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Title: An introduction to Isogeometric Analysis with some applications

Abstract:
Isogeometric Analysis (IGA) is a recent idea [Hughes, Cottrell, Bazilevs (2005); Cottrell, Hughes, Bazilevs (2009)] introduced to bridge the gap between Computational Mechanics and CAD. The key feature of IGA is to extend the finite element method representing geometry by functions which are typically used by CAD systems, and then invoking the isoparametric concept to define field variables. Thus, the computational domain exactly reproduces the CAD description of the physical domain. Numerical testing in different situations has shown the huge potential of IGA, characterized by a substantial increase in the accuracy per degree of freedom with respect to standard finite elements. Within this framework, this short course aims at giving an introduction to Isogeometric Analysis, covering some basic concepts of IGA and its implementation.

Therefore, after some basics of B-Splines and NURBS, the main ingredients toward the implementation of simple isogeometric codes within the framework of Galerkin methods will be shown and discussed. This will include topics such as isoparametric mapping, numerical quadrature, boundary conditions, etc. Tutorials showing the practical implementation of IGA in simple 1D and 2D (Matlab) codes will be also given. The advantages of IGA will be then illustrated through some compelling applications, mainly belong- ing to the field of structural mechanics and biomechanics. In particular, after an introduction about the IGA approximation properties of structural vibrations, the application to a real-life case, the so-called NASA "Aluminum Testbed Cylinder", will be shown along with comparisons with experimental results. As a further example, a demanding explicit structural dynamics simulation of a patient-specific aortic valve, modeled by nonlinear hyperelastic shells and involving large deformations and contact, will be presented and carefully analyzed in terms of accuracy and efficiency. As a third representative case study, the bending behavior of complex structures like shape memory alloy stents will be 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 re- spect to standard finite elements will be clearly pointed out.

Finally, isogeometric collocation techniques will be introduced as an interesting high-order low-cost alternative to standard Galerkin approaches, and some convincing applications will be shown.

(Approximate) content of lectures:
Lecture 1: Motivation and introduction to IGA; basics of B-Splines and NURBS; basic IGA implementation ingredients.
Lecture 2: IGA applications in structural mechanics and biomechanics.
Lecture 3: IGA collocation methods.
Tutorial 1: Practical implementation of IGA in a simple 1D Matlab code.
Tutorial 2: Practical implementation of IGA in a simple 2D Matlab code, with some examples and extensions.