Advanced isogeometric methods for flow and fluid-structure interaction problems

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ABSTRACT

Isogeometric Analysis (IGA) is a recent simulation framework, originally proposed by Hughes et al. in 2005 [1], to bridge the gap between Computational Mechanics and Computer Aided Design (CAD). The basic IGA paradigm consists of adopting the same basis functions used for geometry representations in CAD systems - such as, e.g., Non-Uniform Rational B-Splines (NURBS) - for the approximation of field variables, in an isoparametric fashion. This leads to a cost-saving simplification of the typically expensive mesh generation and refinement processes required by standard finite element analysis. In addition, thanks to the high-regularity properties of its basis functions, IGA has shown a better accuracy per-degree-of-freedom and an enhanced robustness with respect to standard finite elements in a number of applications ranging from solids and structures to fluids and fluid-structure interaction (FSI), opening also the door to geometrically flexible discretizations of higher-order partial differential equations in primal form, as well as to highly efficient (strong-form) collocation methods. Within this context, this work aims at presenting three recent interesting applications, where the unique features of IGA have been exploited to obtain powerful simulation frameworks for some specific flow and FSI problems. The first application consists of the IGA version of the promising family of techniques based on the hierarchical model reduction (HiMod) paradigm, which have been recently proposed to efficiently solve incompressible flow problems in domains given by curved pipes or network of pipes [2]. The second considered application is related to an IGA approach for FSI which exploits a boundary integral formulation of Stokes equations to model the surrounding flow and a nonlinear Kirchhoff-Love shell theory to model the elastic behaviour of the structure [3]. The proposed approach seems to be particularly attractive for applications like the simulation of falling objects, since only the boundary representation (B-Rep) of the thin structure middle surface is indeed constituting the mesh for the studied problem. Finally, the high potential of the so-called "immersogeometric analysis" framework (see, e.g., [4]) will be exemplified in the context of the FSI analysis of patient-specific aortic valve designs.

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