An interpolation-free mesh adaptation approach for unsteady inviscid flows in aeronautical applications

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ABSTRACT

In aerospace applications, numerical simulations often require to update the domain according to the body motion or deformation. When boundary displacements are so large that fixed-connectivity mesh deformation leads to entangled or poor-quality elements, grid can be locally modified to restore mesh quality. However, standard mesh adaptation techniques entail the interpolation of the solution over the new grid, which may undermine the stability and conservation properties of the scheme.

In this work, we present an innovative approach that exploits the Arbitrary Lagrangian-Eulerian (ALE) formulation to recover the solution on the adapted grid without any explicit interpolation [1, 2]. Local modifications due to mesh adaptation are treated as fictitious continuous deformations, which can be taken into account by adding fictitious fluxes to the ALE formulation of the governing equations. Thanks to this approach, no special treatments are required to preserve accuracy, conservativeness and monotonicity of the fixed-connectivity scheme and the Geometric Conservation Law is fulfilled even when grid connectivity changes. The approach is here presented for a node-centered edge-based finite volume scheme for tetrahedral grids, which is equivalent to a linear finite element approach [3].

The developed algorithm proved to be well-suited for problems characterized by large boundary deformations, as occurred in the simulation of a three-dimensional wing at transonic speed performed in the laboratory reference frame. In this test, despite the unsteady scheme was required to follow the wing motion, the steadiness of the solution was exactly reproduced. Furthermore, the numerical investigation of the flow around a transonic pitching wing is presented to assess the capability of the proposed scheme to effectively modify the grid spacing to capture flow features whose location is not known a priori or varies as time evolves.

REFERENCES

[1] Isola, D., Guardone, A., Quaranta, G. Finite-volume solution of two-dimensional compressible flows over dynamic adaptive grids *J. Comput. Phys.*, Vol. **285**, pp. 1–23, (2015).

[2] Re, B. *An adaptive interpolation-free conservative scheme for the three-dimensional Euler equations on dynamic meshes for aeronautical applications*. Phd Thesis, Politecnico di Milano, 2016.

[3] Selmin, V. and Formaggia, L. Unified construction of finite element and finite volume discretisations for compressible flows. *Int. J. Num. Meth. Engng.*, Vol. **39**, pp. 1–32, (1996).