Towards an elastic swimmer framework including contact

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Fluid flows laden with particles interacting with rigid or elastic obstacles are common in industrial and biological processes, such as the cell transport in arteries. The modeling and simulation of such processes remain a challenging task due to the complexity of the fluid-structure interaction and the contact conditions.

In recent years, various approaches to model the contact in the small strain framework have been developed. These approaches include penalty methods, methods based on Lagrange multipliers, and different variants of the Nitsche method [2]. The latter reformulates the contact inequalities as a single equality condition that is weakly incorporated into the variational formulation.

In this presentation, we will employ this Nitsche method to model the contact between an elastic structure and a rigid obstacle in a Newtonian fluid. The finite element method is used to solve the fluid-structure interaction, and the fluid motion is described in the Arbitrary-Lagrangian-Eulerian framework.

First, we will consider static and dynamic numerical experiments, taken from [4, 3], to compare the different approaches in absence of fluid. Then, we will describe the fluid-structure interaction with contact, based on the ideas presented in [1], and show an application of a driven elastic swimmer colliding with a virtual wall in a Newtonian fluid.

All simulations are conducted with the open-source Feel++ library [5].

[1] E. Burman, M. A. Fernández, S. Frei. *A nitsche-based formulation for fluid-structure interactions with contact.* ESAIM : Mathematical Modelling and Numerical Analysis, **54(2)**, 531–564, 2020.

[2] F. Chouly, P. Hild, Y. Renard. *Finite element approximation of contact and friction in elasticity.* Springer, 2023.

[3] F. Chouly, Y. Renard. *Explicit verlet time-integration for a nitsche-based approximation of elastodynamic contact problems.* Advanced Modeling and Simulation in Engineering Sciences, **5**, 1–38, 2018.

[4] P. Hild. *A sign preserving mixed finite element approximation for contact problems*, 2011.

[5] C. Prud'homme, V. Chabannes, T. Metivet, R. Hild, T. Saigre, Trophime, L. Berti, A. SAMAKE, C. V. Landeghem. *feelpp/feelpp : Feel++ release v111 preview.9*, 2024. doi : 10.5281/zenodo.10837178.

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