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Topology-preservation, residual-based error estimation and adaptivity for scan-based immersed isogeometric analysis

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Scan-based simulations contain innate topologically and geometrically complex three-dimensional domains, represented by large data sets in formats which are not directly suitable for analysis. In recent years, immersed finite element methods [1, 2] have been demonstrated to be suitable for scan-based geometries. Immersed techniques have been successfully combined with Isogeometric Analysis (IGA) [3] – a spline-based higher-order finite element framework – enabling its application to complex three-dimensional problems.

To exploit the advantageous properties of IGA in a scan-based setting, it is important to extract a smooth geometry. This can be established by convoluting the voxel data using B-splines [4]. A negative side-effect of this convolution technique is, however, that it can induce topological changes in the process of smoothing when features with a size similar to that of the voxels are encountered. An additional challenge in the context of immersed IGA is the construction of optimal approximations using locally refined splines. For scan-based volumetric domains, hierarchical splines are particularly suitable, as they optimally leverage the advantages offered by the availability of a geometrically simple background mesh. Although truncated hierarchical B-splines have been successfully applied in the context of IGA, their application in the immersed setting is largely unexplored.

In this contribution, we present a topology-preserving segmentation procedure using truncated hierarchical (TH)B-splines. Additionally, we propose a computational strategy for the application of residual-based error estimation and adaptivity for stabilized immersed IGA using THB-splines. We will study the proposed techniques using a range of test cases and scan data.

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