

Implicit two-derivative Runge–Kutta collocation methods for systems of initial value problems

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Abstract

We introduce a new class of implicit two-derivative Runge–Kutta collocation methods designed for the numerical solution of systems of equations and show how they have been implemented in an efficient parallel computing environment. We also discuss the difficulty associated with large systems and how, in this case, one must take advantage of the second derivative terms in the methods. We consider two modified versions of the methods which are suitable for solving stable systems. The first modification involves the introduction of collocation at the two end points of the integration interval in addition to the Gaussian interior collocation points and the second involves the introduction of a different class of basic second derivative methods. With these modifications, fewer function evaluations per step are achieved, resulting into methods that are cheap and easy to implement. The stability properties of these methods are investigated and numerical results are given for each of the modified version to illustrate the computational efficiency of the modified methods.

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Keywords: Block hybrid discrete scheme; Continuous scheme; System of equations; Two-derivative Runge–Kutta methods

1. Introduction

The primary aim of this paper is to introduce a new class of implicit two-derivative Runge–Kutta (TDRK) collocation methods for the numerical solution of initial value problems for systems of ordinary differential equations (ODEs),

$$\begin{cases} y'(x) = f(x, y(x)), & x \in [x_0, T], \\ y(0) = y(x_0). \end{cases} \quad (1)$$

Here $y : [x_0, T] \rightarrow \mathbb{R}^d$ and $f : [x_0, T] \times \mathbb{R}^d \rightarrow \mathbb{R}^d$ is assumed to be sufficiently smooth and $y_0 \in \mathbb{R}^d$ is the given initial value. Let $h > 0$ be a constant stepsize and define the grid by $x_n = x_0 + nh$, $n = 0, 1, 2, \dots, N$ where $Nh = T - x_0$ and a set of equally spaced points on the integration interval is defined by $x_0 < x_1 < x_2 < \dots < x_{n+1} = T$.

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Table of Contents Implicit Two Derivative Runge Kutta Collocation Methods

1. Understanding the eBook Implicit Two Derivative Runge Kutta Collocation Methods
 - The Rise of Digital Reading Implicit Two Derivative Runge Kutta Collocation Methods
 - Advantages of eBooks Over Traditional Books
2. Identifying Implicit Two Derivative Runge Kutta Collocation Methods
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Implicit Two Derivative Runge Kutta Collocation Methods
 - User-Friendly Interface
4. Exploring eBook Recommendations from Implicit Two Derivative Runge Kutta Collocation Methods
 - Personalized Recommendations
 - Implicit Two Derivative Runge Kutta Collocation Methods User Reviews and Ratings
 - Implicit Two Derivative Runge Kutta Collocation Methods and Bestseller Lists

5. Accessing Implicit Two Derivative Runge Kutta Collocation Methods Free and Paid eBooks
 - Implicit Two Derivative Runge Kutta Collocation Methods Public Domain eBooks
 - Implicit Two Derivative Runge Kutta Collocation Methods eBook Subscription Services
 - Implicit Two Derivative Runge Kutta Collocation Methods Budget-Friendly Options
6. Navigating Implicit Two Derivative Runge Kutta Collocation Methods eBook Formats
 - ePub, PDF, MOBI, and More
 - Implicit Two Derivative Runge Kutta Collocation Methods Compatibility with Devices
 - Implicit Two Derivative Runge Kutta Collocation Methods Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Implicit Two Derivative Runge Kutta Collocation Methods
 - Highlighting and Note-Taking Implicit Two Derivative Runge Kutta Collocation Methods
 - Interactive Elements Implicit Two Derivative Runge Kutta Collocation Methods
8. Staying Engaged with Implicit Two Derivative Runge Kutta Collocation Methods
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Implicit Two Derivative Runge Kutta Collocation Methods
9. Balancing eBooks and Physical Books Implicit Two Derivative Runge Kutta Collocation Methods
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Implicit Two Derivative Runge Kutta Collocation Methods
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Implicit Two Derivative Runge Kutta Collocation Methods
 - Setting Reading Goals Implicit Two Derivative Runge Kutta Collocation Methods
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Implicit Two Derivative Runge Kutta Collocation Methods
 - Fact-Checking eBook Content of Implicit Two Derivative Runge Kutta Collocation Methods
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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