Immersogeometric Analysis using B-Rep Models

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ABSTRACT

We present a new method for immersogeometric analysis that makes use of the boundary representation (B-rep) of a complex design object and immerses it into a non-boundary-fitted discretization of the surrounding fluid domain. A complex design geometry is typically modeled using analytic and NURBS surfaces; both need to be directly handled in the immersogeometric analysis. The motivating applications include analyzing the flow over complex geometries, such as moving vehicles, where the detailed geometric features usually require time-consuming, labor-intensive steps of geometry cleanup or mesh manipulation for generating the surrounding boundary-fitted fluid mesh. The proposed method directly immerses the B-rep model into a locally refined, non-boundary-fitted background mesh to avoid the challenges associated with geometry cleanup and mesh generation/manipulation. To faithfully capture the geometry in intersected elements, an adaptive quadrature rule based on the recursive split of elements is implemented. Dirichlet boundary conditions in intersected elements are enforced weakly in the sense of Nitsche's method. To assess the accuracy of the proposed method, we perform computations of the benchmark problem of flow over a sphere represented using B-reps. Quantities of interest such as drag coefficient were in good agreement with reference results obtained with boundary-fitted approaches that used triangular tessellations of the curved surfaces. The results show that the density of the surface quadrature points is crucial for accurate high-fidelity flow analysis. With the number of surface quadrature points that is necessary for accurate weak enforcement of Dirichlet boundary conditions, integration error near the trimmed curves becomes insignificant. Finally, we demonstrate the effectiveness of our immersogeometric method for high-fidelity industrial scale simulations by performing an aerodynamic analysis of a moving vehicle directly represented using B-rep.