An isogeometric design-through-analysis methodology, based on adaptive hierarchical refinement of NURBS, immersed boundary methods, and T-spline CAD surfaces

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Immersed boundary methods, such as the B-spline version of the finite cell method, combine the fictitious domain approach with high-order and high-continuity approximation spaces, adaptive integration of cut elements and weak imposition of unfitted Dirichlet boundary conditions. Their main advantage consists of the extension of the physical domain of interest beyond its potentially complex boundaries into a larger embedding domain of simple geometry, which can be meshed easily by a structured grid.

We present an isogeometric design-through-analysis methodology based on the B-spline version of the finite cell method. It allows for the seamless integration of fully three-dimensional parameterizations of complex engineering parts and assemblies described by T-spline surfaces into finite element analysis. The approach is demonstrated to achieve optimal rates of convergence and to yield accurate stress results not only within the domain of interest, but also directly on the immersed boundary. In this context, we show that accuracy and optimal convergence nonetheless require an accurate description of the immersed boundary as well as the immersed original domain during integration of the stiffness matrix. We also show that hierarchical refinement of NURBS considerably increases the flexibility of the immersed boundary approach in terms of adaptive resolution of local features in the geometry and the solution fields. At the same time, hierarchical refinement of NURBS maintains the key advantage of fully automated mesh generation for complex geometries due to its simplicity and straightforward implementation. We illustrate the versatility of our methodology by several complex industrial examples, such as a ship propeller and an automobile wheel.