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*This book provides an overview
of some recent findings in the
theory and applications of non-
integer order systems.*

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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

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four parts: • Mathematical Foundations • Approximation, Modeling and Simulations • Fractional Systems Analysis and Control • Applications The papers were selected from those presented at the 10th

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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

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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.

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In this volume various applications are discussed, in particular to the hyper-Bessel differential operators and equations, Dzrbashjan-Gelfond-Leontiev operators and Borel type transforms, convolutions,

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new representations of hypergeometric functions, solutions to classes of differential and integral equations, transmutation method, and generalized integral transforms. Some open

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problems are also posed. This book is intended for graduate and post-graduate students, lecturers, researchers and others working in applied mathematical analysis, mathematical physics and

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related disciplines.

Fractional calculus is a collection of relatively little-known mathematical results concerning generalizations of differentiation and integration to noninteger orders. While these

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results have been accumulated over centuries in various branches of mathematics, they have until recently found little appreciation or application in physics and other mathematically oriented

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sciences. This situation is beginning to change, and there are now a growing number of research areas in physics which employ fractional calculus. This volume provides an introduction to fractional calculus for

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physicists, and collects easily accessible review articles surveying those areas of physics in which applications of fractional calculus have recently become prominent. Contents: An Introduction to Fractional

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*Calculus (P L Butzer & U
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Applications of Path-Integration,

Integral Equations, and

Fractional Calculus (J F

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Nonnenmacher & R*

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Readership: Statistical,
theoretical and mathematical
physicists. Keywords: Fractional
Calculus in Physics Reviews:*

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"This monograph provides a systematic treatment of the theory and applications of fractional calculus for physicists. It contains nine review articles surveying those areas in which fractional calculus has become

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*important. All the chapters are
self-contained." Mathematics*

Abstracts

*Theory, Methods and
Applications*

Fractional Calculus with its

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*Applications in Engineering and
Technology*

*Fractional Calculus and Its
Applications*

*Proceedings of the 10th
International Conference on Non-
Integer Order Calculus and Its*

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Applications

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

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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). 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

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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**

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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

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equations. It is a useful resource for fractional calculus scientific community.

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,

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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

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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,

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**geotechnical mechanics,
biomechanics, and rheology.
Theory And Applications of
Fractional Differential Equations
Fractional Calculus - Theory and
Applications
Proceedings of the International
Conference**

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Fractional Calculus
An Application-Oriented
Exposition Using Differential
Operators of Caputo Type

FRACTIONAL CALCULUS:

Theory and Applications deals with
differentiation and integration of

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arbitrary order. The origin of this subject can be traced back to the end of seventeenth century, the time when Newton and Leibniz developed foundations of differential and integral calculus. Nonetheless, utility and

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applicability of FC to various branches of science and engineering have been realized only in last few decades. Recent years have witnessed tremendous upsurge in research activities related to the applications of FC in

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modeling of real-world systems. Unlike the derivatives of integral order, the non-local nature of fractional derivatives correctly models many natural phenomena containing long memory and give more accurate description than

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their integer counterparts. The present book comprises of contributions from academicians and leading researchers and gives a panoramic overview of various aspects of this subject: Introduction to Fractional Calculus Fractional

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Differential Equations Fractional
Ordered Dynamical Systems
Fractional Operators on Fractals
Local Fractional Derivatives
Fractional Control Systems
Fractional Operators and
Statistical Distributions

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Applications to Engineering

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

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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

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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

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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

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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

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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

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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

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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

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interdisciplinary character.

In this book, not only are mathematical abstractions discussed in a lucid manner, but also several practical applications are given particularly for system identification, description and then

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efficient controls. The reader gets a feeling of the wide applicability of fractional calculus in the field of science and engineering. With this book, a starter can understand the concepts of this emerging field with a minimal effort and basic

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mathematics.

Models and Numerical Methods
The Analysis of Fractional
Differential Equations
8th Conference on Non-integer
Order Calculus and Its
Applications, Zakopane, Poland

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Fractional Order Analysis

Papers of a Theme Issue

This book covers applications of fractional calculus used for medical and health science. It offers a collection of research articles built into chapters on

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classical and modern dynamical systems formulated by fractional differential equations describing human diseases and how to control them. The mathematical results included in the book will be helpful to mathematicians and doctors by enabling them to

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explain real-life problems accurately. The book will also offer case studies of real-life situations with an emphasis on describing the mathematical results and showing how to apply the results to medical and health science, and at the same time

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highlighting modeling strategies.

The book will be useful to

graduate level students,

educators and researchers

interested in mathematics and

medical science.

A guide to the new research in

the field of fractional order

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analysis Fractional Order

Analysis contains the most recent research findings in fractional order analysis and its applications. The authors—noted experts on the topic—offer an examination of the theory, methods, applications, and the

modern tools and techniques in the field of fractional order analysis. The information, tools, and applications presented can help develop mathematical methods and models with better accuracy. Comprehensive in scope, the book covers a range of

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topics including: new fractional operators, fractional derivatives, fractional differential equations, inequalities for different fractional derivatives and fractional integrals, fractional modeling related to transmission of Malaria, and dynamics of Zika

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virus with various fractional derivatives, and more. Designed to be an accessible text, several useful, relevant and connected topics can be found in one place, which is crucial for an understanding of the research problems of an applied nature.

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This book: Contains recent development in fractional calculus Offers a balance of theory, methods, and applications Puts the focus on fractional analysis and its interdisciplinary applications, such as fractional models for biological models

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***Helps make research more
relevant to real-life applications
Written for researchers,
professionals and practitioners,
Fractional Order Analysis offers a
comprehensive resource to
fractional analysis and its many
applications as well as***

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***information on the newest
research.***

***Contrary to most books on
fractional calculus which start
with definitions of fractional
derivatives in terms of integrals,
here one uses a definition
expressed as the limit of***

fractional difference, what allows us to expand the theory step by step exactly like with Leibniz calculus, by handling infinitely small increments. It follows that the physical significance of this calculus sticks to real problems and that, as a result, it is quite

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suitable (perhaps excellent) in systems modeling. Physical increments have a parlance in modeling which one can find in our fractional calculus, but is nowhere in the definition of fractional derivative via integrals. Last but not least, the book deals

with non-differentiable functions, whilst most classical approaches to fractional calculus refer to the Caputo definition which deals with differentiable functions.

9th International Conference on Non-Integer Order Calculus and Its Applications, Łódź, Poland

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***Applications of Fractional
Calculus in Physics***

***Fractional Differential Equations:
Numerical Methods for
Applications***

***Fractional Calculus in Medical
and Health Science***

Non-Integer Order Calculus and

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its Applications

In recent years fractional calculus has played an important role in various fields such as mechanics, electricity, chemistry, biology, economics, modeling, identification,

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control theory and signal processing. The scope of this book is to present the state of the art in the study of fractional systems and the application of fractional differentiation. Furthermore,

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the manufacture of nanowires is important for the design of nanosensors and the development of high-yield thin films is vital in procuring clean solar energy. This wide range of applications is of interest to

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*engineers, physicists and
mathematicians.*

*This work aims to present, in a
systematic manner, results
including the existence and
uniqueness of solutions for the
Cauchy Type and Cauchy*

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problems involving nonlinear ordinary fractional differential equations.

This book provides a comprehensive set of practical tools for exploring and discovering the world of

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fractional calculus and its applications, and thereby a means of bridging the theory of fractional differential equations (FDE) with real-world facts. These tools seamlessly blend centuries old

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*numerical methods such as
Gaussian quadrature that have
stood the test of time with
pioneering concepts such as
hypermatrix equations to
harness the emerging
capabilities of modern*

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scientific computing environments. This unique fusion of old and new leads to a unified approach that intuitively parallels the classic theory of differential equations, and results in

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*methods that are
unprecedented in
computational speed and
numerical accuracy. The
opening chapter is an
introduction to fractional
calculus that is geared*

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towards scientists and engineers. The following chapter introduces the reader to the key concepts of approximation theory with an emphasis on the tools of numerical linear algebra. The

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third chapter provides the keystone for the remainder of the book with a comprehensive set of methods for the approximation of fractional order integrals and derivatives. The fourth chapter

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describes the numerical solution of initial and boundary value problems for FDE of a single variable, both linear and nonlinear. Moving to two, three, and four dimensions, the ensuing chapter is devoted

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to a novel approach to the numerical solution of partial FDE that leverages the little-known one-to-one relation between partial differential equations and matrix and hypermatrix equations. The

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*emphasis on applications
culminates in the final chapter
by addressing inverse
problems for ordinary and
partial FDE, such as
smoothing for data analytics,
and the all-important system*

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identification problem. Over a century ago, scientists such as Ludwig Boltzmann and Vito Volterra formulated mathematical models of real materials that -- based on physical evidence -- integrated

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the history of the system. The present book will be invaluable to students and researchers in fields where analogous phenomena arise, such as viscoelasticity, rheology, polymer dynamics, non-

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*Newtonian fluids,
bioengineering,
electrochemistry, non-
conservative mechanics,
groundwater hydrology, NMR
and computed tomography,
mathematical economics,*

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*thermomechanics, anomalous
diffusion and transport,
control theory,
supercapacitors, and genetic
algorithms, to name but a few.
These investigators will be
well-equipped with*

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*reproducible numerical
methods to explore and
discover their particular field
of application of FDE.*

*Fractional Calculus and Its
Applications to Dynamic
Systems*

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Basic Theory

*Theory and Applications of
Non-integer Order Systems*

Theory and Application

*Theory and Applications of
Fractional Differential*

Equations

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*The books Fractional Calculus
with Applications in Mechanics:
Vibrations and Diffusion
Processes and Fractional
Calculus with Applications in
Mechanics: Wave Propagation,
Impact and Variational Principles*

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contain various applications of fractional calculus to the fields of classical mechanics. Namely, the books study problems in fields such as viscoelasticity of fractional order, lateral vibrations of a rod of fractional order type,

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*lateral vibrations of a rod
positioned on fractional order
viscoelastic foundations, diffusion-
wave phenomena, heat
conduction, wave propagation,
forced oscillations of a body
attached to a rod, impact and*

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*variational principles of a
Hamiltonian type. The books will
be useful for graduate students in
mechanics and applied
mathematics, as well as for
researchers in these fields. Part 1
of this book presents an*

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introduction to fractional calculus. Chapter 1 briefly gives definitions and notions that are needed later in the book and Chapter 2 presents definitions and some of the properties of fractional integrals and derivatives. Part 2

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is the central part of the book. Chapter 3 presents the analysis of waves in fractional viscoelastic materials in infinite and finite spatial domains. In Chapter 4, the problem of oscillations of a translatory moving rigid body,

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attached to a heavy, or light viscoelastic rod of fractional order type, is studied in detail. In Chapter 5, the authors analyze a specific engineering problem of the impact of a viscoelastic rod against a rigid wall. Finally, in

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Chapter 6, some results for the optimization of a functional containing fractional derivatives of constant and variable order are presented.

This monograph provides the most recent and up-to-date

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developments on fractional differential and fractional integro-differential equations involving many different potentially useful operators of fractional calculus. The subject of fractional calculus and its applications (that is,

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calculus of integrals and derivatives of any arbitrary real or complex order) has gained considerable popularity and importance during the past three decades or so, due mainly to its demonstrated applications in

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numerous seemingly diverse and widespread fields of science and engineering. Some of the areas of present-day applications of fractional models include Fluid Flow, Solute Transport or Dynamical Processes in Self-

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*Similar and Porous Structures,
Diffusive Transport akin to
Diffusion, Material Viscoelastic
Theory, Electromagnetic Theory,
Dynamics of Earthquakes,
Control Theory of Dynamical
Systems, Optics and Signal*

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*Processing, Bio-Sciences,
Economics, Geology,
Astrophysics, Probability and
Statistics, Chemical Physics, and
so on. In the above-mentioned
areas, there are phenomena with
estranged kinetics which have a*

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microscopic complex behaviour, and their macroscopic dynamics can not be characterized by classical derivative models. The fractional modelling is an emergent tool which use fractional differential equations

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including derivatives of fractional order, that is, we can speak about a derivative of order $1/3$, or square root of 2, and so on. Some of such fractional models can have solutions which are non-differentiable but continuous

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functions, such as Weierstrass type functions. Such kinds of properties are, obviously, impossible for the ordinary models. What are the useful properties of these fractional operators which help in the

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modelling of so many anomalous processes? From the point of view of the authors and from known experimental results, most of the processes associated with complex systems have non-local dynamics involving long-memory

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in time, and the fractional integral and fractional derivative operators do have some of those characteristics. This book is written primarily for the graduate students and researchers in many different disciplines in the

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*mathematical, physical,
engineering and so many others
sciences, who are interested not
only in learning about the various
mathematical tools and
techniques used in the theory and
widespread applications of*

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fractional differential equations, but also in further investigations which emerge naturally from (or which are motivated substantially by) the physical situations modelled mathematically in the book. This monograph consists

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of a total of eight chapters and a very extensive bibliography. The main objective of it is to complement the contents of the other books dedicated to the study and the applications of fractional differential equations.

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The aim of the book is to present, in a systematic manner, results including the existence and uniqueness of solutions for the Cauchy type problems involving nonlinear ordinary fractional differential equations, explicit

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solutions of linear differential equations and of the corresponding initial-value problems through different methods, closed-form solutions of ordinary and partial differential equations, and a theory of the so-

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called sequential linear fractional differential equations including a generalization of the classical Frobenius method, and also to include an interesting set of applications of the developed theory. Key features: - It is mainly

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application oriented. - It contains a complete theory of Fractional Differential Equations. - It can be used as a postgraduate-level textbook in many different disciplines within science and engineering. - It contains an up-to-

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date bibliography. - It provides problems and directions for further investigations. - Fractional Modelling is an emergent tool with demonstrated applications in numerous seemingly diverse and widespread fields of science and

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*engineering. - It contains many
examples. - and so on!*

*This book will give readers the
possibility of finding very
important mathematical tools for
working with fractional models
and solving fractional differential*

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*equations, such as a
generalization of Stirling numbers
in the framework of fractional
calculus and a set of efficient
numerical methods. Moreover,
we will introduce some applied
topics, in particular fractional*

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variational methods which are used in physics, engineering or economics. We will also discuss the relationship between semi-Markov continuous-time random walks and the space-time fractional diffusion equation,

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which generalizes the usual theory relating random walks to the diffusion equation. These methods can be applied in finance, to model tick-by-tick (log)-price fluctuations, in insurance theory, to study ruin, as

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well as in macroeconomics as prototypical growth models. All these topics are complementary to what is dealt with in existing books on fractional calculus and its applications. This book will keep in mind the trade-off

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between full mathematical rigor and the needs of readers coming from different applied areas of science and engineering. In particular, the numerical methods listed in the book are presented in a readily accessible way that

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immediately allows the readers to implement them on a computer in a programming language of their choice. The second edition of the book has been expanded and now includes a discussion of additional, newly developed

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numerical methods for fractional calculus and a chapter on the application of fractional calculus for modeling processes in the life sciences.

**INTERNATIONAL
CONFERENCE.**

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*New Trends in Nanotechnology
and Fractional Calculus*

Applications

*Proceedings of the International
Conference on Fractional*

Differentiation and its

Applications (ICFDA'21)

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*The Fractional Calculus Theory
and Applications of Differentiation
and Integration to Arbitrary Order
Advances in Non-Integer Order
Calculus and Its Applications*

The subject of fractional calculus
and its applications (that is,

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convolution-type pseudo-differential operators including integrals and derivatives of any arbitrary real or complex order) has gained considerable popularity and importance during the past three decades or

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so, mainly due to its applications in diverse fields of science and engineering. These operators have been used to model problems with anomalous dynamics, however, they also are an effective tool as filters and

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controllers, and they can be applied to write complicated functions in terms of fractional integrals or derivatives of elementary functions, and so on. This book will give readers the possibility of finding very

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important mathematical tools for working with fractional models and solving fractional differential equations, such as a generalization of Stirling numbers in the framework of fractional calculus and a set of

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efficient numerical methods.

Moreover, we will introduce
some applied topics, in
particular fractional variational
methods which are used in
physics, engineering or
economics. We will also discuss

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the relationship between semi-Markov continuous-time random walks and the space-time fractional diffusion equation, which generalizes the usual theory relating random walks to the diffusion equation. These

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methods can be applied in finance, to model tick-by-tick (log)-price fluctuations, in insurance theory, to study ruin, as well as in macroeconomics as prototypical growth models. All these topics are complementary

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to what is dealt with in existing books on fractional calculus and its applications. This book was written with a trade-off in mind between full mathematical rigor and the needs of readers coming from different applied areas of

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science and engineering. In particular, the numerical methods listed in the book are presented in a readily accessible way that immediately allows the readers to implement them on a computer in a programming

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language of their choice.

Numerical code is also provided.

In recent years, fractional calculus has led to tremendous progress in various areas of science and mathematics. New definitions of fractional

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derivatives and integrals have been uncovered, extending their classical definitions in various ways. Moreover, rigorous analysis of the functional properties of these new definitions has been an active

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area of research in mathematical analysis. Systems considering differential equations with fractional-order operators have been investigated thoroughly from analytical and numerical points of view, and potential

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applications have been proposed for use in sciences and in technology. The purpose of this Special Issue is to serve as a specialized forum for the dissemination of recent progress in the theory of fractional

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calculus and its potential
applications.

Fractional calculus was first
developed by pure
mathematicians in the middle of
the 19th century. Some 100
years later, engineers and

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physicists have found applications for these concepts in their areas. However there has traditionally been little interaction between these two communities. In particular, typical mathematical works

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provide extensive findings on aspects with comparatively little significance in applications, and the engineering literature often lacks mathematical detail and precision. This book bridges the gap between the two

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communities. It concentrates on the class of fractional derivatives most important in applications, the Caputo operators, and provides a self-contained, thorough and mathematically rigorous study of their

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properties and of the corresponding differential equations. The text is a useful tool for mathematicians and researchers from the applied sciences alike. It can also be used as a basis for teaching

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graduate courses on fractional
differential equations.

Proceedings of the International
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University of New Haven, June
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Applications in Physics

General Fractional Derivatives

In this book, we study
theoretical and practical aspects
of computing methods for
mathematical modelling of
nonlinear systems. A number of

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computing techniques are considered, such as methods of operator approximation with any given accuracy; operator interpolation techniques including a non-Lagrange interpolation; methods of

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system representation subject to constraints associated with concepts of causality, memory and stationarity; methods of system representation with an accuracy that is the best within a given class of models;

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methods of covariance matrix estimation; methods for low-rank matrix approximations; hybrid methods based on a combination of iterative procedures and best operator approximation; and methods for

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information compression and filtering under condition that a filter model should satisfy restrictions associated with causality and different types of memory. As a result, the book represents a blend of new

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methods in general
computational analysis, and
specific, but also generic,
techniques for study of systems
theory and its particular
branches, such as optimal
filtering and information

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compression. - Best operator
approximation, - Non-Lagrange
interpolation, - Generic
Karhunen-Loeve transform -
Generalised low-rank matrix
approximation - Optimal data
compression - Optimal

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nonlinear filtering

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Applications provides
knowledge of the special
functions with respect to
another function, and the

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integro-differential operators
where the integrals are of the
convolution type and exist the
singular, weakly singular and
nonsingular kernels, which
exhibit the fractional
derivatives, fractional integrals,

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general fractional derivatives,
and general fractional integrals
of the constant and variable
order without and with respect
to another function due to the
appearance of the power-law
and complex herbivores to

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figure out the modern developments in theoretical and applied science. Features: Give some new results for fractional calculus of constant and variable orders. Discuss some new definitions for fractional

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calculus with respect to another function. Provide definitions for general fractional calculus of constant and variable orders. Report new results of general fractional calculus with respect to another function. Propose

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news special functions with respect to another function and their applications. Present new models for the anomalous relaxation and rheological behaviors. This book serves as a reference book and textbook for

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scientists and engineers in the fields of mathematics, physics, chemistry and engineering, senior undergraduate and graduate students. Dr. Xiao-Jun Yang is a full professor of Applied Mathematics and

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Mechanics, at China University of Mining and Technology, China. He is currently an editor of several scientific journals, such as Fractals, Applied Numerical Mathematics, Mathematical Modelling and

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Analysis, International Journal
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& Fluid Flow, and Thermal
Science.

This book collects papers from
the 8th Conference on Non-
Integer Order Calculus and Its

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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

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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

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Applications in Mechanics

In the last two decades, fractional (or non integer) differentiation has played a very important role in various fields such as mechanics, electricity, chemistry, biology, economics, control theory and

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signal and image processing. For example, in the last three fields, some important considerations such as modelling, curve fitting, filtering, pattern recognition, edge detection, identification, stability, controllability, observability and

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robustness are now linked to long-range dependence phenomena. Similar progress has been made in other fields listed here. The scope of the book is thus to present the state of the art in the study of fractional systems and

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the application of fractional differentiation. As this volume covers recent applications of fractional calculus, it will be of interest to engineers, scientists, and applied mathematicians. Fractional Calculus and Fractional

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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

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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

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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

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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

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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

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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

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book's content as applied to
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This multi-volume handbook is

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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

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calculus, including fractional-order operators, integral transforms and equations, special functions, calculus of variations, and probabilistic and other aspects.

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Wave Propagation, Impact and
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*introduces the newly
established fractional-
order calculus operators
involving singular and
non-singular kernels
with applications to
fractional-order*

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*viscoelastic models from
the calculus operator
viewpoint. Fractional
calculus and its
applications have gained
considerable popularity
and importance because*

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*of their applicability
to many seemingly
diverse and widespread
fields in science and
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operations in physics
and engineering can be*

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*defined accurately by
using fractional
derivatives to model
complex phenomena.*

*Viscoelasticity is chief
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evolved as an empirical
method of describing the
properties of
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*Derivatives with
Applications in
Viscoelasticity makes a
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