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A Mortar approach for Fluid-Structure Interaction problems: Immersed strategies for deformable and rigid bodies

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Abstract

This paper proposes a new Fluid Structure Interaction immersed computational framework. The coupling between an underlying incompressible fluid and an embedded solid is formulated by means of the overlapping domain decomposition method in conjunction with a mortar approach, leading to a variationally consistent scheme which is capable of unifying a range of methodologies currently available in the literature. This novel framework provides great flexibility and enables the modelling of immersed deformable solids (compressible and incompressible) as well as rigid bodies through the use of a weak director based formulation. A novel Null-Space reduction scheme is employed in order to enhance the conditioning of the resulting system of equations and reduce the computational cost. An implicit structure preserving time integration algorithm is used to yield extra stability and robustness and the use of a segmentation technique near the boundary between fluid and solid also leads to enhanced accuracy. The methodology is benchmarked against results obtained by using alternative boundary fitted methodologies.

Keywords: Fluid-Structure Interaction, Immersed Boundary Method, Mortar method, Rigid bodies, Overlapping domain decomposition, Discrete Null-Space method

1 Introduction

From the spatial discretisation point of view, two general approaches can be established within the field of Fluid-Structure Interaction (FSI), namely boundary fitted methods and immersed methods. Boundary fitted methods rely on the coupling of the velocity field at the interface between the two phases describing the problem (i.e. fluid and solid). This coupling can be carried out either in a monolithic manner [46, 10] or in a partitioned staggered manner [54, 53], always requiring the consistent update of the interface and the use of an Arbitrary Lagrangian Eulerian approach to describe the fluid phase. In cases where the deformations are extreme and even topological changes emerge, the introduction of an adaptive remeshing technique becomes necessary, leading to prohibitively expensive numerical simulations.

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