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Isogeometric shape optimization of general curved geometry: generalized shape sensitivity analysis in curvilinear coordinates and shell applications

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Abstract

Geometric modeling in CAD systems is usually described by the NURBS (non-uniform rational B-Splines) basis functions. In finite element based shape sensitivity analysis and optimization, the finite element meshes are approximated from the given CAD geometry while designs are directly embedded in CAD systems. The geometric approximations have been usually accomplished by piecewise linear polynomials, which leads accuracy problems in response analysis and more unfavorably in shape sensitivity analysis. In the isogeometric approach, however, the analysis model employs the same basis functions in the CAD systems rather than uses the shape functions for the finite element meshes. The geometric flexibility of the NURBS basis is further capable to exactly represent the CAD geometry and makes the subsequent refinements greatly simplified due to no need of additional communications with the CAD systems. In this study, a generalized continuum-based isogeometric shape sensitivity analysis method is derived in the curvilinear coordinate system. Due to the higher continuity of the NURBS functions, it is capable to enhance the accuracy of shape sensitivities of complex geometries including higher order geometric effects, such as normal, curvature, etc. The isogeometric shape optimization for the shell components is performed with the derived adjoint sensitivity analysis. Through numerical examples, the developed isogeometric shape sensitivity is verified to demonstrate excellent agreements with finite difference sensitivity. Also, the importance of higher order geometric information in the sensitivity expressions is identified. For the shape optimization problem of the shell, the proposed method works well with boundary resultants accompanying severe curvature changes.