Unstructured Moving Grids for Large Relative Body Motion

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The numerical modeling of unsteady problems with large amplitude or relative motion of bodies, requires considerable care in the formulation of the domain discretisation, specifically in devising schemes for the movement of the grids. These types of problems have led to development of algorithms ([1, 3]) for simulating fluid physics, where dynamic grid generation play a significant role. Despite the considerable efforts addressed at this problem, efficiency and robustness remain critical issues.

The management of large grid motions are typically addressed through refinement and coarsening of the mesh. This requires complex mesh management data structures together with interpolation of the flow variables. In addition this makes the enforcement of the geometric conservation law (GCL) a nontrivial task.

An attempt to resolve these difficulties was proposed in [2] based on a flow-based analogy, where grid cells were allowed to slide past moving walls. The mesh has a fixed connectivity and the elements preserve their identify. A special treatment of mesh elements at separation and re-attachment points on moving bodies was described, in order to maintain a fixed mesh topology while accommodating boundary movement. This treatment, formulated directly in physical space, presents difficulties regarding management of grid valence at separation and re-attachment points, which require local element splitting. Another difficulty is nodal velocity propagation inside the domain to avoid tangled meshes.

In the present paper, these difficulties are addressed by managing grid motion in computational space, and mapping the grid to physical space using an elliptic-type operator. The proposed approach consists in generating a mesh in computational space for a generic configuration where the boundaries in relative motion are replaced by a trajectory within which the body slides. The velocity of the boundary nodes is imparted to the internal nodes through smoothing operators such as Winslow. This dimensional reduction of the moving objects in the computational domain where the mesh motion is performed, followed by a mapping to physical space avoids grid modifications and preserves the mesh topology and validity during boundary motion and increases the robustness of the mesh generation procedure. For complex geometries and arbitrary motion, an unstructured grid is used in computational space, which requires to solve the the Winslow operator using a finite volume discretization directly on the computational grid by linearizing the operator and applying the Green theorem to each term of the differential equation [4].

Minimizing or avoiding grid modifications preserves the mesh topology and validity during boundary motion and increases the robustness of the mesh generation procedure. In addition, this approach simplifies the application of Arbitrary Eulerian-Lagrangian (ALE) methods and the satisfaction of geometric conservation laws (GCL).

References

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