Explicit Isogeometric Topology Optimization Using Moving Morphable Components (MMC)

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Abstract

In general, structural topology optimization aims at finding the appropriate material distribution in a prescribed design domain so that the optimal structure has some exceptional properties. The most well-established topology optimization approaches are the SIMP approach [1-4] and level set approach [5-8]. Guo et al.[9-11] proposed a novel topology optimization approach based on the concept of Moving Morphable Component (MMC). In the MMC-based topology optimization approach, more geometric and mechanical information are incorporated, and the number of design variables is reduced substantially. However, the low-order shape function used to approximate the design domain often lead to numerical instabilities.

Isogeometric analysis (IGA) was developed by Hughes et al.[12], with the aim of unifying the fields of computer aided design (CAD) and finite element analysis (FEA). The NURBS basis functions for IGA have higher accuracy than the shape functions in the traditional FEA for an equal number of DOF. Hence, IGA has been applied in a variety of computational mechanical fields including topology optimization. Hassani et al. proposed an isogeometric SIMP topology optimization approach using optimality criteria[13]. Wang et al. applied IGA to the conventional level set method where the level set function is updated by the optimality criteria [14, 15]. Recently, Jahangiry et al. proposed an isogeometric level set optimization approach where the control mesh (controlling the level set function) is updated by calculating the Hamilton-Jacobi equation[16]. All the aforementioned isogeometric topology optimization approaches employ an implicit optimization framework.

In this work, we propose an explicit isogeometric topology optimization approach using MMCs. The prescribed design domain is discretized by a NURBS patch and NURBS-based IGA is adopted for structural response analysis and sensitivity analysis. We employ MMCs to represent the geometries of structural components (a subset of the design domain) with explicit design parameters. The central coordinates, half-length, half-width, and inclined angles of MMCs are taken as design variables. The proposed method not only inherits the explicitness of the original MMC-based approach, but also embraces the merits of the IGA such as high-order continuity. Several numerical examples illustrate that the presented method based on IGA is more robust and stable than the FEM-based topology optimization using MMCs.

Keywords: Isogeometric analysis, NURBS, Topology optimization, Moving morphable components, Topology description function, Sensitivity analysis.

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