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# Stabilization And Control Of Fractional Order Systems A Sliding Mode Approach

## Lecture Notes In Electrical Engineering

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5th Conference on Non-integer Order Calculus and Its Applications, Cracow, Poland  
Theory and Application  
Robust Adaptive Control for Fractional-Order Systems with Disturbance and Saturation  
Issues in Robotics and Automation: 2011 Edition  
Stabilization and Control of Fractional Order Systems: A Sliding Mode Approach  
Systems, Automation, and Control  
Advanced Applications of Fractional Differential Operators to Science and Technology  
Sliding Modes in Control and Optimization  
Mathematical Techniques of Fractional Order Systems  
Automatic Control, Robotics, and Information Processing  
Theory and Applications  
Automatic Control, Mechatronics and Industrial Engineering  
Third Maple Conference, MC 2019, Waterloo, Ontario, Canada, October 15-17, 2019, Proceedings  
Fractional Order Systems--Control Theory and Applications  
Fractional Calculus with its Applications in Engineering and Technology  
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Stability, Simulation, Applications and Perspectives  
Application of Intelligent Control Algorithms to Study the Dynamics of Hybrid Power System  
Fractional Dynamics and Control  
Theory, Numerics, Applications, and Experiments  
Fractional Order Systems  
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Proceedings of KKA 2017—The 19th Polish Control Conference, Kraków, Poland, June 18-21, 2017  
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Proceedings of the 25th Conference on Robotics in Alpe-Adria-Danube Region (RAAD16)  
Methods, Algorithms and Applications  
Stabilization and Synchronization of Fractional-order Chaotic Systems Via Fractional Sliding Mode Control  
Robust Adaptive Control for Fractional-Order Systems with Disturbance and Saturation  
Basic Theory

Selected Problems of Fractional Systems Theory  
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Robust Adaptive Control for Fractional-Order Systems with Disturbance and Saturation  
Proceedings of the 10th International Conference on Non-Integer Order Calculus and Its Applications

*Stabilization And Control Of Fractional Order Systems A  
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Engineering*

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## LIZETH ATKINSON

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### **5th Conference on Non-integer Order Calculus and Its Applications, Cracow, Poland** Springer Nature

The book is devoted to systems with discontinuous control. The study of discontinuous dynamic systems is a multifacet problem which embraces mathematical, control theoretic and application aspects. Times and again, this problem has been approached by mathematicians, physicists and engineers, each profession treating it from its own positions. Interestingly, the results obtained by specialists in different disciplines have almost always had a significant effect upon the development of the control theory. It suffices to mention works on the theory of oscillations of discontinuous nonlinear systems, mathematical studies in ordinary differential equations with discontinuous righthand parts or variational problems in nonclassic statements. The unremitting interest to discontinuous control systems enhanced by their effective application to solution of problems most diverse in their physical nature and functional purpose is, in the author's opinion, a cogent argument in favour of the importance of this area of studies. It seems a useful effort to consider, from a control theoretic viewpoint, the mathematical and application aspects of the theory of discontinuous dynamic systems and determine their place within the scope of the present-day control theory. The first attempt was made by the author in 1975-1976 in his course on "The Theory of Discontinuous Dynamic Systems" and "The Theory of Variable Structure Systems" read to post-graduates at the University of Illinois, USA, and then presented in 1978-1979 at the seminars held in the Laboratory of Systems with Discontinuous Control at the Institute of Control Sciences in Moscow.

### **Theory and Application** Springer Nature

A treatise on investigating tracking control and synchronization control of fractional-order nonlinear systems with system uncertainties, external disturbance, and input saturation Robust Adaptive Control for Fractional-Order Systems, with Disturbance and Saturation provides the reader with a good understanding on how to achieve tracking control and synchronization control of fractional-order nonlinear systems with system uncertainties, external disturbance, and input saturation. Although some texts have touched upon control of fractional-order systems, the issues of input saturation and disturbances have rarely been considered together. This book offers chapter coverage of fractional calculus and fractional-order systems; fractional-order PID controller and fractional-order disturbance observer; design of fractional-order controllers for nonlinear chaotic systems and some applications; sliding mode control for fractional-order nonlinear systems based on

disturbance observer; disturbance observer based neural control for an uncertain fractional-order rotational mechanical system; adaptive neural tracking control for uncertain fractional-order chaotic systems subject to input saturation and disturbance; stabilization control of continuous-time fractional positive systems based on disturbance observer; sliding mode synchronization control for fractional-order chaotic systems with disturbance; and more. Based on the approximation ability of the neural network (NN), the adaptive neural control schemes are reported for uncertain fractional-order nonlinear systems Covers the disturbance estimation techniques that have been developed to alleviate the restriction faced by traditional feedforward control and reject the effect of external disturbances for uncertain fractional-order nonlinear systems By combining the NN with the disturbance observer, the disturbance observer based adaptive neural control schemes have been studied for uncertain fractional-order nonlinear systems with unknown disturbances Considers, together, the issue of input saturation and the disturbance for the control of fractional-order nonlinear systems in the present of system uncertainty, external disturbance, and input saturation Robust Adaptive Control for Fractional-Order Systems, with Disturbance and Saturation can be used as a reference for the academic research on fractional-order nonlinear systems or used in Ph.D. study of control theory and engineering.

### **Robust Adaptive Control for Fractional-Order Systems with Disturbance and Saturation** Springer Nature

This monograph covers some selected problems of positive fractional 1D and 2D linear systems. It is an extended and modified English version of its preceding Polish edition published by Technical University of Bialystok in 2009. This book is based on the lectures delivered by the author to the Ph.D. students of the Faculty of Electrical Engineering of Bialystok University of Technology and of Warsaw University of Technology and on invited lectures in several foreign universities in the last three years.

### **Issues in Robotics and Automation: 2011 Edition** Springer Science & Business Media

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**Stabilization and Control of Fractional Order Systems: A Sliding Mode Approach** Springer Science & Business Media

Distributed-order differential equations, a generalization of fractional calculus, are of increasing importance in many fields of science and engineering from the behaviour of complex dielectric media to the modelling of nonlinear systems. This Brief will broaden the toolbox available to researchers interested in modeling, analysis, control and filtering. It contains contextual material outlining the progression from integer-order, through fractional-order to distributed-order systems. Stability issues are addressed with graphical and numerical results highlighting the fundamental differences between constant-, integer-, and distributed-order treatments. The power of the distributed-order model is demonstrated with work on the stability of noncommensurate-order linear time-invariant systems. Generic applications of the distributed-order operator follow: signal processing and viscoelastic damping of a mass-spring set up. A new general approach to discretization of distributed-order derivatives and integrals is described. The Brief is rounded out with a consideration of likely future research and applications and with a number of MATLAB® codes to reduce repetitive coding tasks and encourage new workers in distributed-order systems.

*Systems, Automation, and Control* Springer Nature

This book provides an overview of some recent findings in the theory and applications of non-integer order systems. Discussing topics ranging from the mathematical foundations to technical applications of continuous-time and discrete-time fractional calculus, it includes 22 original research papers and is subdivided into four parts: • Mathematical Foundations • Approximation, Modeling and Simulations • Fractional Systems Analysis and Control • Applications The papers were selected from those presented at the 10th International Conference of Non-integer Order Calculus and its Applications, which was held at the Bialystok University of Technology, Poland, September 20–21, 2018. Thanks to the broad spectrum of topics covered, the book is suitable for researchers from applied mathematics and engineering. It is also a valuable resource for graduate students, as well as for scholars looking for new mathematical tools.

*Advanced Applications of Fractional Differential Operators to Science and Technology* Springer

**Stabilization and Control of Fractional Order Systems: A Sliding Mode Approach** Springer

*Sliding Modes in Control and Optimization* Springer Science & Business Media

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.

*Mathematical Techniques of Fractional Order Systems* IGI Global

This volume presents various aspects of non-integer order systems, also known as fractional systems, which have recently attracted an increasing attention in the scientific community of systems science, applied mathematics, control theory. Non-integer systems have become relevant for many fields of science and technology exemplified by the modeling of signal transmission, electric noise, dielectric polarization, heat transfer, electrochemical reactions, thermal processes, acoustics, etc. The content is divided into six parts, every of which considers one of the currently relevant problems. In the first part the Realization problem is discussed, with a special focus on positive systems. The second part considers stability of certain classes of non-integer order systems with and without delays. The third part is focused on such important aspects as controllability, observability and optimization especially in discrete time. The fourth part is focused on distributed systems where non-integer calculus leads to new and interesting results. The next part considers problems of solutions and approximations of non-integer order equations and systems. The final and most extensive part is devoted to applications. Problems from mechatronics, biomedical engineering, robotics and others are all analyzed and solved with tools from fractional systems. This volume came to fruition thanks to high level of talks and interesting discussions at RRNR 2013 - 5th Conference on Non-integer Order Calculus and its Applications that took place at AGH University of Science and Technology in Kraków, Poland, which was organized by the Faculty of Electrical Engineering, Automatics, Computer Science and Biomedical Engineering.

**Automatic Control, Robotics, and Information Processing** Springer Science & Business Media

This book presents the proceedings of the 25th International Conference on Robotics in Alpe-Adria-Danube Region, RAAD 2016 held in Belgrade, Serbia, on June 30th–July 2nd, 2016. In keeping with the tradition of the event, RAAD 2016 covered all the important areas of research and innovation in new robot designs and intelligent robot control, with papers including Intelligent robot motion control; Robot vision and sensory processing; Novel design of robot manipulators and grippers; Robot applications in manufacturing and services; Autonomous systems, humanoid and walking robots; Human-robot interaction and collaboration; Cognitive robots and emotional intelligence; Medical, human-assistive robots and prosthetic design; Robots in construction and arts, and Evolution, education, legal and social issues of robotics. For the first time in RAAD history, the themes cloud robots, legal and ethical issues in robotics as well as robots in arts were included in the technical program. The book is a valuable resource for researchers in fields of robotics, engineers who implement robotic solutions in manufacturing, services and healthcare, and master's and Ph.D. students working on robotics projects.

*Theory and Applications* Springer Nature

Fractional Dynamics and Control provides a comprehensive overview of recent advances in the areas of nonlinear dynamics, vibration and control with analytical, numerical, and experimental results. This book provides an overview of recent discoveries in fractional control, delves into fractional variational principles and differential equations, and applies advanced techniques in fractional calculus to solving complicated mathematical and physical problems. Finally, this book also discusses the role that fractional order modeling can play in complex systems for engineering and science.

*Automatic Control, Mechatronics and Industrial Engineering* Academic Press

Networked control systems (NCS) confer advantages of cost reduction, system diagnosis and flexibility, minimizing wiring and simplifying the addition and replacement of individual elements; efficient data sharing makes taking globally intelligent control decisions easier with NCS. The applications of NCS range from the large scale of factory automation and plant monitoring to the smaller networks of computers in modern cars, planes and autonomous robots. Networked Control Systems presents recent results in stability and robustness analysis and new developments related to networked fuzzy and optimal control. Many chapters contain case-studies, experimental, simulation or other application-related work showing how the theories put forward can be implemented. The state-of-the art research reported in this volume by an international team of contributors makes it an essential reference for researchers and postgraduate students in control, electrical, computer and mechanical engineering and computer science.

*Third Maple Conference, MC 2019, Waterloo, Ontario, Canada, October 15-17, 2019, Proceedings* Springer Science & Business Media

"Fractional-Order Nonlinear Systems: Modeling, Analysis and Simulation" presents a study of fractional-order chaotic systems accompanied by Matlab programs for simulating their state space trajectories, which are shown in the illustrations in the book. Description of the chaotic systems is clearly presented and their analysis and numerical solution are done in an easy-to-follow manner. Simulink models for the selected fractional-order systems are also presented. The readers will understand the fundamentals of the fractional calculus, how real dynamical systems can be described using fractional derivatives and fractional differential equations, how such equations can be solved, and how to simulate and explore chaotic systems of fractional order. The book addresses to mathematicians, physicists, engineers, and other scientists interested in chaos phenomena or in fractional-order systems. It can be used in courses on dynamical systems, control theory, and applied mathematics at graduate or postgraduate level. Ivo Petráš is an Associate Professor of automatic control and the Director of the Institute of Control and Informatization of Production Processes, Faculty of BERG, Technical University of Košice, Slovak Republic. His main research interests include control systems, industrial automation, and applied mathematics.

Fractional Order Systems--Control Theory and Applications John Wiley & Sons

This multi-volume handbook is the most up-to-date and comprehensive reference work in the field of fractional calculus and its numerous applications. This first volume collects authoritative chapters covering the mathematical theory of fractional calculus, including fractional-order operators, integral transforms and equations, special functions, calculus of variations, and probabilistic and other aspects.

Fractional Calculus with its Applications in Engineering and Technology Stabilization and Control of Fractional Order Systems: A Sliding Mode Approach

This book at hand is an appropriate addition to the field of fractional calculus applied to control systems. If an engineer or a researcher wishes to delve into fractional-order systems, then this book has many collections of such systems to work upon, and this book also tells the reader about how one can convert an integer-order system into an appropriate fractional-order one through an efficient and simple algorithm. If the reader further wants to explore the controller design for the fractional-order systems, then for them, this book provides a variety of controller design strategies.

The use of fractional-order derivatives and integrals in control theory leads to better results than integer-order approaches and hence provides solid motivation for further development of control theory. Fractional-order models are more useful than the integer-order models when accuracy is of paramount importance. Real-time experimental validation of controller design strategies for the fractional-order plants is available. This book is beneficial to the academic institutes for postgraduate and advanced research-level that need a specific textbook on fractional control and its applications in robotic manipulators. The book is also a valuable teaching and learning resource for undergraduate and postgraduate students.

Advances in the Theory and Applications of Non-integer Order Systems Springer Nature

This volume contains the proceedings of the KKA 2017 - the 19th Polish Control Conference, organized by the Department of Automatics and Biomedical Engineering, AGH University of Science and Technology in Kraków, Poland on June 18-21, 2017, under the auspices of the Committee on Automatic Control and Robotics of the Polish Academy of Sciences, and the Commission for Engineering Sciences of the Polish Academy of Arts and Sciences. Part 1 deals with general issues of modeling and control, notably flow modeling and control, sliding mode, predictive, dual, etc. control. In turn, Part 2 focuses on optimization, estimation and prediction for control. Part 3 is concerned with autonomous vehicles, while Part 4 addresses applications. Part 5 discusses computer methods in control, and Part 6 examines fractional order calculus in the modeling and control of dynamic systems. Part 7 focuses on modern robotics. Part 8 deals with modeling and identification, while Part 9 deals with problems related to security, fault detection and diagnostics. Part 10 explores intelligent systems in automatic control, and Part 11 discusses the use of control tools and techniques in biomedical engineering. Lastly, Part 12 considers engineering education and teaching with regard to automatic control and robotics.

Emerging Trends in Sliding Mode Control Frontiers Media SA

The book presents selected, extended and peer reviewed papers from the International Multiconference on System, Automation and Control held Leipzig in 2018. These are complemented with solicited contributions by international experts. Main topics are automatic control, robotics, synthesis of automation systems. Application examples range from man-machine interaction, mechatronics, on to biological and economical models.

**Stability, Simulation, Applications and Perspectives** Springer

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.

**Application of Intelligent Control Algorithms to Study the Dynamics of Hybrid Power System** MDPI

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 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.

#### **Fractional Dynamics and Control** Springer

This book aims to provide the basic theory of fractional calculus and its applications based on practical schemes and approaches, illustrated with applicable engineering and technical examples, especially focusing on the fractional-order controller design. In the development of this book, the essential theorems and facts in the first two chapters are proven with rigorous mathematical analyses. In addition, the commonly used definitions of Grünwald-Letnikov, Riemann-Liouville, Caputo, and Miller-Ross fractional derivatives are introduced with their properties proved and linked to fractional-order controller design. The last chapter presents several enlightening scenarios of fractional-order control designs, for example, the suppression of machining chatter, the nonlinear motion control of a multilink robot, the simultaneous tracking and stabilization control of a rotary inverted pendulum, and the idle speed control of an internal combustion engine (ICE).

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