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 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 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 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.

Theory and Numerical Approximations of Fractional Integrals and Derivatives

Fractional calculus provides the possibility of introducing integrals and derivatives of an arbitrary order in the mathematical modelling of physical processes, and it has become a relevant subject with applications to various fields, such as anomalous diffusion, propagation in different media, and propagation in relation to materials with different properties. However, many aspects from theoretical and practical points of view have still to be developed in relation to models based on fractional operators. This Special Issue is related to new developments on different aspects of fractional differential equations, both from a theoretical point of view and in terms of applications in different fields such as physics, chemistry, or control theory, for instance. The topics of the Issue include fractional calculus, the mathematical analysis of the properties of the solutions to fractional equations, the extension of classical approaches, or applications of fractional equations to several fields.
The Analysis of Fractional Differential Equations: An Application-Oriented Exposition Using Different Transmutations, Singular and Fractional Differential Equations with Applications to Mathematical Physics

Numerical Methods for Fractional Calculus presents numerical methods for fractional integrals and fractional derivatives, finite difference methods for fractional ordinary differential equations (FODEs) and fractional partial differential equations (FPDEs), and finite element methods for FPDEs. The book introduces the basic definitions and properties.

Hadamard-Type Fractional Differential Equations, Inclusions and Inequalities

The trajectory of fractional calculus has undergone several periods of intensive development, both in pure and applied sciences. During the last few decades fractional calculus has also been associated with the power law effects and its various applications. It is a natural to ask if fractional calculus, as a nonlocal calculus, can produce new results within the well-established field of Lie symmetries and their applications. In Lie Symmetry Analysis of Fractional Differential Equations the authors try to answer this vital question by analyzing different aspects of fractional Lie symmetries and related conservation laws. Finding the exact solutions of a given fractional partial differential equation is not an easy task, but is one that the authors seek to grapple with here. The book also includes generalization of Lie symmetries for fractional integro-differential equations. Features: Provides a solid basis for understanding fractional calculus, before going on to explore in detail Lie Symmetries and their applications. Useful for PhD and postdoc graduates, as well as for all mathematicians and applied researchers who use the powerful concept of Lie symmetries. Filled with various examples to aid understanding of the topics.

Analysis of Fractional Differential Equations

This book covers applications of fractional calculus used for medical and health science. It offers a collection of research articles built into chapters on 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 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 highlighting modeling strategies. The book will be useful to graduate level students, educators and researchers interested in mathematics and medical science.

Analysis, Modeling and Stability of Fractional Order Differential Systems

Fractional calculus was first developed by pure mathematicians in the middle of the 19th century. Some 100 years later, engineers and 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 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 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 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 graduate courses on fractional differential equations.

Fuzzy Fractional Differential Operators and Equations
This invaluable monograph is devoted to a rapidly developing area on the research of qualitative theory of fractional ordinary and partial differential equations. It provides the readers the necessary background material required to go further into the subject and explore the rich research literature. The tools used include many classical and modern nonlinear analysis methods such as fixed point theory, measure of noncompactness method, topological degree method, the technique of Picard operators, critical point theory and semigroup theory. Based on the research work carried out by the authors and other experts during the past seven years, the contents are very recent and comprehensive. In this edition, two new topics have been added, that is, fractional impulsive differential equations, and fractional partial differential equations including fractional Navier–Stokes equations and fractional diffusion equations. Contents:Preliminaries:IntroductionSome Notations, Concepts and LemmasFractional CalculusSome Results from Nonlinear AnalysisSemigroupsFractional Functional Differential Equations:IntroductionNeutral Equations with Bounded Delayp-Type Neutral EquationsNeutral Equations with Infinite DelayIterative Functional Differential EquationsNotes and RemarksFractional Ordinary Differential Equations in Banach Spaces:IntroductionCauchy Problems via Measure of Noncompactness MethodCauchy Problems via Topological Degree MethodCauchy Problems via Picard Operators Technique and RemarksFractional Abstract Evolution Equations:IntroductionEvolution Equations with Riemann–Liouville DerivativeEvolution Equations with Caputo DerivativeNonlocal Problems for Evolution EquationsAbstract Cauchy Problems with Almost Sectorial OperatorsNotes and RemarksFractional Differential Equations:IntroductionImpulsive Initial Value ProblemsImpulsive Boundary Value ProblemsImpulsive Langevin EquationsImpulsive Evolution EquationsNotes and RemarksFractional Boundary Value Problems:IntroductionFractional Equations:Notes and RemarksFractional Partial Differential Equations:IntroductionFractional Navier–Stokes EquationsFractional Euler–Lagrange EquationsFractional Schrödinger EquationsNotes and Remarks Readership: Researchers and graduate or PhD students dealing with fractional calculus and applied analysis, differential equations and related areas of research.

An Introduction to the Fractional Calculus and Fractional Differential Equations

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

The Analysis of Fractional Differential Equations

Due to its ubiquity across a variety of fields in science and engineering, fractional calculus has gained momentum in industry and academia. While a number of books and papers introduce either fractional calculus or numerical approximations, no current literature provides a comprehensive collection of both topics. This monograph introduces fundamental information on fractional calculus, provides a detailed treatment of existing numerical approximations, and presents an inclusive review of fractional calculus in terms of theory and numerical methods and systematically examines almost all existing numerical approximations for fractional integrals and derivatives. The authors consider the relationship between the fractional Laplacian and the Riesz derivative, a key component absent from other related texts, and
highlight recent developments, including their own research and results. The core audience spans several fractional communities, including those interested in fractional partial differential equations, the fractional Laplacian, and applied and computational mathematics. Advanced undergraduate and graduate students will find the material suitable as a primary or supplementary resource for their studies.

Analysis of Sequential Caputo Fractional Differential Equations with Applications

This book introduces a series of problems and methods insufficiently discussed in the field of Fractional Calculus – a major, emerging tool relevant to all areas of scientific inquiry. The authors present examples based on symbolic computation, written in Maple and Mathematica, and address both mathematical and computational areas in the context of mathematical modeling and the generalization of classical integer-order methods. Distinct from most books, the present volume fills the gap between mathematics and computer fields, and the transition from integer- to fractional-order methods.

Fractional Differential Equations

General Fractional Derivatives: Theory, Methods and Applications provides knowledge of the special functions with respect to another function, and the 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, 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 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 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 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 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 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 Analysis, International Journal of Numerical Methods for Heat & Fluid Flow, and Thermal Science.

Fractional Calculus and Fractional Differential Equations

This monograph provides an accessible introduction to the regional analysis of fractional diffusion processes. It begins with background coverage of fractional calculus, functional analysis, distributed parameter systems and relevant basic control theory. New research problems are then defined in terms of their actuation and sensing policies within the regional analysis framework. The results presented provide insight into the control-theoretic analysis of fractional-order systems for use in real-life applications such as hard-disk drives, sleep stage identification and classification, and unmanned aerial vehicle control. The results can also be extended to complex fractional-order distributed-parameter systems and various open questions with potential for further investigation are discussed. For instance, the problem of fractional order distributed-parameter systems with mobile actuators/sensors, optimal parameter identification, optimal locations/trajectory of actuators/sensors and regional actuation/sensing configurations are of great interest. The book's use of illustrations and consistent examples throughout helps readers to understand the significance of the proposed fractional models and methodologies and to enhance their comprehension. The applications treated in the book run the gamut from environmental science to national security. Academics and graduate students working with cyber-physical and distributed systems or interested in the applications of fractional calculus will find this book to be an instructive source of state-of-the-art results and inspiration for further research.
Fractional Differential Equations

This graduate textbook provides a self-contained introduction to modern mathematical theory on fractional differential equations. It addresses both ordinary and partial differential equations with a focus on detailed solution theory, especially regularity theory under realistic assumptions on the problem data. The text includes an extensive bibliography, application-driven modeling, extensive exercises, and graphic illustrations throughout to complement its comprehensive presentation of the field. It is recommended for graduate students and researchers in applied and computational mathematics, particularly applied analysis, numerical analysis and inverse problems.

Fractional Calculus in Medical and Health Science

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 second volume collects authoritative chapters covering the mathematical theory of fractional calculus, including ordinary and partial differential equations of fractional order, inverse problems, and evolution equations.

Functional and Impulsive Differential Equations of Fractional Order

Implicit Fractional Differential and Integral Equations

This book is a landmark title in the continuous move from integer to non-integer in mathematics: from integer numbers to real numbers, from factorials to the gamma function, from integer-order models to models of an arbitrary order. For historical reasons, the word 'fractional' is used instead of the word 'arbitrary'. This book is written for readers who are new to the fields of fractional derivatives and fractional-order mathematical models, and feel that they need them for developing more adequate mathematical models. In this book, not only applied scientists, but also pure mathematicians will find fresh motivation for developing new methods and approaches in their fields of research. A reader will find in this book everything necessary for the initial study and immediate application of fractional derivatives fractional differential equations, including several necessary special functions, basic theory of fractional differentiation, uniqueness and existence theorems, analytical numerical methods of solution of fractional differential equations, and many inspiring examples of applications. A unique survey of many applications of fractional calculus Presents basic theory Includes a unified presentation of selected classical results, which are important for applications Provides many examples Contains a separate chapter of fractional order control systems, which opens new perspectives in control theory The first systematic consideration of Caputo's fractional derivative in comparison with other selected approaches Includes tables of fractional derivatives, which can be used for evaluation of all considered types of fractional derivatives

Fractional-Order Nonlinear Systems

The trajectory of fractional calculus has undergone several periods of intensive development, both in pure and applied sciences. During the last few decades fractional calculus has also been associated with the power law effects and its various applications. It is a natural to ask if fractional calculus, as a nonlocal calculus, can produce new results within the well-established field of Lie symmetries and their applications. In Lie Symmetry Analysis of Fractional Differential Equations the authors try to answer this vital question by analyzing different aspects of fractional Lie symmetries and related conservation laws. Finding the exact solutions of a given fractional
partial differential equation is not an easy task, but is one that the authors seek to grapple with here. The book also includes generalization of Lie symmetries for fractional integro differential equations. Features Provides a solid basis for understanding fractional calculus, before going on to explore in detail Lie Symmetries and their applications Useful for PhD and postdoc graduates, as well as for all mathematicians and applied researchers who use the powerful concept of Lie symmetries Filled with various examples to aid understanding of the topics

Implicit Fractional Differential and Integral Equations

This book contains new and useful materials concerning fuzzy fractional differential and integral operators and their relationship. As the title of the book suggests, the fuzzy subject matter is one of the most important tools discussed. Therefore, it begins by providing a brief but important and new description of fuzzy sets and the computational calculus they require. Fuzzy fractals and fractional operators have a broad range of applications in the engineering, medical and economic sciences. Although these operators have been addressed briefly in previous papers, this book represents the first comprehensive collection of all relevant explanations. Most of the real problems in the biological and engineering sciences involve dynamic models, which are defined by fuzzy fractional operators in the form of fuzzy fractional initial value problems. Another important goal of this book is to solve these systems and analyze their solutions both theoretically and numerically. Given the content covered, the book will benefit all researchers and students in the mathematical and computer sciences, but also the engineering sciences.

General Fractional Derivatives

This book provides a broad overview of the latest developments in fractional calculus and fractional differential equations (FDEs) with an aim to motivate the readers to venture into these areas. It also presents original research describing the fractional operators of variable order, fractional-order delay differential equations, chaos and related phenomena in detail. Selected results on the stability of solutions of nonlinear dynamical systems of the non-commensurate fractional order have also been included. Furthermore, artificial neural network and fractional differential equations are elaborated on; and new transform methods (for example, Sumudu methods) and how they can be employed to solve fractional partial differential equations are discussed. The book covers the latest research on a variety of topics, including: comparison of various numerical methods for solving FDEs, the Adomian decomposition method and its applications to fractional versions of the classical Poisson processes, variable-order fractional operators, fractional variational principles, fractional delay differential equations, fractional-order dynamical systems and stability analysis, inequalities and comparison theorems in FDEs, artificial neural network approximation for fractional operators, and new transform methods for solving partial FDEs. Given its scope and level of detail, the book will be an invaluable asset for researchers working in these areas.

Fractional Differential Equations

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

Fractional Differential Equations

Commences with the historical development of fractional calculus, its mathematical theory—particularly the Riemann-Liouville version. Numerous examples and theoretical applications of the theory are presented. Features topics associated with fractional differential equations. Discusses Weyl fractional calculus and some of its
uses. Includes selected physical problems which lead to fractional differential or integral equations.

The Variable-Order Fractional Calculus of Variations

The study of fractional calculus theory has attracted the attention of many of the world’s applied mathematicians during the past decades, mainly because of the popular application of various fractional-order differential equations in modeling challenging physical phenomena including anomalous diffusion that is present in microscopic and macroscopic scales. Compared to integer-order differential equations, the study of fractional-order differential equations becomes more subtle and sophisticated to deal with due to appearance of non-local operators. To date, this subject remains a dynamic field of inquiry, with many interesting open questions. This dissertation collects results of several aspects of fractional-order differential equations and related questions. More precisely, it includes three topics: 1) analysis of fractional order differential equations; 2) investigation of fractional Sobolev spaces from the perspective of Riemann-Liouville operators; 3) study of harmonic analysis from the perspective of Riemann-Liouville operators. The first topic is focused on fractional diffusion-advection-reaction equation and the striking structure of the true solution, which gives a glimpse of some common features shared by general fractional-order differential equations. Existence, uniqueness and regularity of solution will be established. In the second and third topic, it will be shown how fractional Riemann-Liouville operators naturally arise from the subject of fractional Sobolev spaces and harmonic analysis, with an illustration on how Riemann-Liouville operators, fractional Sobolev spaces and analog filters are tangled together.

Lie Symmetry Analysis of Fractional Differential Equations

Starting with an introduction to fractional derivatives and numerical approximations, this book presents finite difference methods for fractional differential equations, including time-fractional sub-diffusion equations, time-fractional wave equations, and space-fractional differential equations, among others. Approximation methods for fractional derivatives are developed and approximate accuracies are analyzed in detail.

Regional Analysis of Time-Fractional Diffusion Processes

This book introduces an original fractional calculus methodology (‘the infinite state approach’) which is applied to the modeling of fractional order differential equations (FDEs) and systems (FDSs). Its modeling is based on the frequency distributed fractional integrator, while the resulting model corresponds to an integer order and infinite dimension state space representation. This original modeling allows the theoretical concepts of integer order systems to be generalized to fractional systems, with a particular emphasis on a convolution formulation.

The Analysis of Fractional Differential Equations

This book deals with the existence and stability of solutions to initial and boundary value problems for functional differential and integral equations and inclusions involving the Riemann-Liouville, Caputo, and Hadamard fractional derivatives and integrals. A wide variety of topics is covered in a mathematically rigorous manner making this work a valuable source of information for graduate students and researchers working with problems in fractional calculus. Contents Preliminary Background Nonlinear Implicit Fractional Differential Equations Impulsive Nonlinear Implicit Fractional Differential Equations Boundary Value Problems for Nonlinear Implicit Fractional Differential Equations Boundary Value Problems for Impulsive NIFDE Integrable Solutions for Implicit Fractional Differential Equations Partial Hadamard Fractional Integral Equations and Inclusions Stability Results for Partial Hadamard Fractional Integral Equations and Inclusions Hadamard–Stieltjes Fractional Integral Equations Ulam Stabilities for Random Hadamard Fractional Integral Equations
Boundary Value Problems For Fractional Differential Equations And Systems

This book focuses on the recent development of fractional differential equations, integro-differential equations, and inclusions and inequalities involving the Hadamard derivative and integral. Through a comprehensive study based in part on their recent research, the authors address the issues related to initial and boundary value problems involving Hadamard type differential equations and inclusions as well as their functional counterparts. The book covers fundamental concepts of multivalued analysis and introduces a new class of mixed initial value problems involving the Hadamard derivative and Riemann-Liouville fractional integrals. In later chapters, the authors discuss nonlinear Langevin equations as well as coupled systems of Langevin equations with fractional integral conditions. Focused and thorough, this book is a useful resource for readers and researchers interested in the area of fractional calculus.

Introduction to Fractional Differential Equations

This book introduces an original fractional calculus methodology (the infinite state approach) which is applied to the modeling of fractional order differential equations (FDEs) and systems (FDSs). Its modeling is based on the frequency distributed fractional integrator, while the resulting model corresponds to an integer order and infinite dimension state space representation. This original modeling allows the theoretical concepts of integer order systems to be generalized to fractional systems, with a particular emphasis on a convolution formulation. With this approach, fundamental issues such as system state interpretation and system initialization – long considered to be major theoretical pitfalls – have been solved easily. Although originally introduced for numerical simulation and identification of FDEs, this approach also provides original solutions to many problems such as the initial conditions of fractional derivatives, the uniqueness of FDS transients, formulation of analytical transients, fractional differentiation of functions, state observation and control, definition of fractional energy, and Lyapunov stability analysis of linear and nonlinear fractional order systems. This second volume focuses on the initialization, observation and control of the distributed state, followed by stability analysis of fractional differential systems.

Numerical Methods for Fractional Calculus

?The Variable-Order Fractional Calculus of Variations is devoted to the study of fractional operators with variable order and, in particular, variational problems involving variable-order operators. This brief presents a new numerical tool for the solution of differential equations involving Caputo derivatives of fractional variable order. Three Caputo-type fractional operators are considered, and for each one, an approximation formula is obtained in terms of standard (integer-order) derivatives only. Estimations for the error of the approximations are also provided. The contributors consider variational problems that may be subject to one or more constraints, where the functional depends on a combined Caputo derivative of variable fractional order. In particular, they establish necessary optimality conditions of Euler–Lagrange type. As the terminal point in the cost integral is free, as is the terminal state, transversality conditions are also obtained. The Variable-Order Fractional Calculus of Variations is a valuable source of information for researchers in mathematics, physics, engineering, control and optimization; it provides both analytical and numerical methods to deal with variational problems. It is also of interest to academics and postgraduates in these fields, as it solves multiple variational problems subject to one or more constraints in a single brief.

Fractional Dynamics

A guide to the new research in the field of fractional order 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 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 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. 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 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 information on the newest research.

Fractional Order Analysis

This book deals with the existence and stability of solutions to initial and boundary value problems for functional differential and integral equations and inclusions involving the Riemann-Liouville, Caputo, and Hadamard fractional derivatives and integrals. A wide variety of topics is covered in a mathematically rigorous manner making this work a valuable source of information for graduate students and researchers working with problems in fractional calculus. ContentsPreliminary Background Nonlinear Implicit Fractional Differential Equations Impulsive Nonlinear Implicit Fractional Differential Equations Boundary Value Problems for Nonlinear Implicit Fractional Differential Equations Boundary Value Problems for Impulsive NIFDE Integrable Solutions for Implicit Fractional Differential Equations Partial Hadamard Fractional Integral Equations and Inclusions Stability Results for Partial Hadamard Fractional Integral Equations and Inclusions Hadamard–Stieltjes Fractional Integral Equations Ulam Stabilities for Random Hadamard Fractional Integral Equations

Theory and Applications of Fractional Differential Equations

Fractional calculus was first developed by pure mathematicians in the middle of the 19th century. Some 100 years later, engineers and 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 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 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 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 graduate courses on fractional differential equations.

Fractional Order Analysis

A guide to the new research in the field of fractional order 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 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 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. 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. 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 information on the newest research.

Analysis and Partial Differential Equations on Manifolds, Fractals and Graphs

The book is devoted to recent developments in the theory of fractional calculus and its applications. Particular attention is paid to the applicability of this currently popular research field in various branches of pure and applied mathematics. In particular, the book focuses on the more recent results in mathematical physics, engineering applications, theoretical and applied physics as quantum mechanics, signal analysis, and in those relevant research fields where nonlinear dynamics occurs and several tools of nonlinear analysis are required. Dynamical processes and dynamical systems of fractional order attract researchers from many areas of sciences and technologies, ranging from mathematics and physics to computer science.

Fractional Differential Equations

Transmutations, Singular and Fractional Differential Equations with Applications to Mathematical Physics connects difficult problems with similar more simple ones. The book’s strategy works for differential and integral equations and systems and for many theoretical and applied problems in mathematics, mathematical physics, probability and statistics, applied computer science and numerical methods. In addition to being exposed to recent advances, readers learn to use transmutation methods not only as practical tools, but also as vehicles that deliver theoretical insights. Presents the universal transmutation method as the most powerful for solving many problems in mathematics, mathematical physics, probability and statistics, applied computer science and numerical methods. Combines mathematical rigor with an illuminating exposition full of historical notes and fascinating details. Enables researchers, lecturers and students to find material under the single "roof".

Basic Theory

The book covers the latest research in the areas of mathematics that deal the properties of partial differential equations and stochastic processes on spaces in connection with the geometry of the underlying space. Written by experts in the field, this book is a valuable tool for the advanced mathematician.

Advances in Fractional Calculus

On Fractional Differential Equations and Related Questions

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.

Analysis, Modeling, and Stability of Fractional Order Differential Systems 2
This book is devoted to the study of existence of solutions or positive solutions for various classes of Riemann-Liouville and Caputo fractional differential equations, and systems of fractional differential equations subject to nonlocal boundary conditions. The monograph draws together many of the authors' results, that have been obtained and highly cited in the literature in the last four years. In each chapter, various examples are presented which support the main results. The methods used in the proof of these theorems include results from the fixed point theory and fixed point index theory. This volume can serve as a good resource for mathematical and scientific researchers, and for graduate students in mathematics and science interested in the existence of solutions for fractional differential equations and systems.

Basic Theory of Fractional Differential Equations

Lie Symmetry Analysis of Fractional Differential Equations

The book presents qualitative results for different classes of fractional equations, including fractional functional differential equations, fractional impulsive differential equations, and fractional impulsive functional differential equations, which have not been covered by other books. It manifests different constructive methods by demonstrating how these techniques can be applied to investigate qualitative properties of the solutions of fractional systems. Since many applications have been included, the demonstrated techniques and models can be used in training students in mathematical modeling and in the study and development of fractional-order models.

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