



Introduction



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Author for correspondence:

Changpin Li
e-mail: lcp@shu.edu.cn

Fractional calculus and its applications

Changpin Li¹, YangQuan Chen² and Jürgen Kurths³

¹Department of Mathematics, Shanghai University, Shanghai
200444, People's Republic of China

²School of Engineering, University of California, Merced, 5200 North
Lake Road, Merced, CA 95343, USA

³Potsdam Institute for Climate Impact Research, Telegrafenberg
A31, 14473 Potsdam, Germany

Fractional calculus was formulated in 1695, shortly after the development of classical calculus. The earliest systematic studies were attributed to Liouville, Riemann, Leibniz, etc. [1,2]. For a long time, fractional calculus has been regarded as a pure mathematical realm without real applications. But, in recent decades, such a state of affairs has been changed. It has been found that fractional calculus can be useful and even powerful, and an outline of the simple history about fractional calculus, especially with applications, can be found in Machado *et al.* [3].

Now, *fractional calculus and its applications* is undergoing rapid developments with more and more convincing applications in the real world [4,5]. This Theme Issue, including one review article and 12 research papers, can be regarded as a continuation of our first special issue of *European Physical Journal Special Topics* in 2011 [4], and our second special issue of *International Journal of Bifurcation and Chaos* in 2012 [5]. These selected papers were mostly reported in *The Fifth Symposium on Fractional Derivatives and Their Applications* (FDTA'11) that was held in Washington DC, USA in 2011.

The first paper presents an overview of chaos synchronization of coupled fractional differential systems. A list of coupling schemes are presented, including one-way coupling, Pecora–Carroll coupling, active–passive decomposition coupling, bidirectional coupling and other unidirectional coupling configurations. Meanwhile, several extended concepts of synchronizations are introduced, namely projective synchronization, hybrid projective synchronization, function projective synchronization, generalized synchronization and generalized projective synchronization. Corresponding to different

Fractional Calculus And Its Applications Research Papers

**Praveen Agarwal, Luis Vázquez
Martínez, Ervin K. Lenzi**



Fractional Calculus And Its Applications Research Papers:

Recent Trends in Fractional Calculus and Its Applications Praveen Agarwal, Luis Vázquez Martínez, Ervin K. Lenzi, 2024-07-02 Recent Trends in Fractional Calculus and Its Applications addresses the answer to this very basic question Why is Fractional Calculus important Until recent times Fractional Calculus was considered as a rather esoteric mathematical theory without applications but in the last few decades there has been an explosion of research activities on the application of Fractional Calculus to very diverse scientific fields ranging from the physics of diffusion and advection phenomena to control systems to finance and economics An important part of mathematical modelling of objects and processes is a description of their dynamics The term Fractional Calculus is more than 300 years old It is a generalization of the ordinary differentiation and integration to noninteger arbitrary order The subject is as old as the calculus of differentiation and goes back to times when Leibniz Gauss and Newton invented this kind of calculation Several mathematicians contributed to this subject over the years People like Liouville Riemann and Weyl made major contributions to the theory of Fractional Calculus In recent decades the field of Fractional Calculus has attracted the interest of researchers in several areas including mathematics physics chemistry engineering finance and social sciences Provides the most recent and up to date developments in the Fractional Calculus and its application areas Presents pre preparation ideas to help researchers scientists clinicians face the new challenges in the application of fractional differential equations Helps researchers and scientists understand the importance of the Fractional Calculus to solve many problems in Biomedical Engineering and applied sciences

Advances in Non-Integer Order Calculus and Its Applications Agnieszka B. Malinowska, Dorota Mozyrska, Łukasz Sajewski, 2019-04-17 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

Theory and Applications of Fractional Differential Equations A.A. Kilbas, H. M. Srivastava, J.J. Trujillo, 2006-02-16 This work aims to present in a systematic manner results including the existence and uniqueness of solutions for the Cauchy Type and Cauchy problems involving nonlinear ordinary fractional differential equations

Non-Integer Order Calculus and its Applications Piotr Ostalczyk, Dominik Sankowski, Jacek Nowakowski, 2018-03-22 This book focuses on fractional calculus presenting novel advances in both the theory and applications of non integer order systems At the end of the

twentieth century it was predicted that it would be the calculus of the twenty first century and that prophecy is confirmed year after year Now this mathematical tool is successfully used in a variety of research areas like engineering e g electrical mechanical chemical dynamical systems modeling analysis and synthesis e g technical biological economical as well as in multidisciplinary areas e g biochemistry electrochemistry As well as the mathematical foundations the book concentrates on the technical applications of continuous time and discrete time fractional calculus investigating the identification analysis and control of electrical circuits and dynamical systems It also presents the latest results Although some scientific centers and scientists are skeptical and actively criticize the applicability of fractional calculus it is worth breaking through the scientific and technological walls Because the fractional community is growing rapidly there is a pressing need for the exchange of scientific results The book includes papers presented at the 9th International Conference on Non integer Order Calculus and Its Applications and is divided into three parts Mathematical foundations Fractional systems analysis and synthesis System modeling Seven papers discuss the mathematical foundations twelve papers address fractional order analysis and synthesis and three focus on dynamical system modeling by the fractional order differential and difference equations It is a useful resource for fractional calculus scientific community

Recent Developments in Theory and Applications of Fractional Order Systems Mehmet Yavuz, Dharmendra Kumar Singh, Stuart Townley, 2025-09-01 Recent Developments in Theory and Applications of Fractional Order Systems presents a rigorous and thorough analysis of various aspects of Fractional Calculus The book provides readers with a thorough understanding of fundamental concepts and methods of applied mathematics utilized in a variety of scientific and engineering disciplines The authors present each computational modeling concept with a definition methods theorems and observations followed by typical application problems and step by step solutions Each topic is covered in detail followed typically by several meticulously worked out examples and a problem set containing many additional related problems In addition the book discusses recent developments and the latest research on Fractional Calculus and its applications demonstrating important applications in Engineering Computer Science Management Social Science and the Humanities Provides readers with a thorough understanding of fundamental concepts and methods of applied mathematics utilized in a variety of scientific and engineering disciplines Presents a systematic introduction to most of the important special functions in Fractional Calculus that commonly arise in scientific and engineering practice Explores many salient computational modeling properties Analyzes theoretical and practical problems in Fractional Calculus in fields such as Engineering Computer Science Management Social Science and the Humanities

Recent Developments in Fractional Calculus: Theory, Applications, and Numerical Simulations Lakhveer Kaur, Pushpendra Kumar, 2025-05-30 This book discusses recent developments in fractional calculus and fractional differential equations in a very elaborative manner and is of interest to research scholars academicians and scientists who want to enhance the knowledge in the context of new insights and mathematical ideas in fractional calculus and its emerging

applications in various fields It focuses on strengthening the existing results along with identifying the practical challenges encountered The purpose of this collection is to provide comprehension of articles that reflect recent mathematical results as well as some results in applied sciences untouched by the tools and techniques of fractional calculus along with their modelling and computation having applications in diverse arenas Proceedings of the International Conference on Fractional Differentiation and its Applications (ICFDA'21) Andrzej Dzieliński, Dominik Sierociuk, Piotr Ostalczyk, 2022-04-26

This book touches upon various aspects of a very interesting and growing in popularity category of models of dynamical systems These are the so called fractional order systems Such models are not only relevant for many fields of science and technology but may also find numerous applications in other disciplines applying the mathematical modelling tools Thus the book is intended for a very wide audience of professionals who want to expand their knowledge of systems modelling and its applications The book includes the selections of papers presented at the International Conference on Fractional Calculus and its Applications organized by the Warsaw University of Technology and was held online on 6-8 September 2021 The International Conference on Fractional Calculus and its Applications ICFDA has an almost twenty years history It started in Bordeaux France in 2004 followed by Porto Portugal 2006 Istanbul Turkey 2008 Badajoz Spain 2010 Nanjing China 2012 Catania Italy 2014 Novi Sad Serbia 2016 Amman Jordan 2018 Next ICFDA was planned in 2020 in Warsaw Poland but COVID 19 pandemic shifted it to 6-8 September 2021 Hence the organizers were forced to change the form of the conference to the online one In the volume twenty eight high quality research papers presented during the ICFDA 2021 eleven Regular Sessions with an additional online Discussion Session are presented The presented papers are scientifically inspiring leading to new fruitful ideas They cover a very broad range of many disciplines Nowadays and especially in such a subject as fractional calculus it is very difficult to assign papers to specific scientific areas So many of the papers included have an interdisciplinary character

Fractional Calculus and Fractional Processes with Applications to Financial Economics Hasan Fallahgoul, Sergio Focardi, Frank Fabozzi, 2016-10-06 Fractional Calculus and Fractional Processes with Applications to Financial Economics presents the theory and application of fractional calculus and fractional processes to financial data Fractional calculus dates back to 1695 when Gottfried Wilhelm Leibniz first suggested the possibility of fractional derivatives Research on fractional calculus started in full earnest in the second half of the twentieth century The fractional paradigm applies not only to calculus but also to stochastic processes used in many applications in financial economics such as modelling volatility interest rates and modelling high frequency data The key features of fractional processes that make them interesting are long range memory path dependence non Markovian properties self similarity fractal paths and anomalous diffusion behaviour In this book the authors discuss how fractional calculus and fractional processes are used in financial modelling and finance economic theory It provides a practical guide that can be useful for students researchers and quantitative asset and risk managers interested in applying fractional calculus and fractional

processes to asset pricing financial time series analysis stochastic volatility modelling and portfolio optimization Provides the necessary background for the book's content as applied to financial economics Analyzes the application of fractional calculus and fractional processes from deterministic and stochastic perspectives

Advances in Differential and Difference Equations with Applications 2020 Dumitru Baleanu, 2021-01-20 It is very well known that differential equations are related with the rise of physical science in the last several decades and they are used successfully for models of real world problems in a variety of fields from several disciplines Additionally difference equations represent the discrete analogues of differential equations These types of equations started to be used intensively during the last several years for their multiple applications particularly in complex chaotic behavior A certain class of differential and related difference equations is represented by their respective fractional forms which have been utilized to better describe non local phenomena appearing in all branches of science and engineering The purpose of this book is to present some common results given by mathematicians together with physicists engineers as well as other scientists for whom differential and difference equations are valuable research tools The reported results can be used by researchers and academics working in both pure and applied differential equations

Methods of Mathematical Modelling and Computation for Complex Systems Jagdev Singh, Hemen Dutta, Devendra Kumar, Dumitru Baleanu, Jordan Hristov, 2021-08-26 This book contains several contemporary topics in the areas of mathematical modelling and computation for complex systems The readers find several new 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

Recent Research in Polynomials Faruk Özger, 2023-07-12 Polynomials are incredibly useful mathematical tools that have a wide array of applications This book provides a comprehensive overview of polynomials and recent developments in the field It includes ten chapters that address such topics as polynomials based cyclic coding Hermite polynomials Routh polynomials fitting parametric polynomials with control point coefficients the thermoelastic wave model and much more

Advances in Real and Complex Analysis with Applications Michael Ruzhansky, Yeol Je Cho, Praveen Agarwal, Iván Area, 2017-10-03 This book discusses a variety of topics in mathematics and engineering as well as their applications clearly explaining the mathematical concepts in the simplest possible way and illustrating them with a number of solved examples The topics include real and complex analysis special functions and analytic number theory q series Ramanujan's mathematics fractional calculus Clifford and harmonic analysis

graph theory complex analysis complex dynamical systems complex function spaces and operator theory geometric analysis of complex manifolds geometric function theory Riemannian surfaces Teichmüller spaces and Kleinian groups engineering applications of complex analytic methods nonlinear analysis inequality theory potential theory partial differential equations numerical analysis fixed point theory variational inequality equilibrium problems optimization problems stability of functional equations and mathematical physics It includes papers presented at the 24th International Conference on Finite or Infinite Dimensional Complex Analysis and Applications 24ICFIDCAA held at the Anand International College of Engineering Jaipur 22-26 August 2016 The book is a valuable resource for researchers in real and complex analysis **Computational**

Modeling and Sustainable Energy Brajesh Kumar Jha, Navnit Jha, Jwngsar Brahma, Mehmet Yavuz, 2025-02-24 This book features best selected research papers presented at International Conference on Computational Modeling and Sustainable Energy ICCMSE 2023 held at Pandit Deendayal Energy University Gandhinagar Gujarat India during December 15-17 2023 It comprises high quality research work by academicians and industrial experts in the field of machine learning mobile computing natural language processing fuzzy computing green computing human computer interaction information retrieval intelligent control data mining and knowledge discovery evolutionary computing big data cloud computing business intelligence Internet security pattern recognition and sustainable energy Applications in Engineering, Life and Social Sciences, Part B Dumitru Băleanu, António Mendes Lopes, 2019-04-01 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 eighth volume collects authoritative chapters covering several applications of fractional calculus in engineering life and social sciences including applications in signal and image analysis and chaos Fractional Calculus and Its Applications B. Ross, 2006-11-15

Fractional Derivative Modeling in Mechanics and Engineering Wen Chen, HongGuang Sun, Xicheng Li, 2022-02-26 This textbook highlights the theory of fractional calculus and its wide applications in mechanics and engineering It describes in details the research findings in using fractional calculus methods for modeling and numerical simulation of complex mechanical behavior It covers the mathematical basis of fractional calculus the relationship between fractal and fractional calculus unconventional statistics and anomalous diffusion typical applications of fractional calculus and the numerical solution of the fractional differential equation It also includes latest findings such as variable order derivative distributed order derivative and its applications Different from other textbooks in this subject the book avoids lengthy mathematical demonstrations and presents the theories in close connection to the applications in an easily readable manner This textbook is intended for students researchers and professionals in applied physics engineering mechanics and applied mathematics It is also of high reference value for those in environmental mechanics geotechnical mechanics biomechanics and rheology

I-Function and Its Applications Vinod Prakash Saxena, Praveen Agarwal, Altaf Ahmad Bhat, 2024-11-21 This book presents the essential role of mathematical modelling and computational methods in representing physical phenomena mathematically

focusing on the significance of the I function Serving as a generalized form of special functions particularly generalised hypergeometric functions the I function emerges from solving dual integral equations prevalent in scenarios such as mixed boundary problems in potential theory energy diffusion and population dynamics Offers the most recent developments on I function and their application in mathematical modelling and possible applications to some other research areas Expands the area of special functions that have been developed and applied in a variety of fields such as combinatory astronomy applied mathematics physics and engineering Highlights the importance of fundamental results and techniques based on the theory of complex analysis and emphasizes articles devoted to the mathematical aspect and applications Shows the importance of fundamental results and techniques derived from the theory of complex analysis laying the groundwork for further exploration and potential applications of the I function in solving complex problems Discusses dual integral equations solving and its crucial role in various physical phenomena such as potential theory and population dynamics Expanding the field of special functions I function and Its Applications serves as a platform for recent theories and applications offering students researchers and scholars of Mathematics insight into advanced mathematical techniques and their practical implications across various fields

Applications in Physics, Part A Vasily E. Tarasov, 2019-02-19 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 fourth volume collects authoritative chapters covering several applications of fractional calculus in physics including classical and continuum mechanics

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 **Computational Science and its Applications** A. H. Siddiqi, R. C. Singh, G. D. Veerappa Gowda, 2020-10-20 Computational science is a rapidly growing multidisciplinary field concerned with the design implementation and use of mathematical models to analyze and solve real world problems It is an area of science that spans many disciplines and which involves the development of models and allows the use of computers to perform simulations or numerical analysis to understand problems that are computational and theoretical Computational Science and its Applications provides an opportunity for readers to develop abilities to pose and solve problems that combine insights from one or more disciplines from the natural sciences with mathematical tools and computational skills This requires a unique combination of applied and theoretical knowledge and skills The topics covered in this edited book are applications of wavelet and fractals modeling by partial differential equations on flat structure as well as on graphs and networks computational linguistics prediction of natural calamities and diseases like epilepsy seizure heart attack stroke biometrics modeling through inverse problems interdisciplinary topics of physics mathematics and medical science and modeling of terrorist attacks and human behavior The focus of this book is not to educate computer specialists but to provide readers with a solid understanding of basic science as well as an integrated knowledge on how to use essential methods from computational science Features Modeling of complex systems Cognitive computing systems for real world problems Presentation of inverse problems in medical science and their numerical solutions Challenging research problems in many areas of computational science This book could be used as a reference book for researchers working in theoretical research as well as those who are doing modeling and simulation in such disciplines as physics biology geoscience and mathematics and those who have a background in computational science

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