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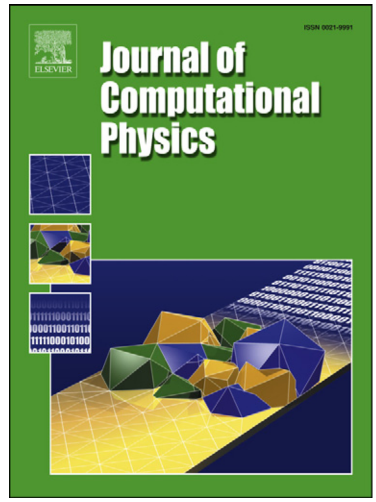

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The Radial Basis Function Finite Collocation Approach for Capturing Sharp Fronts in Time Dependent Advection Problems

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Abstract

We propose a node-based local meshless method for advective transport problems that is capable of operating on centrally defined stencils and is suitable for shock-capturing purposes. High spatial convergence rates can be achieved; in excess of eighth-order in some cases. Strongly-varying smooth profiles may be captured at infinite Péclet number without instability, and for discontinuous profiles the solution exhibits neutrally stable oscillations that can be damped by introducing a small artificial diffusion parameter, allowing a good approximation to the shock-front to be maintained for long travel times without introducing spurious oscillations.

The proposed method is based on local collocation with radial basis functions (RBFs) in a "finite collocation" configuration. In this approach the PDE governing and boundary equations are enforced directly within the local RBF collocation systems, rather than being reconstructed from fixed interpolating functions as is typical of finite difference, finite volume or finite element methods. In this way the interpolating basis functions naturally incorporate information from the governing PDE, including the strength and direction of the convective velocity field. By using these PDE-enhanced interpolating functions an "implicit upwinding" effect is achieved, whereby the flow of information naturally respects the specifics of the local convective field. This implicit upwinding effect allows high-convergence solutions to be obtained on centred stencils for advection problems.

The method is formulated using a high-convergence implicit timestepping algorithm based on Richardson extrapolation. The spatial and temporal convergence of the proposed approach is demonstrated using smooth functions with large gradients. The capture of discontinuities is then investigated, showing how the addition of a dynamic stabilisation parameter can damp the neutrally stable oscillations with limited smearing of the shock front.

KEYWORDS: Meshless, radial basis functions, RBF local, advection, Finite collocation, Shock capturing, Richardson Extrapolation