Stabilized explicit coupling for fluid-structure interaction using Nitsche's method

Erik Burman
Institute of Analysis and Scientific Computing, Ecole Polytechnique Federale de
erik.burman@epfl.ch

Abstract

In this talk we address the numerical simulation of fluid-structure interaction problems involving a viscous incompressible fluid and an elastic structure. This problem is particularly difficult to treat efficiently when the fluid added-mass, acting on the structure, is strong. In other words, when the fluid and solid densities are close. Indeed, in such situations, *explicit* coupling schemes, *i.e.* that only involve the solution of the fluid and the structure once (or just a few times) per time step, are known to give rise to numerical instabilities. Theoretical explanations of this issue have been reported in [2], in particular, it has been pointed out that reducing the time step does not "cure" the problem. Up to now, these instabilities have been overcome through the use of *implicit* coupling schemes. Such an approach leads to a monolithic (*i.e.* fully coupled) problem at each time step, the solution of which often requires a high computational effort. Recent advances suggest the use of *semi-implicit* coupling schemes, involving a reduced monolithic problem [3]. Although significant improvement have been achieved in the last years, to the authors knowledge, none of the existing strategies are able to allow fully explicit coupling without compromising stability.

We propose a stabilized explicit coupling scheme, based on Nitsche's method [4,1], whose stability properties are independent of the fluid and structure density ratio. This is possible thanks to a careful anal-

ysis of the dissipative structure of the Nitsche coupling and a stabilization term giving control of the time fluctuations of the interface fluid load. The main disadvantage of the method is that the weak consistency of the stabilization term is of order $O(\delta t^{\frac{1}{2}})$ leading to a scheme that is too dissipative in practice. In order to enhance accuracy, we propose an improved explicit coupling scheme involving a few defect-correction iterations.

REFERENCES

[1] R. Becker, P. Hansbo, and R. Stenberg. A finite element method for domain decomposition with non-matching grids. *M2AN Math. Model. Numer. Anal.*, 37(2):209–225, 2003.

[2] P. Causin, J.-F. Gerbeau, and F. Nobile. Added-mass effect in the design of partitioned algorithms for fluid-structure problems. *Comput. Methods Appl. Mech. Engrg.*, 194(42–44):4506–4527, 2005.

[3] 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.*, 69(4):794–821, 2007.

[4] J. Nitsche.