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Spectral Quasi Linearization Techniques for the Solution of Time Fractional Diffusion Wave Equations in Boundary Value Problems

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Abstract : This paper presents a spectral quasi-linearization technique (SQLT) for solving time fractional diffusion wave equations in boundary value problems. The proposed method integrates spectral approximations for spatial derivatives with a quasi-linearization approach to address the nonlinearity introduced by fractional time derivatives. Time fractional differential equations typically formulated using Caputo or Riemann-Liouville derivatives, model complex phenomena such as anomalous diffusion and wave propagation, which are not captured by classical integer-order models. The SQLT method iteratively linearizes the nonlinear terms at each time step, transforming the original problem into a series of linear subproblems, which can be efficiently solved. Using high-order spectral methods such as Chebyshev or Legendre polynomials for spatial discretization, the technique achieves high accuracy in approximating the solution. A convergence analysis is provided, demonstrating the method's efficiency and establishing error bounds. Numerical experiments on a range of test problems confirm the effectiveness of SQLT in solving fractional diffusion wave equations with various boundary conditions. The method offers a robust framework for addressing time fractional differential equations in diverse fields, including materials science, bioengineering, and anomalous transport phenomena.

Keywords : spectral methods, quasilinearization, time-fractional diffusion-wave equations, boundary value problems, fractional calculus
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