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Compatible Discrete Operator schemes for the Navier-Stokes equations

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We discretize the unsteady incompressible Navier-Stokes equations by means of face-based *Compatible Discrete Operator* (CDO) schemes in space and either monolithic or fractional time stepping methods. CDO schemes [Bonelle, Ern, M2AN, 48(2):553-581, 2014] provide low-order discretizations and are part of the so-called mimetic schemes. CDO schemes can handle polytopal, nonmatching or deformed meshes while still showing optimal orders of convergence in space and good computational performances.
For the problem at hand, the so-called face-based discretization has been retained. The velocity is hybrid and defined both at faces and cells, whereas the pressure is defined only at cells. The viscous part of the problem relies on a discrete stabilized velocity gradient reconstruction which is piecewise constant on the face-based subpyramids of each cell: some similarities may be found with the *Hybrid Mixed Mimetic* schemes [Droniou et al, IMA J. Numer. Anal., 36(4):1636-1669, 2015]. This gradient, which is exact for affine functions, is also the tool on which the velocity-pressure coupling is based, via a discrete divergence operator which satisfies an inf-sup condition. Finally, the discretization of the convection term is inspired by the one used in the *Hybrid High-Order* framework [Di Pietro, Droniou, Ern, SIAM J. Numer. Anal., 53(5):2135-2157, 2015]. The discrete convection term is proved to be dissipative, an important property for the energy balance.
Two strategies for the time stepping are analyzed. The first one hinges on the traditional strong velocity-pressure coupling and leads to saddle-point problems at each time step. An alternative hinges on the *Artificial Compressibility* (AC) technique and allows one to decouple velocity and pressure at the price of a relaxed incompressibility constraint. Common convection treatments (implicit, linearized or explicit convection) are considered and their conservative properties are evaluated. For all the considered strategies, both first- and second-order time-schemes are addressed: for the strong coupling a BDF2 scheme is chosen, whereas a bootstrapping technique [Guermond and Minev, SIAM J. Sci. Comput., 37(6):A2656-A2681, 2015] is considered when dealing with the AC method. Results for classical test cases validate the proposed framework in terms of convergence rates for smooth solutions. Moreover, attention is paid to experimentally explore the limits of stability when an explicit convection is used.

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