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The finite difference/finite volume method for solving the fractional diffusion equation

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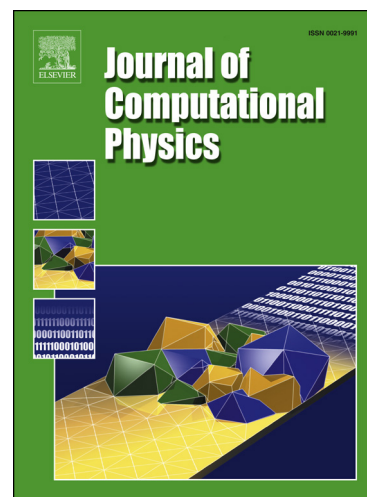
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Highlights

- In this paper, we consider the initial-boundary problem of the time-fractional diffusion equation:

$$\begin{cases} \partial_t^\alpha u - \operatorname{div}(A\nabla u) = f(t, x), & \text{in } \Omega, 0 < t \leq T, \\ u = 0, & \text{on } \partial\Omega, 0 < t \leq T, \\ u(0, x) = u_0(x), & x \in \Omega, \end{cases} \quad (0.1)$$

where ∂_t^α denotes the time-fractional differential operator of Caputo type with order $0 < \alpha < 1$, $\Omega \subset \mathbb{R}^2$ is a convex polygonal domain with boundary $\partial\Omega$, $A = (a_{ij}(x))_{2 \times 2}$ is the coefficient matrix and $T > 0$ is a fixed value.

We present and analyze a fully discrete numerical scheme which is based on the linear finite volume method for the spatial discretization and the $L1$ difference approximation to $\partial_t^\alpha u$. The main contribution of this paper is as follows.

1 We establish a new error bound of $O(\Delta t^{1+\delta-\alpha})$ -order for the $L1$ formula under the condition of $u(t) \in C^{1,\delta}[0, T]$ where $0 \leq \delta \leq 1$ is the Hölder continuity index.

2 We prove that this fully discrete finite volume scheme is unconditionally stable and the discrete solution admits the optimal error estimate of $O(\Delta t^{1+\delta-\alpha} + h^2)$ -order in the $L2$ norm.

We emphasize that few finite volume research works can be found in existing literatures for solving the time-fractional diffusion equations.

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