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Higher order space-time discretizations of the Navier-Stokes equations on evolving and fixed domains

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A higher order space-time finite element approach for solving the nonstationary, incompressible Navier-Stokes equations on evolving domains is presented. Therein, the physical fluid domain is embedded into a fixed computational mesh such that arbitrary intersections of the moving domain's boundaries with the background mesh occur. Cut finite element techniques are applied to capture the intersections. The key ingredients of the approach are the weak formulation of Dirichlet boundary conditions by Nitsche's method, the flexible integration over all types of intersections of cells by moving boundaries and the spatial extension of the discrete physical quantities to the entire computational background mesh. The implicitly defined extension simultaneously penalizes spurious oscillations caused by irregular intersections of mesh cells. The convergence and stability of this approach is evaluated for various numerical examples, including benchmarks problems on time independent domains.

Further, we address the design of an efficient linear solver for the arising Newton linearized systems. A geometric multigrid approach for higher order finite element space–time discretizations of the Navier–Stokes equations is discussed. Firstly, this is done for time-independent domains. The solver is based on a Vanka smoother. Optimal performance and parallel (MPI based) scaling properties are illustrated for 3d flow benchmarks. Secondly, its application to evolving domains is studied. Arising new challenges are addressed, open problems and required improvements are discussed.

References

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