An Accurate and Efficient Varying-order NURBS Discretization Method for Isogeometric Contact Analysis

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ABSTRACT

In the past few years, NURBS-based isogeometric analysis (IGA) [1] has been established as an advantageous computational technology for various classes of problems, especially for contact problems where the non-smooth description of the contact surface strongly influences the accuracy of the solution [2]. This is attributed to the distinguished intrinsic features of its underlying basis function, i.e. the ability to represent complex geometry exactly even with a coarse mesh, variation diminishing and convex-hull properties, tailorable inter-element continuity, and the non-negativeness [2]. However, the application of IGA to contact has turned out to be computationally expensive since the NURBS structure can only be refined in a global manner due to its rigid tensor product nature. The interpolation order of the NURBS that are used to describe the overall domain of the geometry is elevated in a uniform manner. From the analysis point of view, employing higher-order NURBS for the description of the major part of domain that does not come into contact may not be desirable since the accuracy of the contact solution is primarily governed by the description of the contact interface.

To this date, in order to enable local mesh refinement in the context of IGA, T-splines [3], NURBS-based hierarchical refinement [4], and the locally refined (LR) NURBS [5] based approaches have been introduced. Moreover, a NURBS-enriched formulation that combines the accuracy features of the NURBS with the efficiency characteristic of standard FE discretization has also been introduced [6, 7]. But, the idea to refine the NURBS discretized geometry through controllable order-elevation remains unexplored.

For this purpose, a novel varying-order (VO) NURBS discretization method is introduced. The method makes use of higher-order NURBS polynomials for the evaluation of the contact integrals while minimum-order NURBS that are capable of representing the complex geometries exactly are used for the computation of the bulk domain. To achieve this, a higher-order NURBS layer, which accompanies a large number of degrees of freedom and matches with the bulk parametrization, is utilized as the contact boundary layer of the geometry. This, as a result, avoids the usage of higher-order NURBS in the region away from the contact interface. Moreover, a large number of degrees of freedom are introduced even with a coarse mesh across the contact interface. In this work, the isogeometric mortar contact formulation presented by De Lorenzis et al. [8] is used for the treatment of contact with VO NURBS discretization. The impenetrability and sticking contact constraints are enforced in a weak sense at the active control points. For the regularization of the impenetrability and tangential sticking constraints the penalty method is adopted.

In order to demonstrate the capabilities and performance of the introduced VO NURBS discretization methodology a number of numerical examples are considered. It is shown that with the proposed method accurate solution can be achieved at a relatively coarser mesh than that with existing discretization approach. Moreover, to obtain the results of same accuracy the method requires lower computational cost as compared to existing discretization approach. The simplicity of the current approach allows itself to be conveniently embedded into existing isogeometric contact codes.

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