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On the Solution of Fractional-Order Dynamical Systems Endowed with Block Hybrid Methods

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Abstract : This paper presents a distinct approach to solving fractional dynamical systems using hybrid block methods (HBMs). Fractional calculus extends the concept of derivatives and integrals to non-integer orders and finds increasing application in fields such as physics, engineering, and finance. However, traditional numerical techniques often struggle to accurately capture the complex behaviors exhibited by these systems. To address this challenge, we develop HBMs that integrate single-step and multi-step methods, enabling the simultaneous computation of multiple solution points while maintaining high accuracy. Our approach employs polynomial interpolation and collocation techniques to derive a system of equations that effectively models the dynamics of fractional systems. We also directly incorporate boundary and initial conditions into the formulation, enhancing the stability and convergence properties of the numerical solution. An adaptive step-size mechanism is introduced to optimize performance based on the local behavior of the solution. Extensive numerical simulations are conducted to evaluate the proposed methods, demonstrating significant improvements in accuracy and efficiency compared to traditional numerical approaches. The results indicate that our hybrid block methods are robust and versatile, making them suitable for a wide range of applications involving fractional dynamical systems. This work contributes to the existing literature by providing an effective numerical framework for analyzing complex behaviors in fractional systems, thereby opening new avenues for research and practical implementation across various disciplines.

Keywords : fractional calculus, numerical simulation, stability and convergence, Adaptive step-size mechanism, collocation methods
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