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Stress-based Topology Optimization with Discrete Geometric Components

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Abstract

In this paper, we introduce a framework for the stress-based topology optimization of structures made by the assembly of discrete geometric components, such as bars and plates, that are described by explicit geometry representations. To circumvent re-meshing upon design changes, we employ the geometry projection method to smoothly map the geometric components onto a continuous density field defined over a uniform finite element grid for analysis. The geometry projection is defined in a manner that prevents the singular optima phenomenon widely reported in the literature, and that effectively considers stresses only on the geometric components and not on the void region. As in previous work, a size variable is ascribed to each geometry component and penalized in the spirit of solid isotropic material with penalization (SIMP), allowing the optimizer to entirely remove geometric components from the design. We demonstrate our method on the L-bracket benchmark for stress-based optimization problems in 2-d and 3-d.

Keywords: Topology optimization, Geometry projection, Stress constraints, Bar structures, Plate structures, Design for manufacturing

1. Introduction

Topology optimization is a powerful tool to explore the design of lightweight structures and material systems with optimized stiffness and other structural responses. Although stiffness-based topology optimization is already widely used in industry for conceptual design, the translation from the optimization design to a manufacturable and functional design is not straightforward due to two major challenges. First, an interpretation is needed to translate the organic designs that are typically rendered by free-form topology optimization into a design that conforms to manufacturing requirements. This post-processing step often introduces weight to the design and/or decreases the structural performance. Second, substantial design changes are required to go from a stiffest design to one that fulfills other structural criteria such as stress. In many cases, these changes add weight to the structure. Therefore, both challenges result in a final design that is typically sub-optimal.

These challenges are more severe if one seeks a design that employs only stock material such as structural shapes, which are common in many manufacturing processes available in industry applications. Recently, several works have proposed topology optimization techniques for structures made of stock material. These works relate an analytical description of the geometry of stock components with a fixed finite element grid for the primal and sensitivity analyses. In [1, 2] and [3], a geometry projection method smoothly projects a set of flat bars and

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