Fractional Calculus and applications

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Abstract

Fractional calculus is a branch of mathematics that deals with linear applications having non integer powers, such as fractional derivative operator or fractional integral operators, these two extends the notion of power in regular differentiations operators to non integer values and even to complex values. This article deals only with the two previous operators due to their importance in many fields of mathematics and engineering.

I. INTRODUCTION

Fractional calculus is a branch of mathematics that deals with linear applications having non integer powers, such as fractional derivative operator or fractional integral operators, those two extends the notion of power in regular differentiations operators to non integer values and even to complex values. What drives the research in this particular field is that, the previously mentioned operators have a strange and yet interesting behavior, they act as an intermediate case between integer order integral and/or derivative operators.

The fractional calculus is 300 years old since the days of Leibniz, many brilliant mathematicians contributed to the development of this field (Joseph Liouville, Letnikov, Grunwald, ...) and yet until the beginning of the 20th century there were no major applications of its results in engineering due to the lack of physical interpretation of an intermediate case between integer values, the subject of gained momentum with the discovery of fractals by Benoit Mandelbrot, nowadays recent applications of fractional calculus are dominated by modern examples of applications in physics, signal processing, fluid mechanics, viscoelasticity, mathematical biology, and electro-chemistry. For example, a new paradigm appeared in electronics "Fractance".

The Fractance is introduced as a generalization of resistance and capacitance, it can be seen as an electrical component with an impedance having a fractional order $\frac{1}{2}$.

$$Z(jw) = (jw)^{\frac{1}{2}} X \qquad (1)$$

I. The fractional paradigm

The fractional calculus holds too many interesting results that are yet to be applied in engineering, using the fractional paradigm in applied science gives researchers all the arsenal of fractional calculus such as fractional integration or differentiation and even the fractionalization of many other operators such as translation, rotation and many others, to solve problems in electromagnetic problems.
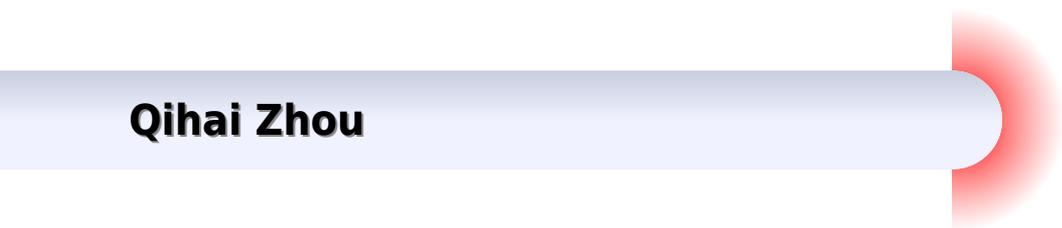
The idea behind this paradigm is quiet simple :

- Find canonical solutions for a given problem.

- Find an operator L that maps the canonical solution with each other.

- Investigate the possibility of a generalization in fractional order of this operator.

- Find the correlation between all the solutions of the problem.

A fractional response is an intermediate case between two canonical solutions to a given problem.

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Fractional Calculus And Its Applications Research Papers:

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 **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 **Fractional Calculus and its Applications in Physics** Dumitru Baleanu,Devendra Kumar,2019-11-15 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 modelingSeven 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 **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 *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 **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 *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 Teichm ller 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 **Proceedings of the International Conference on Fractional Differentiation and its Applications (ICFDA'21)** Andrzej Dzielinski,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 **Handbook of Research on Advances and Applications of Fuzzy Sets and Logic** Broumi, Said,2022-03-04 Fuzzy logic which is based on the concept of fuzzy set has enabled scientists to create models under conditions of imprecision vagueness or both at once As a result it has now found many important applications in almost all sectors of human activity becoming a complementary feature and supporter of probability theory which is suitable for modelling situations of uncertainty derived from randomness Fuzzy mathematics has also significantly developed at the theoretical level providing important insights into branches of traditional mathematics like algebra analysis geometry topology and more With such widespread applications fuzzy sets and logic are an important area of focus in mathematics The Handbook of Research on Advances and Applications of Fuzzy Sets and Logic studies recent theoretical advances of fuzzy sets and numbers fuzzy systems fuzzy logic and their generalizations extensions and more This book also

explores the applications of fuzzy sets and logic applied to science technology and everyday life to further provide research on the subject This book is ideal for mathematicians physicists computer specialists engineers practitioners researchers academicians and students who are looking to learn more about fuzzy sets fuzzy logic and their applications *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 Advances in Mathematical Modelling, Applied Analysis and Computation Jagdev Singh,George A. Anastassiou,Dumitru Baleanu,Carlo Cattani,Devendra Kumar,2022-10-13 This book is a valuable source for graduate students and researchers and provides a comprehensive introduction to recent theories and applications of mathematical modeling and numerical simulation It includes selected peer reviewed papers presented at the 4th International Conference on Mathematical Modelling Applied Analysis and Computation ICMMAAC 2021 held at JECRC University Jaipur India during August 5 7 2021 The book is focused on mathematical modeling of various problems arising in science and engineering and new efficient numerical approaches for solving linear nonlinear problems and rigorous mathematical theories which can be used to analyze different kinds of mathematical models Applications of mathematical methods in physics chemistry biology mechanical engineering civil engineering computer science social science and finance are presented **Computational Science and its Applications** A. H. Siddiqi,R. C. Singh,G. D. Veerappa Gowda,2020-10-21 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 <u>Applications in Physics, Part A</u> 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 *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 *Novel Methods for Solving Linear and Nonlinear Integral Equations* Santanu Saha Ray,Prakash Kumar Sahu,2018-12-07 This book deals with the numerical solution of integral equations based on approximation of functions and the authors apply wavelet approximation to the unknown function of integral equations The book s goal is to categorize the selected methods and assess their accuracy and efficiency **Applied Analysis in Biological and Physical Sciences** Jim M. Cushing,M. Saleem,H. M. Srivastava,Mumtaz Ahmad Khan,M. Merajuddin,2016-12-01 The book contains recent developments and

contemporary research in mathematical analysis and in its application to problems arising from the biological and physical sciences The book is of interest to readers who wish to learn of new research in such topics as linear and nonlinear analysis mathematical biology and ecology dynamical systems graph theory variational analysis and inequalities functional analysis differential and difference equations partial differential equations approximation theory and chaos All papers were prepared by participants at the International Conference on Recent Advances in Mathematical Biology Analysis and Applications ICMBAA 2015 held during 4 6 June 2015 in Aligarh India A focal theme of the conference was the application of mathematics to the biological sciences and on current research in areas of theoretical mathematical analysis that can be used as sophisticated tools for the study of scientific problems The conference provided researchers academicians and engineers with a platform that encouraged them to exchange their innovative ideas in mathematical analysis and its applications as well as to form interdisciplinary collaborations The content of the book is divided into three parts Part I contains contributions from participants whose topics are related to nonlinear dynamics and its applications in biological sciences Part II has contributions which concern topics on nonlinear analysis and its applications to a variety of problems in science engineering and industry Part III consists of contributions dealing with some problems in applied analysis **Theoretical and Mathematical Foundations of Computer Science** Qihai Zhou,2011-10-29 This book constitutes the refereed post proceedings of the Second International Conference on Theoretical and Mathematical Foundations of Computer Science ICTMF 2011 held in Singapore in May 2011 The conference was held together with the Second International Conference on High Performance Networking Computing and Communication systems ICHCC 2011 which proceedings are published in CCIS 163 The 84 revised selected papers presented were carefully reviewed and selected for inclusion in the book The topics covered range from computational science engineering and technology to digital signal processing and computational biology to game theory and other related topices

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Table of Contents Fractional Calculus And Its Applications Research Papers

- Integration of Multimedia Elements
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