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Journal of the Nigerian Mathematical Society
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Implicit two-derivative Runge–Kutta collocation methods for systems of initial value problems

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Received 9 August 2014; received in revised form 16 December 2014; accepted 14 January 2015

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.

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).

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

Here $y : [x_0, T] \longrightarrow \mathbb{R}^d$ and $f : [x_0, T] \times \mathbb{R}^d \longrightarrow \mathbb{R}^d$ 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 $x_n = x_0 + nh$, $n = 0, 1, 2, \ldots, N$ where $Nh = T - x_0$ and a set of equally spaced points on the integration interval is defined by $x_0 < x_1 < x_2 < \cdots < x_{n+1} = T$.

Peer review under responsibility of Nigerian Mathematical Society.
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http://dx.doi.org/10.1016/j.jnnms.2015.01.001
0189-8965/

Please cite this article in press as: Yakubu DG, Kwami AM. Implicit two-derivative Runge–Kutta collocation methods for systems of initial value problems. Journal of the Nigerian Mathematical Society (2015), http://dx.doi.org/10.1016/j.jnnms.2015.01.001

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