FRACTIONAL ORDER SYSTEMS

Modeling and Control Applications

Riccardo Caponetto • Giovanni Dongola
Luigi Fortuna • Ivo Petráš

Fractional Order Systems Modeling And Control Applications World Scientific Series On Nonlinear Science Series A

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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 introductive 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 *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 **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 **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 RAssler Ren r 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 RAssler and not just the RAssler attractor Gumowski and Mira s contributions in electronics Poincar r s heritage in nonlinear dynamics but also some recent applications in laser dynamics biology

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

Chaos in Nature Christophe Letellier,2013 Chaos theory deals with the description of motion in a general sense which cannot be predicted in the long term although produced by deterministic system as well exemplified by meteorological phenomena It directly comes from the Lunar theory a three body problem and the difficulty encountered by astronomers to accurately predict the long term evolution of the Moon using Newtonian mechanics Henri Poincar s deep intuitions were at the origin of chaos theory They also led the meteorologist Edward Lorenz to draw the first chaotic attractor ever published But the main idea consists of plotting a curve representative of the system evolution rather than finding an analytical solution as commonly done in classical mechanics Such a novel approach allows the description of population interactions and the solar activity as well Using the original sources the book draws on the history of the concepts underlying chaos theory from the 17th century to the last decade and by various examples show how general is this theory in a wide range of applications meteorology chemistry populations astrophysics biomedicine etc **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 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 Robust Chaos and Its Applications Elhadj Zeraoulia,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 **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 fledge 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 an 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 **2-d Quadratic Maps And 3-d Ode Systems: A Rigorous Approach** Zeraoulia 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 H non map and in 3 D ODE s 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 H non 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 Poincar 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 Poincar mapping in addition to other analytical methods 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   **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

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

Advances in Harmonic Analysis and Operator Theory Alexandre Almeida,Luís Castro,Frank-Olme Speck,2013-01-31 This volume is dedicated to Professor Stefan Samko on the occasion of his seventieth birthday The contributions display the range of his scientific interests in harmonic analysis and operator theory Particular attention is paid to fractional integrals and derivatives singular hypersingular and potential operators in variable exponent spaces pseudodifferential operators in various modern function and distribution spaces as well as related applications to mention but a few Most contributions were firstly presented in two conferences at Lisbon and Aveiro Portugal in June July 2011   **Mathematical Analysis and**

Applications Hari Mohan Srivastava,2019-01-14 This book is a printed edition of the Special Issue Mathematical Analysis and Applications that was published in Axioms *Perspectives in Dynamical Systems II: Mathematical and Numerical Approaches* Jan Awrejcewicz,2022-01-01 This volume is part of collection of contributions devoted to analytical and experimental techniques of dynamical systems presented at the 15th International Conference Dynamical Systems Theory and Applications held in d Poland on December 2 5 2019 The wide selection of material has been divided into three volumes each focusing on a different field of applications of dynamical systems The broadly outlined focus of both the conference and these books includes bifurcations and chaos in dynamical systems asymptotic methods in nonlinear dynamics dynamics in life sciences and bioengineering original numerical methods of vibration analysis control in dynamical systems optimization problems in applied sciences stability of dynamical systems experimental and industrial studies vibrations of lumped and continuous systems non smooth systems engineering systems and differential equations mathematical approaches to dynamical systems and mechatronics

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