Isogeometric Analysis applications in structural biomechanics involving complex geometries, explicit dynamics, large deformations, inelasticity, contact, and buckling.

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ABSTRACT

Isogeometric Analysis (IGA) is a recent simulation framework, originally proposed by TJR Hughes and coworkers in 2005, 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. 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, opening also the door to geometrically flexible discretizations of higher-order partial differential equations in primal form.

This lecture aims at giving an overview of the basic features of IGA and of its main advantages, which are illustrated through some convincing applications, belonging to the field of structural biomechanics. In particular, a demanding explicit structural dynamics simulation of a patient-specific aortic valve, modeled by nonlinear hyperelastic shells and involving large deformations and contact, is presented and carefully analyzed in terms of accuracy and efficiency. As a further representative case study, the bending behavior of complex structures like shape memory alloy stents is simulated in the large deformation regime, with particular attention to a correct modeling of buckling phenomena. In all these cases, the superior results which can be provided by isogeometric analysis with respect to standard finite elements are clearly pointed out.