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Editorial

Editorial for the Special Issue "Analytical and Computational Methods in Differential Equations, Special Functions, Transmutations and Integral Transforms"

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This editorial text is a short introductory guide to the book edition of the Special Issue "Analytical and Computational Methods in Differential Equations, Special Functions, Transmutations and Integral Transforms", which was published in the MDPI journal Mathematics in the years 2022–2023.

This Special Issue includes research and survey papers that cover a wide range of topics in Classical, Computational and Applied Mathematics. High-quality papers on the next wide range of topics from different fields of Mathematics are included:

- Differential equations, especially concerning singular solutions and coefficients;
- Transmutation theory with all kinds of applications;
- Integral transforms;
- Special functions;
- Differential-difference equations;
- Classical and advanced inequalities, convex functions;
- Special-type polynomials;
- q-trigonometric and hypergeometric functions and q-differential equations;
- The Gauss hypergeometric functions, Fox–Wright generalized hypergeometric functions;
- Mathieu-type and extended hypergeometric series;
- Inverse Sturm–Liouville problems;
- The general fractional integrals and derivatives;
- Nonlinear equations with KPZ-type nonlinearities;
- Higher order differential equations;
- Cellular automaton and Markov Chains;
- Stochastic equations and systems;
- Numerical methods for all above mentioned problems.

As a whole, the Special Issue consists of 24 papers on the above-mentioned topics. Among its authors are the following well–known researchers in different fields of mathematics: Prof. Hari M. Srivastava (University of Victoria, Victoria, Canada), Prof. Dr. Tibor K. Pogány (Faculty of Maritime Studies, University of Rijeka, Croatia), Prof. Vasily Tarasov (Lomonosov Moscow State University, Russia), Dr. Natalia P. Bondarenko (Saratov State University, Saratov, Russia), Prof. Yuri Luchko (Berlin University of Applied Sciences and Technology, Berlin, Germany), Prof. Andrey Muravnik (the Director of S.M. Nikol'skii mathematical institute, Peoples Friendship University of Russia, Moscow, Russia), Prof. Vladimir Vasilyev (Belgorod State National Research University, Belgorod, Russia), Prof. Sergei M. Sitnik (Belgorod State National Research University, Belgorod, Russia), Prof. Vladimir Fedorov (Chelyabinsk State University, Chelyabinsk, Russia), Prof. Vladislav V. Kravchenko (Cinvestav, Unidad Querétaro, Querétaro, Mexico), Dr. Dmitrii Karp (Holon

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Institute of Technology, Holon, Israel), Dr. Alexander Dyachenko (Keldysh Institute of Applied Mathematics, Moscow, Russia) and others.

Below, the papers of the Special Issue with corresponding brief annotations are listed as per their publication order.

In the paper [1], the author investigates the half-space Dirichlet problem with summable boundary-value functions for an elliptic equation with an arbitrary number of potentials undergoing translations in arbitrary directions. In the classical case of partial differential equations, the half-space Dirichlet problem for elliptic equations attracts great interest from researchers due to the following phenomenon: the solutions acquire qualitative properties specific for nonstationary (more exactly, parabolic) equations. In this paper, such a phenomenon is studied for nonlocal generalizations of elliptic differential equations, more exactly, for elliptic differential-difference equations with nonlocal potentials arising in various applications not covered by the classical theory. A Poisson-like kernel is found such that its convolution with the boundary-value function satisfies the investigated problem, proves that the constructed solution is infinitely smooth outside the boundary hyperplane, and proves its uniform power-like decay as the timelike independent variable tends to infinity.

In the paper [2], the authors define q-cosine and q-sine Apostol-type Frobenius–Euler polynomials and derive interesting relations and also obtain new properties by making use of power series expansions of q-trigonometric functions, properties of q-exponential functions, and q-analogues of the binomial theorem. By using the Mathematica program, the computational formulae and graphical representation for the aforementioned polynomials are obtained. By making use of a partial derivative operator, some interesting finite combinatorial sums are derived. Finally, some special cases for these results are considered.

In the paper [3], some infinite sums are calculated containing the digamma function in closed form. These sums are related either to the incomplete beta function or to the Bessel functions. The calculations yield interesting new results as by-products, such as parameter differentiation formulas for the beta incomplete function, reduction formulas for hypergeometric functions, or a definite integral, which does not seem to be tabulated in the most common literature. As an application of certain sums involving the digamma function, in the paper are calculated some reduction formulas for the parameter differentiation of the Mittag–Leffler function and the Wright function.

In the paper [4], integral form expressions are obtained for the Mathieu-type series and for their associated alternating versions, the terms of which contain an extended Gauss hypergeometric function. Contiguous recurrence relations are found for the Mathieu-type series with respect to two parameters, and finally, particular cases and related bounding inequalities are established.

In the paper [5], an extension of the general fractional calculus (GFC) is proposed as a generalization of the Riesz fractional calculus, which was suggested by Marsel Riesz in 1949. The proposed Riesz form of GFC can be considered as an extension GFC from the positive real line and the Laplace convolution to the m-dimensional Euclidean space and the Fourier convolution. To formulate the general fractional calculus in the Riesz form, the Luchko approach to construction of the GFC, which was suggested by Yuri Luchko in 2021, is used. The general fractional integrals and derivatives are defined as convolution-type operators. In these definitions the Fourier convolution on m-dimensional Euclidean space is used instead of the Laplace convolution on positive semi-axis. Some properties of these general fractional operators are described. The general fractional analogs of first and second fundamental theorems of fractional calculus are proved. The fractional calculus of the Riesz potential and the fractional Laplacian of the Riesz form are special cases of proposed general fractional calculus of the Riesz form.

In the paper [6], the authors study for the first time the inverse Sturm–Liouville problem with polynomials of the spectral parameter in the first boundary condition and with entire analytic functions in the second one. For the investigation of this new inverse problem, an approach is developed based on the construction of a special vector functional sequence in a suitable Hilbert space. The uniqueness of recovering the potential and the polynomials of the boundary condition from a part of the spectrum is proved. Furthermore, the main results are applied to the Hochstadt–Lieberman-type problems with polynomial dependence on the spectral parameter not only in the boundary conditions, but also in discontinuity (transmission) conditions inside the interval. Novel uniqueness theorems are proved, which generalize and improve the previous results in this direction. Note that all the spectral problems in this paper are investigated in the general non-self-adjoint form, and used methods does not require the simplicity of the spectrum. Moreover, the method under consideration is constructive and can be developed in the future for numerical solution and for the study of solvability and stability of inverse spectral problems.

In the paper [7], the general fractional integrals and derivatives considered so far in the Fractional Calculus literature have been defined for functions on the real positive semi-axis. The main contribution of this paper is in introducing the general fractional integrals and derivatives of the functions on a finite interval. As in the case of the Riemann–Liouville fractional integrals and derivatives on a finite interval, the authors define both the left- and right-sided operators and investigate their interconnections. The main results presented in the paper are the first and the second fundamental theorems of Fractional Calculus formulated for the general fractional integrals and derivatives of the functions on a finite interval as well as the formulas for integration by parts that involve the general fractional integrals and derivatives.

The paper [8] presents, for quasilinear partial differential and integrodifferential equations and inequalities containing nonlinearities of the Kardar—Parisi—Zhang type, various (old and recent) results on qualitative properties of solutions (such as the stabilization of solutions, blow-up phenomena, long-time decay of solutions, and others). Descriptive examples demonstrating the Bitsadze approach (the technique of monotone maps) applied in this research area are provided.

In the paper [9], the method of transmutation operators is used to construct an exact solution of the Goursat problem for a fourth-order hyperbolic equation with a singular Bessel operator. It is emphasized that in many other papers and monographs the fractional Erdélyi–Kober operators are used as integral operators, but our approach used them as transmutation operators with additional new properties and important applications. Specifically, it extends its properties and applications to singular differential equations, especially with Bessel-type operators. Using this operator, the problem under consideration is reduced to a similar problem without the Bessel operator. The resulting auxiliary problem is solved by the Riemann method. On this basis, an exact solution of the original problem is constructed and analyzed.

In the paper [10], the authors constructs highly accurate and efficient time integration methods for the solution of transient problems. The motion equations of transient problems can be described by the first-order ordinary differential equations, in which the right-hand side is decomposed into two parts, a linear part and a nonlinear part. In the proposed methods of different orders, the responses of the linear part at the previous step are transferred by the generalized Padé approximations, and the nonlinear part's responses of the previous step are approximated by the Gauss–Legendre quadrature together with the explicit Runge–Kutta method, where the explicit Runge–Kutta method is used to calculate function values at quadrature points. For reducing computations and rounding errors, the 2 m algorithm and the method of storing an incremental matrix are employed in the calculation of the generalized Padé approximations. The proposed methods can achieve higher-order accuracy, unconditional stability, flexible dissipation, and zero-order overshoots. For linear transient problems, the accuracy of the proposed methods can reach 10–16 (computer precision), and they enjoy advantages both in accuracy and efficiency compared with some well-known explicit Runge–Kutta methods, linear multi-step methods, and composite methods in solving nonlinear problems.

In the paper [11], the one-parameter two-dimensional cellular automaton with the Margolus neighborhood is analyzed based on considering the projection of the stochastic movements of a single particle. Introducing the auxiliary random variable associated with the direction of the movement, the problem under consideration is reduced to the study of a two-dimensional Markov chain. The master equation for the probability distribution is derived and solved exactly using the probability-generating function method. The probability distribution is expressed analytically in terms of Jacobi polynomials. The moments of the obtained solution allowed to derive the exact analytical formula for the parametric dependence of the diffusion coefficient in the two-dimensional cellular automaton with the Margolus neighborhood. Analytic results of the paper agree with earlier empirical results of other authors and refine them. The results are of interest for the modeling of two-dimensional diffusion using cellular automata especially for the multicomponent problem.

In the paper [12], the Cauchy problem is studied in a strip for a two-dimensional hyperbolic equation containing the sum of a differential operator and a shift operator acting on a spatial variable that varies over the real axis. An operating scheme is used to construct the solutions of the equation. The solution of the problem is obtained in the form of a convolution of the function found using the operating scheme and the function from the initial conditions of the problem. It is proved that classical solutions of the considered initial problem exist if the real part of the symbol of the differential-difference operator in the equation is positive.

In the paper [13], the unique solvability for the Cauchy problem in a class of degenerate multi-term linear equations with Gerasimov–Caputo derivatives in a Banach space is investigated. To this aim, is used the condition of sectoriality for the pair of operators at the oldest derivatives from the equation and the general conditions of the other operators' coordination with invariant subspaces, which exist due to the sectoriality. An abstract result is applied to the research of unique solvability issues for the systems of the dynamics and of the thermoconvection for some viscoelastic media.

In the paper [14], the purpose is to organize various types of higher order q-differential equations that are connected to q-sigmoid polynomials and obtain certain properties regarding their solutions. Using the properties of q-sigmoid polynomials, it is shown that the symmetric properties of q-differential equations of higher order. Moreover, special properties for the approximate roots of q-sigmoid polynomials that are solutions of higher order q-differential equations are derived.

In the paper [15], the authors consider the Sturm–Liouville equation on a finite interval with a real-valued integrable potential and propose a method for solving the following general inverse problem. They recover the potential from a given set of the output boundary values of a solution satisfying some known initial conditions for a set of values of the spectral parameter. Special cases of this problem include the recovery of the potential from the Weyl function, the inverse two-spectra Sturm–Liouville problem, as well as the recovery of the potential from the output boundary values of a plane wave that interacted with the potential. The method is based on the special Neumann series of Bessel function representations for solutions of Sturm–Liouville equations. With their aid, the problem is reduced to the classical inverse Sturm–Liouville problem of recovering the potential from two spectra, which is solved again with the help of the same representations. The overall approach leads to an efficient numerical algorithm for solving the inverse problem. Its numerical efficiency is illustrated by several examples.

In the paper [16], given real parameters a, b, c and integer shifts n_1, n_2, m, the authors consider the ratio of the Gauss hypergeometric functions. A formula is derived for two-sided limits of this ratio in terms of real hypergeometric polynomial P, beta density and the absolute value of the Gauss hypergeometric function. This allows the construction of explicit integral representations for the ratio of the Gauss hypergeometric functions when the asymptotic behavior at unity is mild and the denominator does not vanish. The results are illustrated with a large number of examples.

In the paper [17], the authors consider a nonlinear system of three connected delay differential neoclassical growth models along with stochastic effect and additive white noise, which is influenced by stochastic perturbation. The conditions are derived for positive equilibria, stability and positive solutions of the stochastic system. It is observed that when a constant delay reaches a certain threshold for the steady state, the asymptotic stability is lost, and the Hopf bifurcation occurs. In the case of the finite domain, the three connected, delayed systems will not collapse to infinity but will be bounded ultimately. A Legendre spectral collocation method is used for the numerical simulations. Moreover, a comparison of a stochastic delayed system with a deterministic delayed system is also provided. Some numerical test problems are presented to illustrate the effectiveness of the theoretical results. Numerical results further illustrate the obtained stability regions and behavior of stable and unstable solutions of the proposed system.

In the paper [18] are established new generalizations of the Hermite–Hadamard-type inequalities. These inequalities are formulated in terms of modules of certain powers of proper functions. Generalizations for convex functions are also considered. As applications, some new inequalities for the digamma function in terms of the trigamma function and some inequalities involving special means of real numbers are given. The results also include estimates via arithmetic, geometric and logarithmic means. The examples are derived in order to demonstrate that some of our results in this paper are more exact than the existing ones and some improve several known results available in the literature. The constants in the derived inequalities are calculated; some of these constants are sharp. As a visual example, graphs of some technically important functions are included in the text.

In the paper [19], several new functional bounds and uniform bounds (with respect to the variable) are established for the lower incomplete generalized Fox–Wright functions by means of the representation formulae for the McKay I_ν Bessel probability distribution's cumulative distribution function. New cumulative distribution functions are generated and expressed in terms of lower incomplete Fox–Wright functions and/or generalized hypergeometric functions, whilst in the closing part of the article, related bounding inequalities are obtained for them.

In the paper [20], the author considers fully degenerate Daehee numbers and polynomials by using a degenerate logarithm function. We investigate some properties of these numbers and polynomials. We also introduce higher-order multiple fully degenerate Daehee polynomials and numbers, which can be represented in terms of Riemann integrals on the interval $(0,1)$. Finally, some connected summation formulas are derived.

In the paper [21], exceptional orthogonal X1-polynomials of symmetric and nonsymmetric types are considered as eigenfunctions of a Sturm–Liouville problem. By defining a generic second-order differential equation, a unified classification of all these polynomials is presented, and ten particular cases of them are introduced and analyzed.

In the paper [22], the authors present a numerical approach to solving singularly perturbed semilinear convection-diffusion problems. The nonlinear part of the problem is linearized via the quasilinearization technique. A fitted operator by finite difference method is designed and operated to solve the sequence of linear singularly perturbed problems that emerges from the quasilinearization process. A rigorous analysis to attest to the convergence of the proposed procedure is performed. The method is first-order uniformly convergent. Some numerical evaluations are implemented on model examples to confirm the proposed theoretical results and to show the efficiency of the method.

In the paper [23], Cesáro means are investigated for the weighted orthogonal polynomial expansions on spheres with weights being invariant under a general finite reflection group on $\mathbb{R}^d$. The theorems in the paper extend previous results only for specific reflection groups and weight functions on the unit sphere. The upper estimates of the Cesáro kernels and Cesáro means are obtained and used to prove the convergence of the (C,δ) Cesáro means in the weighted L^p space for δ above the corresponding index. Similar results are also established for the corresponding estimates on the unit ball and the simplex.

In the paper [24], the authors study a general family of basic (or q-) polynomials with double q-binomial coefficients as well as some homogeneous q-operators in order to construct several q-difference equations involving seven variables. We derive the Rogers type and the extended Rogers type formulas as well as the Srivastava–Agarwal-type bilinear generating functions for the general q-polynomials, which generalize the generating functions for the Cigler polynomials. We also derive a class of mixed generating functions by means of the aforementioned q-difference equations. The various results, which we have derived in this paper, are new and sufficiently general in character. Moreover, the generating functions presented here are potentially applicable not only in the study of the general q-polynomials, which they have generated, but indeed also in finding solutions of the associated q-difference equations. Finally, we remark that it will be a rather trivial and inconsequential exercise to produce the so-called (p, q)-variations of the q-results, which we have investigated here, because the additional forced-in parameter p is obviously redundant.

Note that for a deeper understanding of background and problems that are basic for this Special Issue "Analytical and Computational Methods in Differential Equations, Special Functions, Transmutations and Integral Transforms", the following classical and relatively new monographs [25–40] are highly recommended.

The articles presented in this Special Issue provide insights into fields related to "Analytical and Computational Methods in Differential Equations, Special Functions, Transmutations and Integral Transforms", including pure mathematics and application developments. We wish that readers can benefit from the insights of these papers and contribute to these rapidly growing areas. We also hope that this Special Issue sheds light on major development areas of analytical and computational methods in differential equations, special functions, transmutations, integral transforms and attracts the attention of the scientific community to pursue further investigations leading to the rapid implementation of these fruitful topics and techniques.

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