A new time-splitting scheme for unfitted mesh approximations of FSI with immersed solids

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The mechanical interaction of an incompressible viscous fluid with an immersed structure appears in a wide variety of engineering fields (from micro-encapsulation to aeroelasticity) and is particularly ubiquitous in nature (from heart valves to the wings of a bird). For this type of multi-physics systems, Nitsche based unfitted mesh approximations are very appealing from a mathematical and computational point of view (see [1]). Indeed, they allow for weak and strong discontinuities, respectively in the discrete velocity and the pressure (which guarantees accuracy), and are Lagrange multiplier free (no additional unknowns are introduced). These advantages come however at a price: the weak treatment (à la Nitsche) of the kinematic coupling complicates the design of efficient time splitting schemes (i.e., which avoid strong coupling). For instance, standard loosely coupled schemes do not necessarily retain their time splitting features when formulated in an unfitted mesh framework. In this work we generalize the projection based semi-implicit coupling paradigm introduced in [2] to the case of unfitted mesh approximations with cut-elements. The fundamental idea consists in combining a fractional-step time-marching of the unfitted mesh fluid approximation with an explicit-implicit treatment of the interface conditions (which avoids added-mass stability issues). The proposed method retains the time-splitting features and the energy stability properties of the original splitting scheme with fitted meshes. Numerical results in 2D, motivated by biomedical applications and involving dynamic interfaces, illustrate the capabilities of the proposed approach.

Références

[1] E. Burman and M.A. Fernández, *An unfitted Nitsche method for incompressible fluid-structure interaction using overlapping meshes*, Comput. Methods Appl. Mech. Engrg., 2014.

[2] M.A. Fernández, J.F. Gerbeau, and C. Grandmont, *A projection semi-implicit scheme for the coupling of an elastic structure with an incompressible fluid*, Int. J. Num. Meth. Engrg., 2007.

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