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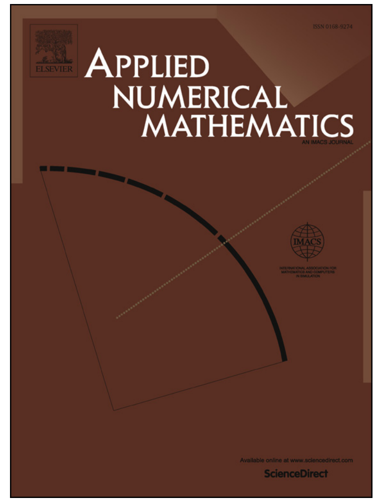

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Modal spectral element method in curvilinear domains

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Abstract

We present a high-order spectral element method (SEM) using modal or hierarchical basis for modeling of the two-dimensional linear and non-linear partial differential equations in complex geometry. The discretisation is based on conforming spectral element in space and finite difference methods in time. Unlike the nodal SEM which is based on the Lagrange polynomials associated with the Gauss-Lobatto-Legendre or Chebyshev quadrature nodes, the Lobatto polynomials are used in this paper as modal basis. Using modal bases, due to their orthogonal properties, enables us to obtain the elemental matrices efficiently in the linear problems. The difficulty of implementation of modal approximations for non-linear problems is treated in this paper by expanding the non-linear terms in the weak form of differential equations in terms of the Lobatto polynomials on each element using the fast Fourier transform (FFT) algorithm. Utilization of Fourier interpolation on equidistant points in the FFT algorithm can be suitable at minimizing aliasing error. On the other hand, the polynomial order of approximations for non-linear terms can be sufficiently large to capture major variations and render the aliasing error so small. The proposed approach also leads to finding numerical solution of a non-linear differential equation through solving a system of linear algebraic equations. The non-constant Jacobian, as well as any non-polynomial coefficients and nonlinearities arisen in the entries of mass and stiffness matrices are also expanded in terms of the Lobatto polynomials by FFT algorithm and so they can be produced in the complex geometry accurately even in a tensor product form. Efficiency and exponential convergence properties of the approximation scheme are validated through several non-trivial examples in the numerical results section.

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