Fractional calculus with an integral operator containing a generalized Mittag–Leffler function in the kernel

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ARTICLE INFO

ABSTRACT

In this paper, we introduce and investigate a fractional calculus with an integral operator which contain the following family of generalized Mittag–Leffler functions:

$$E_{\alpha,\beta}^{\gamma}(z) = \sum_{n=0}^{\infty} \frac{(\gamma)_n}{\Gamma(\alpha n + \beta)} \frac{z^n}{n!} \quad (\alpha, \beta, \gamma \in \mathbb{C};\ \Re(\alpha) > \max\{0, \Re(\kappa) - 1\};\ \Re(\kappa) > 0)$$

in its kernel, $(\lambda)_n$ being the familiar Pochhammer symbol. A number of corollaries and consequences of the main results presented here are also considered.

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1. Introduction, definitions and preliminaries

As mentioned in the survey article by Gorenflo and Mainardi [4], even the classical Mittag–Leffler functions have remained, for a long time, almost totally ignored in the common handbooks on special functions and tables of integral transforms, although a reasonably adequate description of many of their interesting and potentially useful properties appeared already in the *third* volume of the celebrated Bateman Manuscript Project (see Erdélyi et al. [2, Chapter 18]) in a chapter devoted to *Miscellaneous Functions*). The Mittag–Leffler functions $E_\alpha(z)$ and $E_{\alpha,\beta}(z)$ are defined by the following series:

$$E_\alpha(z) = \sum_{n=0}^{\infty} \frac{z^n}{\Gamma(\alpha n + 1)} \quad (z \in \mathbb{C};\ \Re(\alpha) > 0) \tag{1.1}$$

and

$$E_{\alpha,\beta}(z) = \sum_{n=0}^{\infty} \frac{z^n}{\Gamma(\alpha n + \beta)} \quad (z, \beta \in \mathbb{C};\ \Re(\alpha) > 0), \tag{1.2}$$

respectively. These functions are natural extensions of the exponential, hyperbolic and trigonometric functions, since

$$E_1(z) = e^z, \quad E_2(z^2) = \cosh z \quad \text{and} \quad E_2(-z^2) = \cos z.$$

For a detailed account of the various properties, generalizations and applications of the Mittag–Leffler functions, the reader may refer to the recent works by (for example) Džrbašjan [1], Kilbas and Saigo [11], Gorenflo and Mainardi [4], Gorenflo et al.

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Fractional Calculus With An Integral Operator Containing A

Dumitru Baleanu,Devendra Kumar

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   Fractional Calculus and its Applications in Physics Dumitru Baleanu,Devendra Kumar,2019-11-15   Fractional Integrals and Derivatives: "True" versus "False" Yuri Luchko,2021-03-16 This Special Issue is devoted to some serious problems that the Fractional Calculus FC is currently confronted with and aims at providing some answers to the questions like What are the fractional integrals and derivatives What are their decisive mathematical properties What fractional operators make sense in applications and why etc In particular the new fractional derivatives and integrals and the models with these fractional order operators are critically addressed The Special Issue contains both the surveys and the research contributions A part of the articles deals with foundations of FC that are considered from the viewpoints of the pure and applied mathematics and the system theory Another part of the Special issue addresses the applications of the FC operators and the fractional differential equations Several articles devoted to the numerical treatment of the FC operators and the fractional differential equations complete the Special Issue   **Fractional Differential Equations, Inclusions and Inequalities with Applications** Sotiris K. Ntouyas,2020-11-09 During the last decade there has been an increased interest in fractional differential equations inclusions and inequalities as they play a fundamental role in the modeling of numerous phenomena in particular in physics biomathematics blood flow phenomena ecology environmental issues viscoelasticity aerodynamics electrodynamics of complex medium electrical circuits electron analytical chemistry control theory etc This book presents collective works published in the recent Special Issue SI entitled Fractional Differential Equation Inclusions and Inequalities with Applications of the journal Mathematics This Special Issue presents recent developments in the theory of fractional differential equations and inequalities Topics include but are not limited to the existence and uniqueness results for boundary value problems for different types of fractional differential equations a variety of fractional inequalities impulsive fractional differential equations and applications in sciences and engineering   *General Fractional Derivatives with Applications in Viscoelasticity* Xiao-Jun Yang,Feng Gao,Yang Ju,2020-04-03 General Fractional Derivatives with Applications in Viscoelasticity introduces the newly established fractional order calculus operators involving singular and non singular kernels with applications to fractional order viscoelastic models from the calculus operator viewpoint Fractional calculus and its applications have gained considerable popularity and importance because of their applicability to many seemingly diverse and widespread fields in science and engineering Many operations in physics and engineering can be defined accurately by using fractional derivatives to model complex phenomena Viscoelasticity is chief among them as the general fractional calculus approach to viscoelasticity has evolved as an empirical method of describing the properties of viscoelastic materials General Fractional Derivatives with Applications in Viscoelasticity makes a concise presentation of general fractional calculus Presents a comprehensive overview of the fractional derivatives and their applications in viscoelasticity Provides help in handling the power law functions Introduces and explores the questions about general

fractional derivatives and its applications   <u>Basic Theory</u> Anatoly Kochubei,Yuri Luchko,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 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   **Integral Transforms and Operational Calculus** H. M. Srivastava,2019-11-20 Researches and investigations involving the theory and applications of integral transforms and operational calculus are remarkably wide spread in many diverse areas of the mathematical physical chemical engineering and statistical sciences This Special Issue contains a total of 36 carefully selected and peer reviewed articles which are authored by established researchers from many countries Included in this Special Issue are review expository and original research articles dealing with the recent advances on the topics of integral transforms and operational calculus as well as their multidisciplinary applications   *Applications of Fractional Calculus to Modeling in Dynamics and Chaos* J. F. Gómez-Aguilar,Abdon Atangana,2022-09-29 Applications of Fractional Calculus to Modeling in Dynamics and Chaos aims to present novel developments trends and applications of fractional order derivatives with power law and Mittag Leffler kernel in the areas of chemistry mechanics chaos epidemiology fluid mechanics modeling and engineering Non singular and non local fractional order derivatives have been applied in different chapters to describe complex problems The book offers theory and practical applications for the solutions of real life problems and will be of interest to graduate level students educators researchers and scientists interested in mathematical modeling and its diverse applications Features Discusses real world problems theory and applications Covers new developments and advances in the various areas of nonlinear dynamics signal processing and chaos Suitable to teach master s and or PhD level graduate students and can be used by researchers from any field of the social health and physical sciences   *Fractional Calculus and Waves in Linear Viscoelasticity* Francesco Mainardi,2010 This monograph provides a comprehensive overview of the author s work on the fields of fractional calculus and waves in linear viscoelastic media which includes his pioneering contributions on the applications of special functions of the Mittag Leffler and Wright types It is intended to serve as a general introduction to the above mentioned areas of mathematical modeling The explanations in the book are detailed enough to capture the interest of the curious reader and complete enough to provide the necessary background material needed to delve further into the subject and explore the research literature given in the huge general bibliography This book is likely to be of interest to applied scientists and engineers   *Unification of Fractional Calculi with Applications* George A. Anastassiou,2021-11-21 This book demonstrates the unifying methods of generalized versions of Hilfer Prabhakar and Hilfer Prabhakar fractional calculi and we establish related unifying fractional integral inequalities of the following types Iyengar Landau Polya Ostrowski Hilbert Pachpatte Hardy Opial Csiszar s f Divergence self adjoint operator and related to fuzziness Our results are univariate and multivariate This book s results are

expected to find applications in many areas of pure and applied mathematics especially in fractional inequalities and fractional differential equations Other interesting applications can be in applied sciences like geophysics physics chemistry economics and engineering This book is appropriate for researchers graduate students practitioners and seminars of the above disciplines also to be in all science and engineering libraries   Solved Exercises in Fractional Calculus Edmundo Capelas de Oliveira,Jayme Vaz,2025-04-28 This textbook provides a comprehensive exploration of special functions and fractional calculus offering a structured approach through solved and proposed exercises Covering key mathematical concepts such as Mittag Leffler functions Kilbas Saigo functions and the Erd lyi Kober fractional integral it balances theoretical insights with practical applications Appendices introduce Barnes G functions and demonstrate the use of Mathematica for fractional calculus expanding the book s accessibility With an updated index and extensive references this edition serves as a valuable resource for researchers graduate students and professionals in applied mathematics and related fields   *Fractional Differential Equations* Praveen Agarwal,Carlo Cattani,Shaher Momani,2024-04-29 Fractional Differential Equations Theoretical Aspects and Applications presents the latest mathematical and conceptual developments in the field of Fractional Calculus and explores the scope of applications in research science and computational modelling Fractional derivatives arise as a generalization of integer order derivatives and have a long history their origin can be found in the work of G W Leibniz and L Euler Shortly after being introduced the new theory turned out to be very attractive for many famous mathematicians and scientists including P S Laplace B Riemann J Liouville N H Abel and J B J Fourier due to the numerous possibilities it offered for applications Fractional Calculus the field of mathematics dealing with operators of differentiation and integration of arbitrary real or even complex order extends many of the modelling capabilities of conventional calculus and integer order differential equations and finds its application in various scientific areas such as physics mechanics engineering economics finance biology and chemistry among others However many aspects from the theoretical and practical point of view have still to be developed in relation with models based on fractional operators Efficient analytical and numerical methods have been developed but still need particular attention Fractional Differential Equations Theoretical Aspects and Applications delves into these methods and applied computational modelling techniques including analysis of equations involving fractional derivatives fractional derivatives and the wave equation analysis of FDE on groups direct and inverse problems functional inequalities and computational methods for FDEs in physics and engineering Other modelling techniques and applications explored by the authors include general fractional derivatives involving the special functions in analysis fractional derivatives with respect to another function in analysis new fractional operators in real world applications fractional order dynamical systems hidden attractors in complex systems nonlinear dynamics and chaos in engineering applications quantum chaos and self excited attractors Provides the most recent and up to date developments in the theory and scientific applications Fractional Differential Equations Includes transportable computer source codes for readers in

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in one and many dimensions this book also contains a mathematical theory of certain important weakly singular integral equations of the first kind arising in mechanics diffraction theory and other areas of mathematical physics The author focuses on explicit inversion formulae that can be obtained by making use of the classical Marchaud s approach and its generalization leading to wavelet type representations New to this Edition Two new chapters and a new appendix related to Radon transforms and harmonic analysis of linear operators commuting with rotations and dilations have been added Contains new exercises and bibliographical notes along with a thoroughly expanded list of references This book is suitable for mathematical physicists and pure mathematicians researching in the area of integral equations integral transforms and related harmonic analysis *Mathematical Methods in Medical and Biological Sciences* Harendra Singh,Hari M Srivastava,2024-11-05 Mathematical Methods in Medical and Biological Sciences presents mathematical methods for computational models arising in the medical and biological sciences The book presents several real life medical and biological models such as infectious and non infectious diseases that can be modeled mathematically to accomplish profound research in virtual environments when the cost of laboratory expenses is relatively high It focuses on mathematical techniques that provide global solutions for models arising in medical and biological sciences by considering their long term benefits In addition the book provides leading edge developments and insights for a range of applications including epidemiological modeling of pandemic dynamics viral infection developments cancer developments blood oxygen dynamics HIV infection spread reaction diffusion models polio infection spread and chaos modeling with fractional order derivatives Presents the mathematical treatment of a wide range of real life medical and biological models including both infectious and non infectious diseases Provides in depth analysis of the spread of Covid 19 polio and HIV including discussion of computational methods and applications Includes computational modeling methods along with their practical applications providing the basis for further exploration and research in epidemiology and applied biomedical sciences *Mathematics and Computer Science, Volume 1* Sharmistha Ghosh,M. Niranjanamurthy,Krishanu Deyasi,Biswadip Basu Mallik,Santanu Das,2023-07-19 MATHEMATICS AND COMPUTER SCIENCE This first volume in a new multi volume set gives readers the basic concepts and applications for diverse ideas and innovations in the field of computing together with its growing interactions with mathematics This new edited volume from Wiley Scrivener is the first of its kind to present scientific and technological innovations by leading academicians eminent researchers and experts around the world in the areas of mathematical sciences and computing The chapters focus on recent advances in computer science and mathematics and where the two intersect to create value for end users through practical applications of the theory The chapters herein cover scientific advancements across a diversified spectrum that includes differential as well as integral equations with applications computational fluid dynamics nanofluids network theory and optimization control theory machine learning and artificial intelligence big data analytics Internet of Things cryptography fuzzy automata statistics and many more Readers of

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