Congress on Numerical Methods in Engineering CMN2017
Valencia, 3–5 July, 2017

Comparison of continuous and hybridizable discontinuous Galerkin methods in incompressible fluid flow problems

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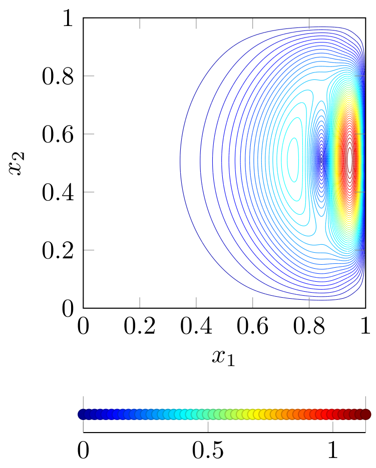
ABSTRACT

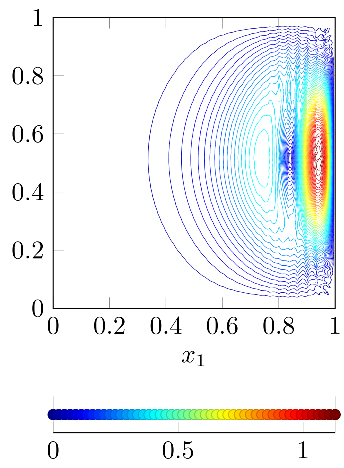
Even though continuous Galerkin (CG) methods had been developed for long time, their applicability for some problems, for instance, highly convective flows, can pose stability issues. Finite volumes (FV) can efficiently handle directional flows, but they are of lower order, which require very fine meshes. Discontinuous Galerkin methods (DG) are new class of finite elements which can handle convective flows but they are often criticised for the higher number of degrees of freedom. Hybrizidable Discontinuous Galerkin methods (HDG) were then introduced to address some of the shortcomings of DG methods and they are nowadays an active area of research. The present work aims at comparing CG and HDG methods for steady incompressible flow problems under the same platform and identical testing conditions.

Steady state Stokes and incompressible Navier–Stokes equations are used to evaluate the computational efficiency and stability properties of CG and HDG methods. Higher-order (up to nineth order) triangular and quadrilateral elements are used in the comparison of computational efficiency. Several plots like error *versus* CPU time of linear solver, error *versus* ratio of CPU times of HDG and CG are presented for a benchmark example. The study is extended to a more practical example like NACA0012 airfoil. Later, a stability study between HDG and CG is presented using a manufactured solution that produces a sharp boundary layer.

It is noticed that computational efficiency of HDG is similar, and sometimes superior, to CG for a given level of accuracy in the case of the benchmark problem. A similar behaviour is observed for NACA airfoil example as well. Numerical results suggests that HDG has better stability properties than its CG counterpart and this fact is demonstrated by comparing both solutions, where numerical instabilities can be noticed in the case of CG as shown in Figure 1.



(a) HDG solution of Navier–Stokes.



(b) CG solution of Oseen.

Figure 1: Isolines of velocity field at $Re = 2000$