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Stochastic Sampling for Deterministic Structural Topology Optimization with Many Load Cases: Density-Based and Ground Structure Approaches

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Abstract

We propose an efficient probabilistic method to solve a fully deterministic problem – we present a randomized optimization approach that drastically reduces the enormous computational cost of optimizing designs under many load cases for both continuum and truss topology optimization. Practical structural designs by deterministic topology optimization typically involve many load cases, possibly hundreds or more. The optimal design minimizes a, possibly weighted, average of the compliance under each load case (or some other objective). This means that, in each optimization step, a large finite element problem must be solved for each load case, leading to an enormous computational effort. On the contrary, the proposed randomized optimization method with stochastic sampling requires the solution of only a few (e.g., 5 or 6) finite element problems (large linear systems) per optimization step. Based on simulated annealing, we introduce a damping scheme for the randomized approach. Through numerical examples in two and three dimensions, we demonstrate that the stochastic algorithm drastically reduces computational cost to obtain similar final topologies and results (e.g., compliance) to those of standard algorithms. The results indicate that the damping scheme is effective and leads to rapid convergence of the proposed algorithm.

Keywords: Topology optimization with many load cases; Stochastic sampling; Randomized algorithm; Trace estimator; Density-based method; Ground structure method

1. Introduction

Structural topology optimization is an important tool that, if properly used, can lead to significantly improved designs. In the field of structural topology optimization, designs accounting for many load cases are common practice [1]. Indeed, real-world structural designs, for example, high-rise buildings and long-span bridges, generally involve numerous load cases [1]. For the end-

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