An interpolation-free approach to exploit mesh adaptation within the ALE framework

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ABSTRACT

Mesh adaptation proved to be a valuable tool for unsteady numerical simulations of flow fields encompassing different spatial scales or flow structures whose location is not known a priori. In particular, local connectivity changes—as node insertion, node deletion and edge swapping—can be successfully exploited, along with node relocation, to modify the grid spacing according to the solution behavior. If grid topology changes, a re-mapping step is required to transfer the numerical solution from the old to the adapted grid. To this end, standard adaptation techniques usually entail an interpolation step, which, however, may undermine conservativeness and monotonicity of the numerical scheme and complicate the implementation of multi-step time integration algorithms.

In this work, we present a novel strategy that exploits the Arbitrary Lagrangian-Eulerian (ALE) formulation [1] and the finite-volume discretization to recover the solution on the adapted grid without any explicit interpolation. Thanks to a three-steps procedure, local connectivity changes are described as fictitious continuous deformations, which can be taken into account by adding fictitious fluxes to the ALE formulation of the governing equations [2, 3]. Minor modifications are required to the underlying fixed-connectivity ALE scheme and its properties, such as conservativeness, stability and accuracy, are preserved. Moreover, suitable grid velocities are computed so that the so-called Geometric Conservation Law [4] is fulfilled even when grid connectivity changes.

The proposed strategy is here applied to solve the unsteady Euler equations over adaptive tetrahedral grids. We present the numerical simulation of a piston-induced shock-tube problem, in which mesh adaptation plays a crucial role to deal with both the large boundary displacement and the shock wave that travels trough the domain.

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