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Simulation of fluid-structure interaction problems arising in hemodynamics

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ABSTRACT

We focus on the interaction of an incompressible fluid and an elastic structure. Two cases are considered: 1. the elastic structure covers part of the fluid boundary and undergoes small displacement and 2. the elastic structure is immersed in the fluid and features large displacement. For the first case, we propose an Arbitrary Lagrangian-Eulerian (ALE) method based on Lie's operator splitting. The resulting algorithm is unconditionally stable and weakly coupled: it requires the solution of one fluid subproblem and one structure subproblem, both endowed with Robin type boundary conditions, per time step. This algorithm is applied to blood flow in a healthy straight artery and in a diseased artery with implanted stent. Standard ALE methods fail when the structural displacement is large. Thus, for the second case we propose an extended ALE method that avoids remeshing. The extended ALE approach relies on a variational mesh optimization technique, combined with an additional constraint which is imposed to enforce the alignment of the structure with certain edges of the fluid triangulation without changing connectivity. This method is applied to a 2D benchmark problem modeling valves: a thin elastic 1D leaflet, modeled by an inextensible beam equation, is immersed in a 2D incompressible, viscous fluid driven by the time-dependent inlet and outlet data.

BIO:

Annalisa Quaini earned B.S./ M.S. Degrees in Aerospace Engineering at Politecnico di Milano (Italy) in 2005. She received a Ph.D. in Applied Mathematics from the Ecole Polytechnique Federale de Lausanne (Switzerland) in 2008. Between 2009 and 2011, she worked as a post-doctoral fellow in the Department of Mathematics at the University of Houston, where she has been an Assistant Professor between 2011 and 2017. Since 2017 she is an Associate Professor in the Department of Mathematics at the University of Houston.
Her interests are in the general area of computational fluid dynamics, and more specifically fluid-structure interaction problems motivated by biomedical applications.