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Nitsche-XFEM immersed boundary methods for incompressible fluid-structure interaction

Fréderic Alauzet[1], Benoit Fabrèges[1,2], Miguel A. Fernández[1,2,*] and Mikel Landajuela[1,2]
[1]Inria Paris-Rocquencourt, BP 105, 78153 Le Chesnay, France
[2] UPMC Univ. Paris 6, Lab. Jacques-Louis Lions, 4 Place Jussieu, 75252 Paris, France
`frederic.alauzet, benoit.fabreges, miguel.fernandez, mikel.landajuela_larma@inria.fr`

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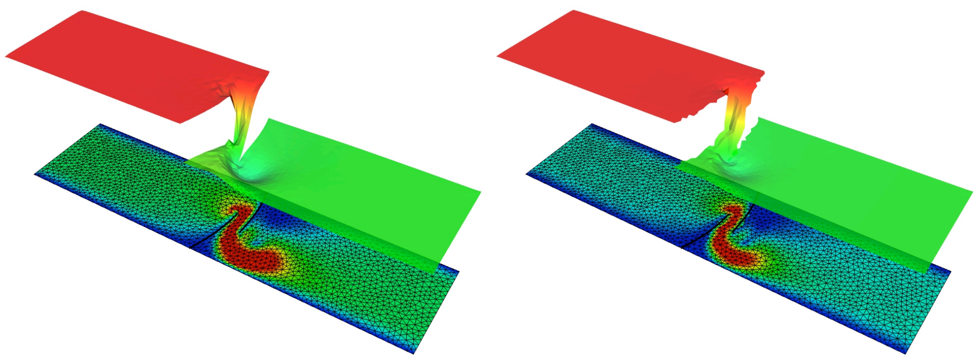
ABSTRACT

The use of fictitious domain or immersed boundary methods for the numerical simulation of fluid-structure interaction problems was pioneered in the works [8, 11, 1, 6] and has recently seen a surge of interest in papers such as [12, 7, 3, 4, 10]. In this work we consider the extension of the Nitsche-XFEM method (see [9, 2]) to fluid-structure interaction problems involving a thin-walled elastic structure (Lagrangian formalism) immersed in an incompressible fluid (Eulerian formalism). The fluid domain is discretized with an unstructured mesh not fitted to the solid mid-surface mesh. Weak and strong discontinuities across the interface are allowed for the velocity and pressure, respectively. The kinematic/dynamic fluid-solid coupling is enforced consistently using a variant of Nitsche's method involving cut elements. Robustness with respect to arbitrary interface/element intersections is guaranteed through suitable stabilization (see [4, 5]). For the temporal discretization, several coupling schemes with different degrees of fluid-solid splitting (implicit, semi-implicit and explicit) are investigated. The stability and convergence properties of the methods proposed are rigorously analyzed in a representative linear setting (fixed interface). Several numerical examples, involving static and moving interfaces, illustrate the performance of the methods (see, e.g., Figure 1).



(a) ALE fitted. (b) Nitsche-XFEM unfitted.

Figure 1: Snapshots of the velocity field magnitude and pressure elevation obtained with an ALE based method (fitted meshes) and the present Nitsche-XFEM method (unfitted meshes).

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