Multilevel-hp adaptive Finite Cell Method for the Navier-Stokes equations using a residual-based Variational Multiscale Method

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ABSTRACT

The Finite Cell Method (FCM) is a practical simulation tool for structural mechanics. FCM simplifies the mesh construction for high-order Finite Elements by embedding the physical domain into a larger fictitious domain. The weak form is multiplied by a small number α on the fictitious domain to eliminate the contribution of this extension and thus recover the influence of the geometry on a Cartesian grid that describes the problem. Therefore, the construction of the mesh becomes trivial at the cost of having a discontinuous integrand. Various methods have been proposed addressing this issue [1].

Furthermore, complex problems may require local refinement in regions of interest. Following the philosophy of the FCM, the multilevel-hp method [2] does not modify the FE mesh but instead enriches it by introducing p-overlay meshes. A simple set of construction rules ensures compatibility and linear independence of the resulting function space. In this way, a dynamic refinement and coarsening procedure is obtained that circumvents the need of constraining hanging nodes.

In [3], the Finite Cell concept has been successfully applied in the context of residual-based Variational Multiscale (VMS) fluid flow simulations. In the present work, we extend this idea by combining the Finite Cell Method with the aforementioned multilevel-hp refinement scheme. We demonstrate that this combination of approaches allows for a highly accurate resolution of complex flow fields at the boundary of embedded geometries. Furthermore, we address the correct choice of the stabilization parameter τ for hp-refined meshes. Finally, we systematically analyse the influence of the integration accuracy on the numerical result by comparing conventionally used space tree approaches and the smart tree integration scheme recently introduced in [1].

REFERENCES

[1] Kudela et al. *Smart octrees: accurately integrating discontinuous functions in 3D*. Comput. Methods Appl. Mech. Engrg., 2016.

[2] Zander et al. *The multi-level hp-method for three-dimensional problems: Dynamically changing high-order mesh refinement with arbitrary hanging nodes*. Comput. Methods Appl. Mech. Engrg., 2016.

[3] Xu et al. *The tetrahedral finite cell method for fluids: Immersogeometric analysis of turbulent flow around complex geometries*. Computer & Fluids, 2015.