Isogeometric collocation for implicit dynamics of three-dimensional geometrically exact beams

Enzo Marino*, Josef Kiendl† and Laura De Lorenzis‡

* Department of Civil and Environmental Engineering, University of Florence
Via di S. Marta 3, 50139 Firenze, Italy
e-mail: enzo.marino@unifi.it

† Department of Marine Technology, Norwegian University of Science and Technology
NO-7491 Trondheim, Norway
e-mail: josef.kiendl@ntnu.no

‡ Institute of Applied Mechanics, Technische Universität Braunschweig
Pockelsstraße 3, 38106 Braunschweig, Germany
e-mail: l.delorenzis@tu-braunschweig.de

ABSTRACT

The isogeometric collocation (IGA-C) method was proposed in [1] with the aim of exploiting the higher smoothness of NURBS basis functions used in isogeometric analysis (IGA) [2] and the low computational cost of collocation. Higher efficiency compared to Galerkin-based IGA is achieved since IGA-C requires only one evaluation point per degree of freedom, regardless of the approximation degree. Moreover, issues related to numerical quadrature in IGA are completely removed since IGA-C is based on the discretization of the strong form of the differential problem. Starting from the basis recently laid in [3-4], where static and explicit dynamic IGA-C formulations were proposed, in this contribution we further develop the method to address the implicit dynamic problem of geometrically exact beams employing the Newmark time integration scheme extended to the rotation group SO(3) [5]. Most of the computational complexities in the formulation of geometrically nonlinear, shear-deformable beams originate from the presence of such a non-additive and non-commutative group. Geometric consistency with SO(3) is a fundamental requirement that the key operations of linearization of the governing equations, initialization and update procedures must meet. In addition to unconditional stability and geometric consistency, the formulation we propose results highly efficient since rotational unknowns are described by the (material) incremental rotation vector [6]. The capabilities of the proposed formulation are shown through numerical examples involving very large and fast motions.

REFERENCES

[1] F. Auricchio, L. Beirão da Veiga, T. J. R. Hughes, A. Reali, G. Sangalli, "Isogeometric collocation methods", *Math. Models Methods Appl. Sci.*, **20**, pp. 2075–2107 (2010).

[2] 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.*, **194,** pp. 4135–4195 (2005).

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

[4] E. Marino, J. Kiendl, L. De Lorenzis, "Explicit isogeometric collocation for the dynamics of three-dimensional beams undergoing finite motions", *Comput. Methods Appl. Mech. Eng.*, **343**, pp. 530–549 (2019).

[5] J. C. Simo, L. Vu-Quoc, "On the dynamics in space of rods undergoing large motions — A geometrically exact approach", *Comput. Methods Appl. Mech. Eng.*, **66(2)**, pp. 125–161.

[6] E. Marino, J. Kiendl, L. De Lorenzis, "Isogeometric collocation for implicit dynamics of three-dimensional beams undergoing finite motions", (submitted).