Immersed boundary method based on hierarchical B-Spline grid for fluid-structure interaction

Chennakesava Kadapa*, **Wulf Dettmer, Djordje Perić**

Zienkiewicz Centre for Computational Engineering,
Swansea University, Swansea SA2 8PP, UK.
c.kadapa@swansea.ac.uk

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ABSTRACT

Fluid-Structure interaction (FSI) is a complex phenomenon and developing robust numerical schemes for studying FSI is quite a challenging task. The most widely used approach to simulate FSI is to use body-fitted meshes with Arbitrary Lagrangian-Eulerian (ALE) formulation. However, the distortions in the fluid mesh due to the movement of solids not only require efficient re-meshing algorithms but also limits the applicability of ALE formulation to problems with moderate deformations. Moreover, creating good quality body-fitted meshes is a cumbersome task in itself. In this scenario immersed-boundary methods (IBMs) offer several advantages over ALE methods. In IBM fluid is solved on a regular cartesian grid on which the solid is free to move and as fluid mesh is independent of the movement of the solid there is no need for re-meshing algorithms.

In the present work we propose IBM based on hierarchical B-Spline cartesian grid. One of the main motivating factors behind using hierachical B-Splines for the background fluid grid is their local refinement capability. The solution space, at the locations of steep gradients, can be enriched by the use of hierarchical B-Splines thereby eliminating the need to refine the whole grid. This results in significant savings in computational time. The immersed solid is represented by a set of Lagrangian points. The standard Galerkin formulation is used to discretise the governing equations and the unconditionally stable and second-order accurate generalised-α method is used for time-integration. Performance of the proposed formulation is demonstrated by studying several benchmark problems and comparing the parameters of interest with the reference values. This method is used to study the performance characteristics of a check-valve and proved to be effective in capturing topology changes during opening and closing of the valve. Without the need for any re-meshing algorithms and with the capability to perform local refinement the proposed formulation proves to be efficient and robust for simulating fluid-structure interaction phenomenon.

References

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