

A coupled HDG-FV method for incompressible flows simulations

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ABSTRACT

The simulation of steady incompressible flows is nowadays routinely performed using low-order methods such as the finite volume (FV) method [1]. When transient incompressible flows are to be considered, the task of generating a suitable mesh becomes more cumbersome. This is due to the increased difficulty of designing a mesh capable of capturing all the transient flow features. In practice, to balance accuracy and efficiency, the use of mesh adaptivity is often considered. Additionally, when flow features such as vortices are to be propagated over long distances, the excessive dissipation and dispersion errors associated with low-order methods force the use of excessively refined meshes. High-order methods have shown the ability to reduce dissipation and dispersion errors compared to low-order methods. However, it is still difficult to obtain high-quality curvilinear meshes of complex geometric objects and without this technology, the advantages of high-order methods cannot be realised.

This work proposes the combination of low and high-order methods to simulate transient incompressible flows using meshes designed for steady simulations. In the vicinity of complex geometric objects, where the mesh used for steady simulations is fine enough, the FV method is employed. However, where the mesh is not good enough to capture the transient features, the solution is computed using the high-order hybridisable discontinuous Galerkin (HDG) method [2]. Contrary to other coupled methods presented, where a monolithic coupling was proposed, this work develops a strategy to produce a staggered coupling. This ensures that legacy FV codes can be employed, and the solution is enriched only where needed.

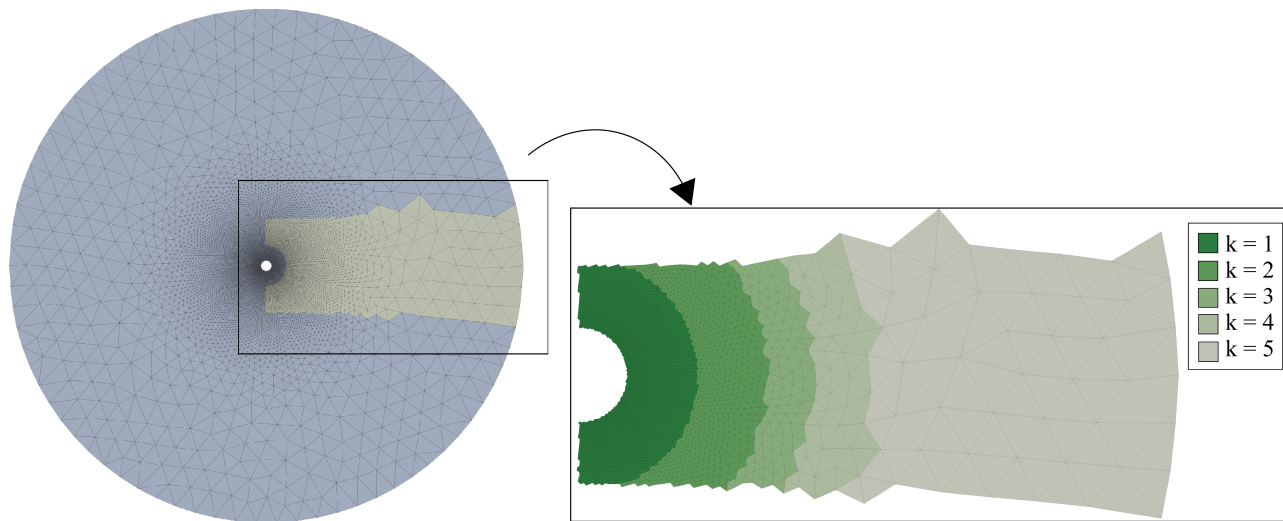


Figure 1: Partition of the domain into the HDG (green) and FV (blue) subdomains.

Figure 1 shows the 3D unstructured mesh used for solving a flow past a cylinder. Elements in blue employ a standard FV strategy, the mesh is good enough to capture the solution, whereas elements

in green employ a high order HDG scheme. The elements in HDG vary in their degree of functional approximation, ranging from linear to an order of five. This is chosen by taking the superconvergent post-process solution as an error indicator at the end of each time-step.

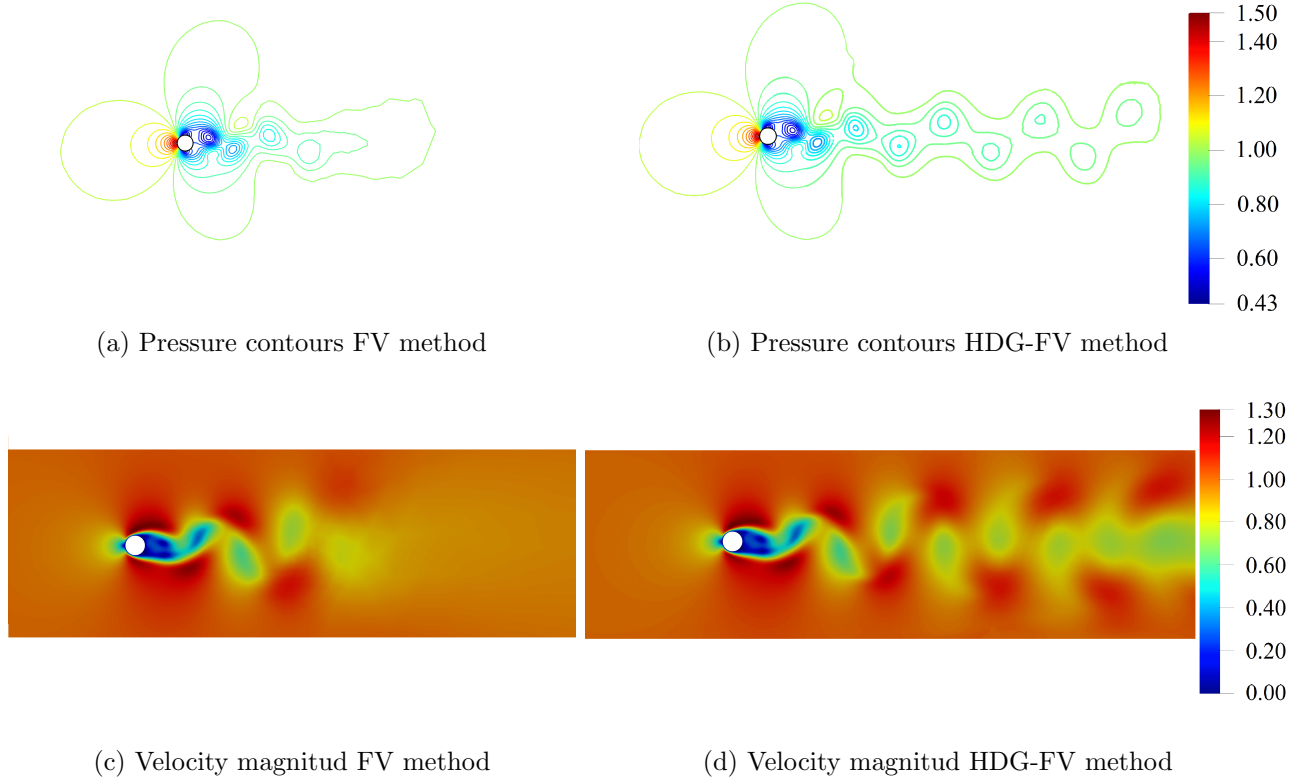


Figure 2: Comparison between pressure and velocity fields with FV method and HDG-FV method.

Figure 2 compares the FV solution with the solution obtained with the proposed HDG-FV scheme. This flow corresponds to a Reynolds number 100. The flow features are well captured by the FV method in the vicinity of the cylinder, whereas the mesh coarsens, the dissipation error is apparent and vortices are not captured. In contrast, by using high-order approximations in the region where the mesh (designed for a steady simulation) is coarse, the solution provides an accurate representation of the transient flow features.

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