An Unfitted Method on Polygonal Meshes for Contact Mechanics in Fluid-Structure Interaction Problems

Paola F. Antonietti[†], Luca Formaggia[†], Christian Vergara[†] and Stefano Zonca[*]

[*] MOX, Dipartimento di Matematica
Politecnico di Milano
Piazza Leonardo da Vinci, 32, 20133 Milan, Italy
e-mail: stefano.zonca@polimi.it

[†] MOX, Dipartimento di Matematica
Politecnico di Milano
Piazza Leonardo da Vinci, 32, 20133 Milan, Italy
e-mail: paola.antonietti@polimi.it , luca.formaggia@polimi.it , christian.vergara@polimi.it

ABSTRACT

We present an unfitted method able to handle polygonal meshes for the simulation of fluid-structure interaction problems in the case of immersed moving solids that may come into contact.

The employment of fluid and solids meshes which are fitted at their interface, as it happens, for example, in the Arbitrary Lagrangian Eulerian approach, imposes some practical restrictions on the magnitude of the structures displacement and the accurate simulation of the contact among the structures. Indeed, it may lead to highly distorted elements or vanishing elements when the displacement is too large or when two structures approach themselves, so that mesh adaptation techniques are required to recover a good-quality mesh.

An alternative is to exploit unfitted meshes such that the solid ones can move independently from the fluid mesh, which remains fixed in the background. However, this numerical technique introduces two difficulties: (1) the presence of polygonal fluid elements near the interface due to the cut between the fluid and solid meshes; (2) the treatment of the fluid-structure and structure-structure coupling at the unfitted interface.

We propose a numerical method that relies on unfitted meshes and on a consistent penalization approach to solve the two issues outlined above. In particular, to deal with the first one, we locally modify the discrete approximation on the fluid elements cut by the structures. To tackle the second issue, we use a Discontinuous Galerkin mortaring both at the fluid-structure interface, to impose the kinematic and dynamic coupling conditions, and at the structure-structure interface, to impose the contact conditions.

The proposed unfitted approach allows considering structures with a thickness smaller than the fluid mesh element size, as it happens in many engineering and biomedical applications. We finally present several numerical results showing the effectiveness of the proposed method.