

EXPLORING ONE-SHOT MULTIGRID PRECONDITIONING IN TOPOLOGY OPTIMIZATION

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Abstract

Topology optimization is a mature computational strategy for producing highly efficient structures that balance material usage and performance. With recent advances in manufacturing enabling the realization of increasingly complex optimized geometries, there is a growing need for topology optimization methods capable of handling fine-resolution designs at reduced computational cost. This has motivated significant interest in developing more efficient algorithms for generating high-fidelity optimized layouts. A recent study examined a one-shot strategy for minimum-compliance topology optimization within the nested formulation. For the convex variable-thickness-sheet (VTS) problem, it was demonstrated that an optimality-criteria (OC) method using only a single iteration of a multigrid-preconditioned conjugate-gradient (MGCG) solver converges to the same solution as a fully converged analysis. This behavior stems from the characteristics of the geometric multigrid preconditioner, which provides sufficiently accurate coarse-scale design sensitivities. When extended to SIMP-based topology optimization, the one-shot approach produces designs that capture the same primary load-bearing features as those obtained with fully accurate solvers. Early results indicate that this strategy may also be applicable to more complex objectives, such as stress. To further understand the potential of one-shot multigrid preconditioning, ongoing work focuses on the Simultaneous Analysis and Design (SAND) framework. Building on the multigrid-preconditioned primal-dual interior-point (IP) method with inexact linear solves, we investigate the use of one-shot MGCG within the nonlinear KKT systems arising in VTS optimization. Numerical experiments show that performing one Newton step per IP iteration, combined with a single MGCG iteration per linear solve, approaches the accurate solution as the barrier parameter step size is reduced—mirroring the success observed with the OC method. Extending this strategy to the SAND formulation of SIMP-based topology optimization presents additional challenges, but initial results are encouraging and will be discussed.