

Energy-Preserving Mixed Finite Element Approximation of the Korteweg–de Vries Equation

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The preservation of energy is an important requirement in the long-time numerical simulation of Hamiltonian partial differential equations. This work develops an energy-preserving mixed finite element approximation of the Korteweg–de Vries (KdV) equation based on the discrete gradient methodology.

Starting from the Hamiltonian formulation of the equation, an energy - preserving time integration scheme is constructed using the discrete gradient approach. To accommodate the third-order spatial derivative, the KdV equation is rewritten as a system of first-order equations through the introduction of auxiliary variables, leading to a mixed variational formulation and a mixed finite element approximation in space. The resulting nonlinear systems are solved using iterative linearization techniques.

In addition, a splitting strategy based on the decomposition of the Hamiltonian into linear dispersive and nonlinear components is considered. This leads to a Strang-type splitting formulation in which simpler sub-problems can be evolved separately.

Numerical experiments investigate long-time energy conservation and the propagation of solitary-wave solutions.

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