Finite element methods for viscous incompressible flows: stabilized and least-squares methods and a new approach to reduced-order modeling

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We talk about three aspects related to the simulation of incompressible viscous flows. Our presentation of each topic will be necessarily brief; our intent is to merely highlight some recent developments.

Stabilized finite element methods – We provide a taxonomy of stabilized finite element methods that highlights the properties of the many stabilization approaches that have been proposed. One aspect of the discussion focuses on the performance of iterative methods. We then discuss a new variant of the well-known pressure-Poisson stabilized scheme for which we can rigorously prove absolutely stability for any choice of stabilization parameter and also optimal convergence with respect to mesh-independent norms.

Least-squares finite element methods – Least-squares finite element methods provide another approach to circumventing the inf-sup condition required of mixed Galerkin formulations. After describing how practical least-squares finite element methods can be constructed, we discuss some of their properties and potential advantages over other approaches.

Reduced-order modeling – We describe a new approach, based on centroidal Voronoi tessellations, that provides and alternative to POD (proper orthogonal decomposition) for the reduced-order modeling of incompressible viscous flows. After describing the centroidal Voronoi tessellation-based reduced-order modeling methodology, we present some preliminary numerical results and discuss some advantages our approach has over POD-based reduced-order modeling.