AN ARTIFICIAL COMPRESSIBILITY TREATMENT FOR UNSTEADY INCOMPRESSIBLE FLOWS USING HIGH ORDER DISCONTINUOUS GALERKIN METHODS

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ABSTRACT

The advantages of discontinuous Galerkin [1] methods in providing high order accuracy on arbitrary unstructured grids have been well explored in simulations of Navier-Stokes flows over the past decade. For incompressible flows, a large disparity between convective and acoustic velocity results in a rather stiff system of equations; which, in turns, requires robust and efficient treatments, especially for unsteady flows. Moreover, a weak coupling between pressure and velocity introduces another challenge to any numerical discretization of the system. Applications of discontinuous Galerkin methods for incompressible flows have received a considerable research attention in recent years; however, the topic is believed to be far from fully studied in the context of discontinuous Galerkin methods. In this work, a well-known artificial compressibility approach, introduced by Chorin [2], is adopted in solving unsteady, viscous incompressible flows on unstructured grids. The concept of artificial compressibility has been widely considered in finite volume approaches with great success over the years where the relationship between pressure and density is employed in the pseudo time to handle the pressure-velocity coupling. In this work, artificial compressibility is applied as a generalized preconditioner to the system in order to recover its hyperbolic properties. A discontinuous Galerkin discretization is then used to solve for the preconditioned governing equations in pseudo time. The pseudo explicit time stepping maintains high scalability and efficiency of DG discretization. For unsteady flows, real time derivatives are implicitly treated using a implicit dual time stepping. To improve the convergence, an automatic artificial compressibility parameters are implemented locally element wise. Accuracy, convergence and robustness of the numerical scheme are demonstrated for both steady and unsteady incompressible Navier-Stokes flows in a range of Reynolds numbers as shown in Figure 1.

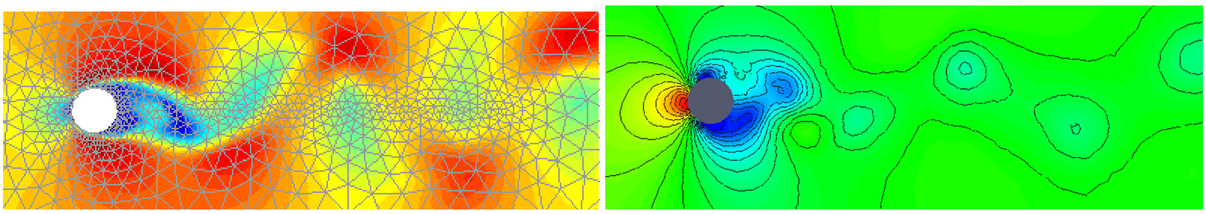

Figure 1: Velocity (left) and pressure (right) profile of laminar flow passing a circular cylinder at Re=100 using third order polynomial discontinuous Galerkin method. Note that the vortex shedding in the wake of the cylinder is well resolved on a rather coarse grid.

REFERENCES

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[2] A.J. Chorin, A numerical method for solving incompressible viscous flow problems, *Journal of Computational Physics* **2**, pp. 12-26 (1967)