International Doctorate in Civil and Environmental Engineering

DOCTORAL COURSE A.Y. 2021/22

An introduction to Isogeometric Analysis and its applications with a focus on nonlinear beams

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Registration form: https://forms.gle/rL4iZDnYbYJiPq6w9
(Registration recommended before March 10, 2022)

Calendar	
2 hours - Prof. A. Reali 15/3/2022 14:30- 16:30	Introduction to B-splines and NURBS basis functions. Curve and surface representations
2 hours - Prof. A. Reali 15/3/2022 16:30- 18:30	Basic implementation aspects (including both Galerkin and collocation IGA) and application examples
2 hours - Prof. A. Reali 16/3/2022 9:00- 11:00	Modal analysis and structural dynamics with applications
2 hours - Prof. A. Reali 16/3/2022 11:00- 13:00	IGA for coupled problems (including fluid-structure interaction and phase-field modeling)
2 hours - Dr. E. Marino 17/3/2022 9:00- 11:00	Nonlinear beams: statics - Part I (finite rotations, rotation vector and exponential map, beam kinematics)
2 hours - Dr. E. Marino 18/3/2022 14:30- 16:30	Nonlinear beams: statics - Part II (governing equations, SO(3)-consistent linearization, solution scheme based on collocation IGA)
2 hours - Dr. E. Marino 21/3/2022 14:30- 16:30	Nonlinear beams: dynamics - Part I (collocation IGA with SO(3)-consistent implicit time integration)
2 hours - Dr. E. Marino 22/3/2022 16:00- 18:00	Nonlinear beams: dynamics - Part II (collocation IGA with SO(3)-consistent explicit time integration)
Total	16 hours – 8 credits

Program

Isogeometric analysis (IGA) is a method for the solution of problems governed by partial differential equations. The method was introduced in 2005 by Hughes et al. [1] with the aim of representing the exact geometry regardless of the mesh refinement level and simplifying the expensive operations of mesh generation and refinement required by traditional Finite Element Analysis (FEA) [2-4]. This is possible by using the higher-order basis functions adopted in Computer Aided Design (CAD), e.g., NURBS [4,5], not only to describe the domain geometry, but also to represent the numerical solution of the differential problem.
This short course will give an overview of the main attributes and potentialities of the IGA methods with a focus on structural mechanics. After an introduction devoted to NURBS basis functions and

basic implementation aspects, the course will cover the following topics: modal analysis and structural dynamics; coupled problems, such as fluid-structure interaction and phase-field modeling. After that, both static and dynamic problems of geometrically exact beams will be addressed by means of the Isogeometric Collocation method (IGA-C) [6-8]. Emphasis will be placed on finite rotations, which require geometrically consistent procedures for the linearization of the governing equations.

References

[1] T.J.R. Hughes, J.A. Cottrell, Y. Bazilevs, "Isogeometric analysis: CAD, finite elements, NURBS, exact geometry and mesh refinement". Comput. Methods Appl. Mech. Eng., vol. 194, pp. 4135–4195, 2005.

[2] J.A. Cottrell, A. Reali, T.J.R. Hughes, Y. Bazilevs, "Isogeometric analysis of structural vibrations". Comput. Methods Appl. Mech. Eng., vol. 195, pp. 5257–5296, 2006.

[3] J.A. Cottrell, T.J.R. Hughes, A. Reali, "Studies of refinement and continuity in isogeometric structural analysis". Comput. Methods Appl. Mech. Eng., vol. 196, pp. 4160–4183, 2007.

[4] J.A. Cottrell, T.J.R. Hughes, Y. Bazilevs, Isogeometric analysis: toward integration of CAD and FEA. John Wiley & Sons, 2009.

[5] L. Piegl and W. Tiller, The NURBS Book. Springer, 1997.

[6] F. Auricchio, L. Beirão Da Veiga, T.J.R. Hughes, A. Reali, G. Sangalli, "Isogeometric Collocation Methods," Math. Model. Methods Appl. Sci., vol. 20, pp. 2075–2107, 2010.

[7] Marino, E. "Locking-free isogeometric collocation formulation for three-dimensional geometrically exact shear-deformable beams with arbitrary initial curvature". Comput. Methods Appl. Mech. Eng., vol. 324, pp. 546-572, 2017.

[8] Marino, E., Kiendl, J., & De Lorenzis, L. "Isogeometric collocation for implicit dynamics of three-dimensional beams undergoing finite motions". Comput. Methods Appl. Mech. Eng., vol. 356, pp. 548-570, 2019.