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Semi-analytic solution of time-fractional Korteweg-de Vries equation using fractional residual power series method

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Abstract

In this paper, we solve the non-linear Korteweg-de Vries equation by considering the time-fraction derivative in Caputo sense and offered intrinsic properties of solitary waves. The fractional residual power series method is used to obtain the approximate solution of the aforesaid equation and compared the obtained results with Adomian Decomposition Method. Obtained results are efficient, reliable, and simple to execute on most of the non-linear fractional partial differential equations, which arise in various dynamical systems.

Keywords: Fractional differential equation, KdV equation, Residual Power series method, Caputo derivative
2020 MSC: 35R11, 33E50, 35Q51, 35L05

1. Introduction

In 1877, Joseph Valentin Boussinesq[1] initiated theoretical investigations on solitary waves induced on shallow water; later in 1895, Diederik Korteweg and Gustav de Vries (Dutch Mathematicians) has retrieved the weakly non-linear partial differential equation (popularly known as KdV equation) and presented a

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Original articles

A novel hybrid technique to obtain the solution of generalized fractional-order differential equations

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Abstract

The motive of the work is to propose a new hybrid technique, the Homotopy Perturbation General Transform Method (HPGTM) for obtaining an analytic solution for a wide class of time-fractional differential equations in the Caputo sense. The efficiency of HPGTM is analyzed using a comparative study with Adomian Decomposition Method (ADM), Residual Power Series Method (RPSM), and exact solution. Numerical examples including well-known equations viz. radioactive decay model, Riccati equation, backward Kolmogorov equation, Klein–Gordon equation, and Rosenau–Hyman equation are considered in arbitrary order. The outcomes of numerical simulations clearly state the effectiveness of the present method.
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Keywords: Fractional differential equation; Caputo fractional derivative; Homotopy perturbation method; General transform

1. Introduction

Fractional calculus is the branch of mathematics that deals with arbitrary ordered differentiation and integration. The fractional differential equations (FDE) and fractional partial differential equations (FPDE) are used to obtain the memory properties of many scientific and engineering problems. Thus, numerous researchers are working on developing new techniques to obtain the analytic and numerical solution of fractional order differential equations [35]. Integral transforms are used to obtain analytic solutions for certain types of differential equations, partial differential equations, FDE, FPDE, integral equations, integro-differential equations as it can be expressed easily by its inversion formulas. Several new integral transforms in the class of Laplace transform [14] have been established in the previous two decades, including Aboodh [1], Elzaki [16], G-transform [26], Kamal [24], Mohand [30], Pourreza [3], Sawi [27], and Sumudu [22] transforms. The list of some transforms and their definitions are mentioned by Jafari [21]. Other analytical and semi-analytical techniques such as Adomian decomposition method (ADM) [40], homotopy perturbation method (HPM) [2], Homotopy analysis method (HAM) [10], residual

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ON THE SEMI-ANALYTIC TECHNIQUE TO DEAL WITH NONLINEAR FRACTIONAL DIFFERENTIAL EQUATIONS

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Abstract. In this article, we present a novel hybrid approach, by combining the Sawi transform with the homotopy perturbation method, to achieve the approximate and analytic solutions of nonlinear fractional differential equations (ODE as well as PDE) using the time-fractional Caputo derivative. The proposed algorithm is faster and simple compared to other iterative methods. The Sawi transform is used along with the homotopy perturbation method to accelerate the convergence of the series solution. The results discussed using calculations, graphs and tables are compatible for comparison with other known methods like the residual power series method and the exact solution which are discussed in the literature.

MSC 2010: *35R11, 33E50, 35Q51, 35L05.*
Keywords: *fractional differential equation, logistic equation, Fornberg-Whitham equation, homotopy perturbation method, Sawi transform*

1. Introduction and preliminaries

There are several well-known integral transforms in the literature, viz. G-transform [1], Sumudu transform [2], Sawi transform [3], Elzaki transform [4], Pourreza transform [5], natural transform [6], Mohand transform [7], Aboodh transform [8], and Kamal transform [9]. These transformations are used to solve various functional equations such as fractional order integral equations, ordinary, and partial type fractional differential equations [10–15]. However, these transformations alone are not enough capable to deal with nonlinear equations because of the difficulties due to the involvement of nonlinear terms.

In recent years, many hybrid methods have been introduced that combine the integral transforms with semi-analytic techniques such as the Sumudu Adomian decomposition method [16], Laplace variational iteration method [17], residual power series method (RPSM) [18, 19], homotopy perturbation general transform method [20] and

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RESEARCH ARTICLE

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Solution of fractional Sawada–Kotera–Ito equation using Caputo and Atangana–Baleanu derivatives

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In the present work, the fractional-order Sawada–Kotera–Ito problem is solved by considering nonlocal Caputo and nonsingular Atangana–Baleanu (ABC) derivatives. The methodology used is an application of the Shehu transform and the Adomian decomposition method. The obtained solution is more accurate when using the ABC type derivative as compared to the Caputo sense, when using the proposed ADShTM method (Adomian decomposition Shehu transform method). The results so obtained by the ADShTM using Caputo and ABC operators are compared, establishing the superiority of the proposed method. The numerical results demonstrate that the application of the ABC derivative is not only relatively more effective and reliable but also straightforward to achieve high precision solution.

KEYWORDS

Adomian decomposition method, Atangana–Baleanu fractional derivative, Caputo fractional derivative, fractional partial differential equation, fractional-order Sawada–Kotera–Ito equation, Shehu transform

MSC CLASSIFICATION

35R11, 33E50, 35Q51, 35L05

1 | INTRODUCTION

Recently, fractional calculus has been extensively used as a mathematical tool to simulate real-world problems across a variety of disciplines. The popularity of the study of fractional calculus has increased due to its applications in mathematical physics [1], viscoelasticity [2], electrical networks [3], fluid flow [4], control theory [5], and other fields [6, 7]. Because the solution relies on all of its preceding phases, integer-order derivatives are local operators, whereas fractional-order derivatives such as Riemann–Liouville and Caputo are nonlocal operators. Furthermore, because of the difficulties of fractional order, investigators sometimes struggle to discover an analytic solution to nonlinear phenomena.

Recently, several fractional derivatives were explored and fruitful results using various elements of fractional derivatives were obtained. As the kernel of the Caputo derivative [8] is singular, Caputo and Fabrizio [9] introduced a nonsingular kernel and eventually defined Caputo–Fabrizio (CF) fractional derivative. Because of its advantages, several mathematicians [10–13] employed this operator to analyze various fractional partial differential equations (FPDEs). However, the CF derivative is a nonlocal one, but the integrand involved does not have a fractional operator; this issue was addressed by Atangana and Baleanu in 2016. By modifying the definition of CF and introducing Atangana–Balenau (ABC) derivative using newly defined nonlocal and nonsingular kernel. This novel fractional operator combines the Reimann–Liouville and Caputo derivatives [14]. This new ABC derivative has a great memory due to the existence of Mittag–Leffler function

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Investigation of fractional diabetes model involving glucose–insulin alliance scheme

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Abstract
The ultimate aim of this study is to develop and analyze a comprehensive regulatory framework for managing glucose and insulin in blood in the presence of diabetes mellitus. This innovative mathematical model of diabetes is demonstrated and examined in fractional order by involving ABC fractional derivative. This whole framework is worked out using a semi-analytical technique, namely the Adomian decomposition Laplace transform method. To prove the efficiency of this ADLTM technique, the results are compared with other classical methods, viz. homotopy perturbation transform method and modified homotopy analysis transform method. Using the Banach fixed point theorem, the existence and stability analysis of the solution has been proved. Certain figures and tables are illustrated for this fractional diabetes model with some fractional order. We used the Maple software to generate all the numerics and graphical plots. This detailed investigation also explores how well the level of glucose and insulin affects the dynamics of disease infection.

Keywords Fractional diabetes model · Atangana–Baleanu fractional derivative · Adomian decomposition Laplace transform method · Stability analysis

Mathematics Subject Classification 26A33 · 34A08 · 92Bxx · 92Dxx

1 Introduction

Diabetes, often known as diabetes mellitus, is a condition that develops when the glucose–insulin balance is disrupted. Diabetes mellitus with persistent hyperglycemia and impairments in carbohydrate, protein, and lipid metabolism brought on by problems with insulin release, secretion of insulin, or both [1]. Two types of diabetes, type-1 and type-2, can be recognized in patients with diabetes. The absence of insulin release leads to insulin-dependent diabetes because type-1 diabetes disables the B cells in the pancreas. Insulin-independent diabetes, also known as type-2 diabetes insulin production, is brought on by a small decrease in the effect of insulin on glucose [2].

In this investigation, we are taking type-1 diabetes patients into consideration. People with type-1 diabetes may have a constant glucose monitor (CGM) to help them manage their blood glucose levels. The surveillance device receives the data from the sensing device, which uses a tiny needle to measure the level of glucose in the tissue fluids [3]. Additionally, its connection with insulin pumps for constant subcutaneous infusion enabled the creation of algorithms that provides insulin doses based on CGM data to reduce the frequency of critical situations. Fractional-order PID, an excellent adaptive algorithm, is used as the controller design [4] (see Fig. 1).

In this work, we examine a unique diabetes mellitus model discussed by Muhammad et al. [5]. The prime parameters utilized in the described model are glucose level as $G(t)$, insulin level as $I(t)$, and insulin level in plasma as $X(t)$. The following set of equations stands as the model:

$$\frac{\mathrm{d}\mathbb{G}(t)}{\mathrm{d}t} = -m_1\mathbb{G}(t) + m_2\mathbb{I}(t) + m_1\mathbb{G}_b,$$

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SOLUTION OF FRACTIONAL MODIFIED KAWAHARA EQUATION: A SEMI-ANALYTIC APPROACH

SAGAR R. KHIRSARIYA, SNEHAL B. RAO, AND JIGNESH P. CHAUHAN

Abstract. The present study introduces and explores the novel application of the Fractional Residual Power Series Method as a highly efficient and reliable approach for solving the challenging non-linear, time-fractional Kawahara and modified Kawahara equations. These equations, which are fifth-order, non-linear partial differential equations, are of significant importance in modeling shallow water waves. In contrast to existing methods such as the Variational Iteration Method (VIM), Homotopy Perturbation Method (HPM), and Adomian Decomposition Method (ADM), our research uniquely demonstrates the superior performance of the Fractional Residual Power Series Method. We emphasize that our approach not only outperforms these conventional techniques but also offers ease of implementation. This novel methodology promises to advance the field of mathematical modeling, providing a powerful tool for solving complex problems in the field of science and engineering.

1. Introduction

In 1972, Kawahara[7] was the first to propose the partial differential equation describing the behavior of solitary waves as follows,

$$\frac{\partial u}{\partial t} + au^m \frac{\partial u}{\partial x} + b\frac{\partial^3 u}{\partial x^3} - \lambda \frac{\partial^5 u}{\partial x^5} = 0, \tag{1.1}$$

where a, b and λ are some specific arbitrary constants. Equation (1.1) arises while modeling wave theory, and scales down to Kortewag-de Vries(KdV) equation [23, 35] for $b = 1$ and $\lambda = 0$. Moreover, the second term of (1.1) is the convective part, and the third term is the dispersive part. Karpman and Vanden-Brock[18] proposed that the fifth order term of equation (1.1) shows critical significance for solitary stability.

Obtaining a solution effectively and accurately due to the involvement of fifth-order derivative terms is not easy. The exact and approximate solution of the space fractional Kawahara equation has already been studied by several authors and a considerable amount of work has been done in this direction. These analytical and numerical methods involve a direct method based on the Jacobi elliptic functions[7], Differential transformation method[35], Iterative Laplace transform method[9] based on Atangana-Baleanu derivative, Fractional complex transform[36], Multiquadric Radial basis functions(MQ-RBF) method[8], Predictor-corrector and RBF-QR method[8], Variational iteration method[28], Homotopy perturbation method[28], and Tanh method[38].

Fractional calculus permits the derivative and integration of arbitrary orders and it has grown popularity in the recent decades in many fields such as physical science[26], electromagnetic theory[13],

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