UNIVERSITY of WISCONSIN
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Dissertation Defense
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Under the Supervision of Prof. Bruce Wade

Friday
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EMS Building
Room E495
3:00pm

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Exponential Integrator Methods for Nonlinear Fractional Reaction-Diffusion Models

Nonlocality and spatial heterogeneity of many practical systems have made fractional differential equations very useful tools in Science and Engineering. However, solving these type of models is computationally demanding. We propose an exponential integrator method for nonlinear fractional reaction-diffusion equations. The algorithm is established to be second-order convergent and proven to be robust for problems involving non-smooth/mismatched initial and boundary conditions and steep solution gradients. It could be easily implemented in parallel to take advantage of multiple processors for increased computational efficiency. We examine the stability of the scheme as well. This numerical scheme, combined with fractional central differencing, is used for important nonlinear fractional models in application. We demonstrate the superiority of our method over competing second order schemes, such as the BDF2 scheme and IMEX schemes. Furthermore, we investigate the trade-off between using fractional central differencing and matrix transfer technique in discretization of Riesz fractional derivatives. The generalized Mittag-Leffler function and its inverse is very useful in solving fractional differential equations and structural derivatives, respectively. However, their computational complexities have made them difficult to deal with numerically. We propose a real distinct pole rational approximation of the generalized Mittag-Leffler function. Under some mild conditions, this approximation is proven and empirically shown to be L-Acceptable. Due to the complete monotonicity property of the Mittag-Leffler function, we derive a rational approximation for the inverse generalized Mittag-Leffler function. These approximations are especially useful in design of efficient and accurate numerical schemes for partial differential equations of fractional order. Several applications are presented, such as complementary error function, solution of fractional differential equations, and the ultraslow diffusion model using the structural derivative.

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