailed description of dynamics, controls and applications of complex networks. The contents of this book can be summarized as follows. First, the dynamics of complex networks, for example, the cluster dynamic analysis by using kernel spectral methods, community detection algorithms in bipartite networks, epidemiological modeling with demographics and epidemic spreading on multi-layer networks, are studied. Second, the controls of complex networks are investigated including topics like distributed finite-time cooperative control of multi-agent systems by applying homogenous-degree and Lyapunov methods, composite finite-time containment control for disturbed second-order multi-agent systems, fractional-order observer design of multi-agent systems, chaos control and anticontrol of complex systems via Parrondos game and many more. Third, the applications of complex networks provide some applicable carriers, which

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show the importance of theories developed in complex networks. In particular, a general model for studying time evolution of transition networks, deflection routing in complex networks, recommender systems for social networks analysis and mining, strategy selection in networked evolutionary games, integration and methods in computational biology, are discussed in detail.

Far from being separate entities, many social and engineering systems can be considered as complex network systems (CNSs) associated with closely linked interactions with neighbouring entities such as the Internet and power grids. Roughly speaking, a CNS refers to a networking system consisting of lots of interactional individuals, exhibiting fascinating collective behaviour that cannot always be anticipated from the inherent properties of the individuals themselves. As one of the most fundamental examples of cooperative behaviour, consensus within CNSs (or the synchronization of complex networks) has gained considerable attention from various fields of research, including systems science, control theory and electrical engineering. This book mainly studies consensus of CNSs with dynamics topologies - unlike most existing books that have focused on consensus control and analysis for CNSs under a fixed topology. As most practical networks have limited communication ability, switching graphs can be used to characterize real-world communication topologies, leading to a wider

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range of practical applications. This book provides some novel multiple Lyapunov functions (MLFs), good candidates for analysing the consensus of CNSs with directed switching topologies, while each chapter provides detailed theoretical analyses according to the stability theory of switched systems. Moreover, numerical simulations are provided to validate the theoretical results. Both professional researchers and laypeople will benefit from this book.

"This book is mainly focused on the recent achievements and applications in the field of control and analysis for complex systems with a special emphasis on how to solve various control design and/or observer design problems for nonlinear systems, interconnected systems, and singular systems and involves modeling, non-ideal systems and applications, synchronization, and control for nonlinear systems, such as mechanical, electrical, electromechanical, mechatronic, and very complex systems"-- Energy exchange is a major foundation of the dynamics of physical systems, and, hence, in the study of complex multi-domain systems, methodologies that explicitly describe the topology of energy exchanges are instrumental in structuring the modeling and the computation of the system's dynamics and its control. This book is the outcome of the European Project "Geoplex" (FP5 IST-2001-34166) that studied and extended such system modeling and control methodologies. This unique book starts from the basic concept of port-based modeling, and extends it to port-Hamiltonian systems. This generic paradigm is applied to various physical domains, showing its power and

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unifying flexibility for real multi-domain systems.

Modeling of Complex Systems: An Introduction describes the framework of complex systems. This book discusses the language of system theory, taxonomy of system concepts, steps in model building, and establishing relations using physical laws. The statistical attributes of data, generation of random numbers fundamental problems of recognition, and input-output type models are also elaborated. This text likewise covers the optimization with equality constraints, transfer function models, and competition among species. This publication is written primarily for senior undergraduate students and beginning graduate students who are interested in an interdisciplinary or multidisciplinary approach to large-scale or complex problems of contemporary societal interest.

Nonlinear dynamics of complex processes is an active research field with large numbers of publications in basic research, and broad applications from diverse fields of science. Nonlinear dynamics as manifested by deterministic and stochastic evolution models of complex behavior has entered statistical physics, physical chemistry, biophysics, geophysics, astrophysics, theoretical ecology, semiconductor physics and -optics, etc. This field of research has induced a new terminology in science connected with new questions, problems, solutions and methods. New scenarios have emerged for spatio-temporal structures in dynamical systems far from equilibrium. Their analysis and possible control are intriguing and challenging aspects of the current research. The

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duality of fundamental and applied research is a focal point of its main attractivity and fascination. Basic topics and foundations are always linked to concrete and precise examples. Models and measurements of complex nonlinear processes evoke and provoke new fundamental questions that diversify and broaden the mathematical concepts and tools. In return, new mathematical approaches to modeling and analysis enlarge the scope and efficiency of applied research.

This book presents two nonlinear control strategies for complex dynamical networks. First, sliding-mode control is used, and then the inverse optimal control approach is employed. For both cases, model-based is considered in Chapter 3 and Chapter 5; then, Chapter 4 and Chapter 6 are based on determining a model for the unknown system using a recurrent neural network, using on-line extended Kalman filtering for learning. The book is organized in four sections. The first one covers mathematical preliminaries, with a brief review for complex networks, and the pinning methodology. Additionally, sliding-mode control and inverse optimal control are introduced. Neural network structures are also discussed along with a description of the high-order ones. The second section presents the analysis and simulation results for sliding-mode control for identical as well as non-identical nodes. The third section describes analysis and simulation results for inverse optimal control considering identical or non-identical nodes. Finally, the last section presents applications of these schemes, using gene regulatory networks and microgrids as examples.

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Comprehension of complex systems comes from an understanding of not only the behavior of constituent elements but how they act together to form the behavior of the whole. However, given the multidisciplinary nature of complex systems, the scattering of information across different areas creates a chaotic situation for those trying to understand possible solutions and applications. Modeling and Control of Complex Systems brings together a number of research experts to present some of their latest approaches and future research directions in a language accessible to system theorists. Contributors discuss complex systems such as networks for modeling and control of civil structures, vehicles, robots, biomedical systems, fluid flow systems, and home automation systems. Each chapter provides theoretical and methodological descriptions of a specific application in the control of complex systems, including congestion control in computer networks, autonomous multi-robot docking systems, modeling and control in cancer genomics, and backstepping controllers for stabilization of turbulent flow PDEs. With this unique reference, you will discover how complexity is dealt with in different disciplines and learn about the latest methodologies, which are applicable to your own specialty. The balanced mix of theory and simulation presented by Modeling and Control of Complex Systems supplies a strong vehicle for enlarging your knowledge base a fueling future advances and incredible breakthroughs. "Complex Systems: Fractionality, Time-delay and Synchronization" covers the most recent developments and advances in the theory and application of complex systems in these areas.

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Each chapter was written by scientists highly active in the field of complex systems. The book discusses a new treatise on fractional dynamics and control, as well as the new methods for differential delay systems and control. Lastly, a theoretical framework for the complexity and synchronization of complex system is presented. The book is intended for researchers in the field of nonlinear dynamics in mathematics, physics and engineering. It can also serve as a reference book for graduate students in physics, applied mathematics and engineering. Dr. Albert C.J. Luo is a Professor at Southern Illinois University Edwardsville, USA. Dr. Jian-Qiao Sun is a Professor at the University of California, Merced, USA.

According to the National Institute of Health, a genome-wide association study is defined as any study of genetic variation across the entire human genome that is designed to identify genetic associations with observable traits (such as blood pressure or weight), or the presence or absence of a disease or condition. Whole genome information, when combined with clinical and other phenotype data, offers the potential for increased understanding of basic biological processes affecting human health, improvement in the prediction of disease and patient care, and ultimately the realization of the promise of personalized medicine. In addition, rapid advances in understanding the patterns of human genetic variation and maturing high-throughput, cost-effective methods for genotyping are providing powerful research tools for identifying genetic variants that contribute to health and disease. This burgeoning science merges the principles of statistics and genetics studies to make sense of the vast amounts of information available with the mapping of genomes. In order to make the most of the information available, statistical tools must be tailored and translated for the analytical issues which are original to large-scale association studies. Analysis of Complex Disease Association

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Studies will provide researchers with advanced biological knowledge who are entering the field of genome-wide association studies with the groundwork to apply statistical analysis tools appropriately and effectively. With the use of consistent examples throughout the work, chapters will provide readers with best practice for getting started (design), analyzing, and interpreting data according to their research interests. Frequently used tests will be highlighted and a critical analysis of the advantages and disadvantage complimented by case studies for each will provide readers with the information they need to make the right choice for their research. Additional tools including links to analysis tools, tutorials, and references will be available electronically to ensure the latest information is available. Easy access to key information including advantages and disadvantage of tests for particular applications, identification of databases, languages and their capabilities, data management risks, frequently used tests Extensive list of references including links to tutorial websites Case studies and Tips and Tricks

Analysis and Control of Boolean Networks presents a systematic new approach to the investigation of Boolean control networks. The fundamental tool in this approach is a novel matrix product called the semi-tensor product (STP). Using the STP, a logical function can be expressed as a conventional discrete-time linear system. In the light of this linear expression, certain major issues concerning Boolean network topology – fixed points, cycles, transient times and basins of attractors – can be easily revealed by a set of formulae. This framework renders the state-space approach to dynamic control systems applicable to Boolean control networks. The bilinear-systemic representation of a Boolean control network makes it possible to investigate basic control problems including controllability, observability, stabilization,

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disturbance decoupling etc.

This book focuses on the stability of the dynamical neural system, synchronization of the coupling neural system and their applications in automation control and electrical engineering. The redefined concept of stability, synchronization and consensus are adopted to provide a better explanation of the complex neural network. Researchers in the fields of dynamical systems, computer science, electrical engineering and mathematics will benefit from the discussions on complex systems. The book will also help readers to better understand the theory behind the control technique and its design.

This book systematizes recent research work on variable-structure control. It is self-contained, presenting necessary mathematical preliminaries so that the theoretical developments can be easily understood by a broad readership. The text begins with an introduction to the fundamental ideas of variable-structure control pertinent to their application in complex nonlinear systems. In the core of the book, the authors lay out an approach, suitable for a large class of systems, that deals with system uncertainties with nonlinear bounds. Its treatment of complex systems in which limited measurement information is available makes the results developed convenient to implement. Various case-study applications are described, from aerospace, through power systems to river pollution control with supporting simulations to aid the transition from mathematical theory to engineering practicalities. The book addresses systems with nonlinearities, time delays and interconnections and considers issues such as stabilization, observer design, and fault detection and isolation. It makes extensive use of numerical and practical examples to render its ideas more readily absorbed. Variable-Structure Control of Complex Systems will be of interest to academic researchers studying control theory

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and its application in nonlinear, time-delayed and modular large-scale systems; the robustness of its approach will also be attractive to control engineers working in industries associated with aerospace, electrical and mechanical engineering.

Analysis, Control and Optimization of Complex Dynamic Systems gathers in a single volume a spectrum of complex dynamic systems related papers written by experts in their fields, and strongly representative of current research trends. Complex systems present important challenges, in great part due to their sheer size which makes it difficult to grasp their dynamic behavior, optimize their operations, or study their reliability. Yet, we live in a world where, due to increasing inter-dependencies and networking of systems, complexity has become the norm. With this in mind, the volume comprises two parts. The first part is dedicated to a spectrum of complex problems of decision and control encountered in the area of production and inventory systems. The second part is dedicated to large scale or multi-agent system problems occurring in other areas of engineering such as telecommunication and electric power networks, as well as more generic context.

Complex systems in nature are those with many interacting parts, all capable of influencing global system outcomes. There is a growing body of research that has modeled sport performance from a complexity sciences perspective, studying the behavior of individual athletes and sports teams as emergent phenomena which self-organise under interacting constraints. This book is the first to bring together experts studying complex systems in the context of sport from across the world to collate core theoretical ideas, current methodologies and

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existing data into one comprehensive resource. It offers new methods of analysis for investigating representative complex sport movements and actions at an individual and team level, exploring the application of methodologies from the complexity sciences in the context of sports performance and the organization of sport practice. *Complex Systems in Sport* is important reading for any advanced student or researcher working in sport and exercise science, sports coaching, kinesiology or human movement.

The thesis considers the stability analysis of certainty equivalence adaptive controllers applied in various complex situations.

This volume presents a collection of contributions to an international conference on complex analysis and its applications held at the newly founded Hong Kong University of Science and Technology in January 1993. The aim of the conference was to advance the theoretical aspects of complex analysis and to explore the application of its techniques to physical and engineering problems. Three main areas were emphasised: Value distribution theory; Complex dynamical system and geometric function theory; and the Application of complex analysis to differential equations and physical engineering problems.

This book contains several contemporary topics in the areas of mathematical modelling and computation for complex systems. The readers find several new

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mathematical methods, mathematical models and computational techniques having significant relevance in studying various complex systems. The chapters aim to enrich the understanding of topics presented by carefully discussing the associated problems and issues, possible solutions and their applications or relevance in other scientific areas of study and research. The book is a valuable resource for graduate students, researchers and educators in understanding and studying various new aspects associated with complex systems. Key Feature " The chapters include theory and application in a mix and balanced way. " Readers find reasonable details of developments concerning a topic included in this book. " The text is emphasized to present in self-contained manner with inclusion of new research problems and questions.

Complexity, Analysis and Control of Singular Biological Systems follows the control of real-world biological systems at both ecological and physiological levels concentrating on the application of now-extensively-investigated singular system theory. Much effort has recently been dedicated to the modelling and analysis of developing bioeconomic systems and the text establishes singular examples of these, showing how proper control can help to maintain sustainable economic development of biological resources. The book begins from the essentials of singular systems theory and bifurcations before tackling the use of various forms

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of control in singular biological systems using examples including predator-prey relationships and viral vaccination and quarantine control. Researchers and graduate students studying the control of complex biological systems are shown how a variety of methods can be brought to bear and practitioners working with the economics of biological systems and their control will also find the monograph illuminating.

Nonlinear dynamics of complex processes is an active research field with large numbers of publications in basic research, and broad applications from diverse fields of science. Nonlinear dynamics as manifested by deterministic and stochastic evolution models of complex behavior has entered statistical physics, physical chemistry, biophysics, geophysics, astrophysics, theoretical ecology, semiconductor physics and -optics, etc. This field of research has induced a new terminology in science connected with new questions, problems, solutions and methods. New scenarios have emerged for spatio-temporal structures in dynamical systems far from equilibrium. Their analysis and possible control are intriguing and challenging aspects of the current research. The duality of fundamental and applied research is a focal point of its main attractivity and fascination. Basic topics and foundations are always linked to concrete and precise examples. Models and measurements of complex nonlinear processes

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evoke and provoke new fundamental questions that diversify and broaden the mathematical concepts and tools. In return, new mathematical approaches to modeling and analysis enlarge the scope and efficiency of applied research.

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