

FRACTIONAL ORDER SYSTEMS

Modeling and Control Applications

Riccardo Caponetto • Giovanni Dongola
Luigi Fortuna • Ivo Petráš



World Scientific

**Fractional Order Systems Modeling And Control
Applications World Scientific Series On Nonlinear
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Fractional Order Systems Riccardo Caponetto, 2010 This book aims to propose implementations and applications of Fractional Order Systems FOS It is well known that FOS can be applied in control applications and systems modeling and their effectiveness has been proven in many theoretical works and simulation routines A further and mandatory step for FOS real world utilization is their hardware implementation and applications on real systems modeling With this viewpoint introductory chapters on FOS are included on the definition of stability region of Fractional Order PID Controller and Chaotic FOS followed by the practical implementation based on Microcontroller Field Programmable Gate Array Field Programmable Analog Array and Switched Capacitor Another section is dedicated to FO modeling of Ionic Polymeric Metal Composite IPMC This new material may have applications in robotics aerospace and biomedicine **Fractional Order Systems: Modeling**

And Control Applications Riccardo Caponetto, Giovanni Dongola, Luigi Fortuna, Ivo Petras, 2010-02-10 This book aims to propose the implementation and application of Fractional Order Systems FOS It is well known that FOS can be utilized in control applications and systems modeling and their effectiveness has been proven in many theoretical works and simulation routines A further and mandatory step for FOS real world utilization is their hardware implementation and applications on real systems modeling With this viewpoint introductory chapters are included on the definition of stability region of Fractional Order PID Controller and Chaotic FOS followed by the practical implementation based on Microcontroller Field Programmable Gate Array Field Programmable Analog Array and Switched Capacitor Another section is dedicated to FO modeling of Ionic Polymeric Metal Composite IPMC This new material will have applications in robotics aerospace and biomedicine *Synchronization of Integral and Fractional Order Chaotic Systems* Rafael Martínez-Guerra, Claudia A.

Pérez-Pinacho, Gian Carlo Gómez-Cortés, 2015-03-17 This book provides a general overview of several concepts of synchronization and brings together related approaches to secure communication in chaotic systems This is achieved using a combination of analytic algebraic geometrical and asymptotical methods to tackle the dynamical feedback stabilization problem In particular differential geometric and algebraic differential concepts reveal important structural properties of chaotic systems and serve as guide for the construction of design procedures for a wide variety of chaotic systems The basic differential algebraic and geometric concepts are presented in the first few chapters in a novel way as design tools together with selected experimental studies demonstrating their importance The subsequent chapters treat recent applications Written for graduate students in applied physical sciences systems engineers and applied mathematicians interested in synchronization of chaotic systems and in secure communications this self contained text requires only basic knowledge of integer ordinary and fractional ordinary differential equations Design applications are illustrated with the help of several physical models of practical interest **Fractional-order Modeling and Control of Dynamic Systems** Aleksei

Tepljakov,2017-02-08 This book reports on an outstanding research devoted to modeling and control of dynamic systems using fractional order calculus It describes the development of model based control design methods for systems described by fractional dynamic models More than 300 years had passed since Newton and Leibniz developed a set of mathematical tools we now know as calculus Ever since then the idea of non integer derivatives and integrals universally referred to as fractional calculus has been of interest to many researchers However due to various issues the usage of fractional order models in real life applications was limited Advances in modern computer science made it possible to apply efficient numerical methods to the computation of fractional derivatives and integrals This book describes novel methods developed by the author for fractional modeling and control together with their successful application in real world process control scenarios

Theory and Applications of Non-integer Order Systems Artur Babiarz,Adam Czornik,Jerzy Klamka,Michał Niezabitowski,2016-09-15 This book collects papers from the 8th Conference on Non Integer Order Calculus and Its Applications that have been held on September 20 21 2016 in Zakopane Poland The preceding two conferences were held in Szczecin Poland in 2015 and in Opole Poland in 2014 This conference provides a platform for academic exchange on the theory and application of fractional calculus between domestic and international universities research institutes corporate experts and scholars The Proceedings of the 8th Conference on Non Integer Order Calculus and Its Applications 2016 brings together rigorously reviewed contributions from leading international experts The included papers cover novel various important aspects of mathematical foundations of fractional calculus modeling and control of fractional systems as well as controllability detectability observability and stability problems for this systems

Fractional Order Systems and Applications in Engineering Dumitru Baleanu,Valentina Emilia Balas,Praveen Agarwal,2022-11-17 Fractional Order Systems and Applications in Engineering presents the use of fractional calculus calculus of non integer order in the description and modelling of systems and in a range of control design and practical applications The book covers the fundamentals of fractional calculus together with some analytical and numerical techniques and provides MATLAB codes for the simulation of fractional order control FOC systems The use of fractional calculus can improve and generalize well established control methods and strategies Many different FOC schemes are presented for control and dynamic systems problems These extend to the challenging control engineering design problems of robust and nonlinear control Practical material relating to a wide variety of applications including among others mechatronics civil engineering irrigation and water management and biological systems is also provided All the control schemes and applications are presented with either system simulation results or real experimental results or both Fractional Order Systems and Applications in Engineering introduces readers to the essentials of FOC and imbues them with a basic understanding of FOC concepts and methods With this knowledge readers can extend their use of FOC in other industrial system applications thereby expanding their range of disciplines by exploiting this versatile new set of control techniques Provides the most recent and up to date developments on

the Fractional order Systems and their analyzing process Integrates recent advancements of modeling of real phenomena on Fractional order Systems via different mathematical equations with demonstrated applications in numerous seemingly diverse and widespread fields of science and engineering Provides readers with illustrative examples of how to use the presented theories of Fractional order Systems in specific cases with associated MATLAB code

Discrete Systems With Memory Ramon Alonso-sanz, 2011-03-08 Memory is a universal function of organized matter What is the mathematics of memory How does memory affect the space time behaviour of spatially extended systems Does memory increase complexity This book provides answers to these questions It focuses on the study of spatially extended systems i e cellular automata and other related discrete complex systems Thus arrays of locally connected finite state machines or cells update their states simultaneously in discrete time by the same transition rule The classical dynamics in these systems is Markovian only the actual configuration is taken into account to generate the next one Generalizing the conventional view on spatially extended discrete dynamical systems evolution by allowing cells or nodes to be featured by some trait state computed as a function of its own previous state values the transition maps of the classical systems are kept unaltered so that the effect of memory can be easily traced The book demonstrates that discrete dynamical systems with memory are not only priceless tools for modeling natural phenomena but unique mathematical and aesthetic objects

A Nonlinear Dynamics Perspective of Wolfram's New Kind of Science Leon O. Chua, 2012 This penultimate volume contains numerous original elegant and surprising results in 1 dimensional cellular automata Perhaps the most exciting if not shocking new result is the discovery that only 82 local rules out of 256 suffice to predict the time evolution of any of the remaining 174 local rules from an arbitrary initial bit string configuration This is contrary to the well known folklore that 256 local rules are necessary leading to the new concept of quasi global equivalence Another surprising result is the introduction of a simple yet explicit infinite bit string called the super string S which contains all random bit strings of finite length as sub strings As an illustration of the mathematical subtlety of this amazing discrete testing signal the super string S is used to prove mathematically in a trivial and transparent way that rule 170 is as chaotic as a coin toss Yet another unexpected new result among many others is the derivation of an explicit basin tree generation formula which provides an analytical relationship between the basin trees of globally equivalent local rules This formula allows the symbolic rather than numerical generation of the time evolution of any local rule corresponding to any initial bit string configuration from one of the 88 globally equivalent local rules But perhaps the most provocative idea is the proposal for adopting rule 137 over its three globally equivalent siblings including the heretofore more well known rule 110 as the prototypical universal Turing machine

Nonlinear Dynamics Perspective Of Wolfram's New Kind Of Science, A (Volume V) Leon O Chua, 2012-03-13 This penultimate volume contains numerous original elegant and surprising results in 1 dimensional cellular automata Perhaps the most exciting if not shocking new result is the discovery that only 82 local rules out of 256 suffice to predict the time evolution of any of the remaining 174

local rules from an arbitrary initial bit string configuration This is contrary to the well known folklore that 256 local rules are necessary leading to the new concept of quasi global equivalence Another surprising result is the introduction of a simple yet explicit infinite bit string called the super string S which contains all random bit strings of finite length as sub strings As an illustration of the mathematical subtlety of this amazing discrete testing signal the super string S is used to prove mathematically in a trivial and transparent way that rule 170 is as chaotic as a coin toss Yet another unexpected new result among many others is the derivation of an explicit basin tree generation formula which provides an analytical relationship between the basin trees of globally equivalent local rules This formula allows the symbolic rather than numerical generation of the time evolution of any local rule corresponding to any initial bit string configuration from one of the 88 globally equivalent local rules But perhaps the most provocative idea is the proposal for adopting rule 137 over its three globally equivalent siblings including the heretofore more well known rule 110 as the prototypical universal Turing machine

Topology and Dynamics of Chaos Christophe Letellier, 2013 The book surveys how chaotic behaviors can be described with topological tools and how this approach occurred in chaos theory Some modern applications are included The contents are mainly devoted to topology the main field of Robert Gilmore's works in dynamical systems They include a review on the topological analysis of chaotic dynamics works done in the past as well as the very latest issues Most of the contributors who published during the 90's including the very well known scientists Otto Rössler René Lozi and Joan Birman have made a significant impact on chaos theory discrete chaos and knot theory respectively Very few books cover the topological approach for investigating nonlinear dynamical systems The present book will provide not only some historical OCo not necessarily widely known OCo contributions about the different types of chaos introduced by Rössler and not just the Rössler attractor Gumowski and Mira's contributions in electronics Poincaré's heritage in nonlinear dynamics but also some recent applications in laser dynamics biology

Robust Chaos and Its Applications Elhadj Zeraouia, Julien C. Sprott, 2012 Robust chaos is defined by the absence of periodic windows and coexisting attractors in some neighborhoods in the parameter space of a dynamical system This unique book explores the definition sources and roles of robust chaos The book is written in a reasonably self contained manner and aims to provide students and researchers with the necessary understanding of the subject Most of the known results experiments and conjectures about chaos in general and about robust chaos in particular are collected here in a pedagogical form Many examples of dynamical systems ranging from purely mathematical to natural and social processes displaying robust chaos are discussed in detail At the end of each chapter is a set of exercises and open problems more than 260 in the whole book intended to reinforce the ideas and provide additional experiences for both readers and researchers in nonlinear science in general and chaos theory in particular

Automation 2018 Roman Szewczyk, Cezary Zieliński, Małgorzata Kaliczyńska, 2018-03-07 This book consists of papers presented at Automation 2018 an international conference held in Warsaw from March 21 to 23 2018 It discusses the radical technological

changes occurring due to the INDUSTRY 4.0 with a focus on offering a better understanding of the Fourth Industrial Revolution. Each chapter presents a detailed analysis of interdisciplinary knowledge, numerical modeling and simulation as well as the application of cyber physical systems where information technology and physical devices create synergic systems leading to unprecedented efficiency. The theoretical results, practical solutions and guidelines presented are valuable for both researchers working in the area of engineering sciences and practitioners looking for solutions to industrial problems.

Elements of Mathematical Theory of Evolutionary Equations in Banach Spaces Anatoly M. Samoilenko, Yuriy V. Teplinsky, 2013. Evolutionary equations are studied in abstract Banach spaces and in spaces of bounded number sequences. For linear and nonlinear difference equations which are defined on finite dimensional and infinite dimensional tori, the problem of reducibility is solved in particular in neighborhoods of their invariant sets and the basics for a theory of invariant tori and bounded semi-invariant manifolds are established. Also considered are the questions on existence and approximate construction of periodic solutions for difference equations in infinite dimensional spaces and the problem of extendibility of the solutions in degenerate cases. For nonlinear differential equations in spaces of bounded number sequences, new results are obtained in the theory of countable point boundary value problems. The book contains new mathematical results that will be useful towards advances in nonlinear mechanics and theoretical physics.

2-d Quadratic Maps And 3-d Ode Systems: A Rigorous Approach Zeraouia Elhadj, Julien Clinton Sprott, 2010-07-08. This book is based on research on the rigorous proof of chaos and bifurcations in 2-D quadratic maps, especially the invertible case such as the Hénon map, and in 3-D ODEs, especially piecewise linear systems such as the Chua's circuit. In addition, the book covers some recent works in the field of general 2-D quadratic maps, especially their classification into equivalence classes and finding regions for chaos, hyperchaos and non-chaos in the space of bifurcation parameters. Following the main introduction to the rigorous tools used to prove chaos and bifurcations in the two representative systems is the study of the invertible case of the 2-D quadratic map where previous works are oriented toward Hénon mapping. 2-D quadratic maps are then classified into 30 maps with well-known formulas. Two proofs on the regions for chaos, hyperchaos and non-chaos in the space of the bifurcation parameters are presented using a technique based on the second derivative test and bounds for Lyapunov exponents. Also included is the proof of chaos in the piecewise linear Chua's system using two methods: the first of which is based on the construction of Poincaré map and the second is based on a computer-assisted proof. Finally, a rigorous analysis is provided on the bifurcational phenomena in the piecewise linear Chua's system using both an analytical 2-D mapping and a 1-D approximated Poincaré mapping in addition to other analytical methods.

Fractional Dynamical Systems: Methods, Algorithms and Applications Piotr Kulczycki, Józef Korbicz, Janusz Kacprzyk, 2022-01-04. This book presents a wide and comprehensive spectrum of issues and problems related to fractional order dynamical systems. It is meant to be a full-fledged comprehensive presentation of many aspects related to the broadly perceived fractional order dynamical systems which constitute an extension of the

traditional integer order type descriptions This implies far reaching consequences both analytic and algorithmic because in general properties of the traditional integer order systems cannot be directly extended by a straightforward generalization to fractional order systems modeled by fractional order differential equations involving derivatives of a non integer order This can be useful for describing and analyzing for instance anomalies in the behavior of various systems chaotic behavior etc The book contains both analytic contributions with state of the art and theoretical foundations algorithmic implementation of tools and techniques and finally some examples of relevant and successful practical applications **Analysis and Control for Fractional-order Systems** Yonggui Kao, Changhong Wang, Hongwei Xia, Yue Cao, 2024-07-07 This book focuses on the applications of various types of fractional order differential equations The authors present their latest research results This book for the first time introduces the concept of general fractional chaotic systems and their synchronisation investigates the synchronisation of a fractional coupled reaction diffusion system using a sliding mode control approach and considers the impacts of fear and prey escape on a fractional order prey predator system with Beddington DeAngelis functional response Authors believe that these recent research results can promote the applications of fractional order differential equations in diverse areas The book will be attractive to researchers in various fields of mathematics biomathematics and engineering Graduate students in related fields may also find this book useful **Trends in Biomathematics: Modeling Health Across Ecology, Social Interactions, and Cells** Rubem P. Mondaini, 2025-09-26 This volume compiles selected peer reviewed papers presented at the 24th International Symposium on Mathematical and Computational Biology BIOMAT 2024 held from October 27 to November 1 2024 at the Orthodox Academy of Crete in Kolympari Crete Island Greece The book covers a wide range of topics from epidemiological modeling and optimal infection control to the application of machine learning and artificial intelligence in cell biology imaging It also explores the dynamics of disease spread protein structure modeling and mathematical models of HIV 1 COVID 19 monkeypox and measles featuring contributions from some of the most esteemed researchers in the field as well as findings from a new generation of researchers fostering cross disciplinary collaborations Carefully edited this volume will appeal to both researchers and students looking for topics for further study Previous BIOMAT volumes from 2018 to 2024 are also available from Springer **Integral Methods in Science and Engineering** Christian Constanda, Bardo E.J. Bodmann, Haroldo F. de Campos Velho, 2013-08-13 Advances in science and technology are driven by the development of rigorous mathematical foundations for the study of both theoretical and experimental models With certain methodological variations this type of study always comes down to the application of analytic or computational integration procedures making such tools indispensable With a wealth of cutting edge research in the field Integral Methods in Science and Engineering Progress in Numerical and Analytic Techniques provides a detailed portrait of both the construction of theoretical integral techniques and their application to specific problems in science and engineering The chapters in this volume are based on talks given by well known researchers at the Twelfth International Conference on

Integral Methods in Science and Engineering July 23 27 2012 in Porto Alegre Brazil They address a broad range of topics from problems of existence and uniqueness for singular integral equations on domain boundaries to numerical integration via finite and boundary elements conservation laws hybrid methods and other quadrature related approaches The contributing authors bring their expertise to bear on a number of topical problems that have to date resisted solution thereby offering help and guidance to fellow professionals worldwide Integral Methods in Science and Engineering Progress in Numerical and Analytic Techniques will be a valuable resource for researchers in applied mathematics physics and mechanical and electrical engineering for graduate students in these disciplines and for various other professionals who use integration as an essential tool in their work

Advanced Synchronization Control and Bifurcation of Chaotic Fractional-Order Systems Boulkroune, Abdesselem, Ladaci, Samir, 2018-05-11 In the recent years fractional order systems have been studied by many researchers in the engineering field It was found that many systems can be described more accurately by fractional differential equations than by integer order models Advanced Synchronization Control and Bifurcation of Chaotic Fractional Order Systems is a scholarly publication that explores new developments related to novel chaotic fractional order systems control schemes and their applications Featuring coverage on a wide range of topics including chaos synchronization nonlinear control and cryptography this publication is geared toward engineers IT professionals researchers and upper level graduate students seeking current research on chaotic fractional order systems and their applications in engineering and computer science

Advanced Mathematical Methods Francesco Mainardi, Andrea Giusti, 2020-02-05 The many technical and computational problems that appear to be constantly emerging in various branches of physics and engineering beg for a more detailed understanding of the fundamental mathematics that serves as the cornerstone of our way of understanding natural phenomena The purpose of this Special Issue was to establish a brief collection of carefully selected articles authored by promising young scientists and the world's leading experts in pure and applied mathematics highlighting the state of the art of the various research lines focusing on the study of analytical and numerical mathematical methods for pure and applied sciences

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