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Geometric Feature Identification from Topology Optimization Results

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Abstract

Topology optimization yields an overall layout of a structure in the form of discrete density (e.g., SIMP), or continuous boundary geometry (e.g., level-set method). One of important drawbacks, however, is that it leads to geometries with zigzag boundaries and/or irregular shapes, which is difficult to be interpreted for manufacturability, as well as to be utilized in subsequent applications such as shape optimization. It is considered the most significant bottleneck to interpret topology optimization results and to produce a parametric CAD model that can be used for section optimization and shape optimization. Some conventional methods were proposed in the literatures to identify geometric boundaries by using image interpretation, density contour, geometric templates, and B-spline curves et al. However, shortcomings still exist with these methods. For example, too much manual intervention is involved in image processing, no parameterized model or geometric features could be obtained by density contour detection, limited geometric features could be represented by templates, and B-spline curves are expensive in the perspective of manufacturing. Therefore, the objective of this paper is to interpret geometric features out of a topology design to minimize human intervention in producing a parametric CAD model.

In order to achieve the goal, a framework for geometric features identification involving several boundary extraction techniques and optimization methods are proposed. Based on a greyscale image or density results of a topology result, the active contour method is firstly used to extract boundary segments from the topology shapes. Using the information of roundness and curvature of the boundary segments, simple geometric features, such as lines, arcs, circles, fillets, extrusion and sweep, are then identified. An optimization method is used to find parameters of these geometric features by minimizing errors between the analytical expressions and the initial boundary segments. Lastly, using the parametric CAD model, surrogate-based optimization design method is employed to perform shape optimization for the structures. The entire process is automated with MATLAB and Python scripts in Abaqus, while manual intervention is needed only when defining geometric constraints and choosing design parameters. A 2-D plane and a cantilever beam are used as testing examples to demonstrate effectiveness of the proposed methods. The results show that the proposed framework can identify topological results very well, and the whole process is easy and efficient for application.

Although the proposed framework for geometric features identification could integrate topology optimization and sequential section/shape optimization together and support structural design effectively, there is still some future work required to be considered, for example, parameterizing boundary conditions to make process fully automatic, and applying this integration framework into three dimensional structures.