

SCALING TOPOLOGY OPTIMIZATION FOR TIME HARMONIC DYNAMIC PROBLEMS

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Abstract

Today, topology optimization is a key tool in the mechanical, automotive, and aerospace industries. The fundamental idea is to distribute material within a predefined domain by minimizing a chosen objective while satisfying a set of constraints, such as minimizing power dissipation or maximizing heat transfer, subject to a limited amount of material. The solution process involves repeated system analyses, gradient evaluations via adjoint sensitivity analysis, and design updates via mathematical programming methods. The result of the topology optimization procedure is a bitmap image of the design, leading to design freedom unmatched by any other approach. However, this freedom comes at the cost of substantially increased computational power requirements. Finer discretizations provide better design descriptions while demanding the use of large parallel machines. The size of the discrete problems necessitates the deployment of iterative techniques, with convergence hindered by the sharp contrast between the properties of the different constituent materials and the ill-conditioned nature of the discretized system of equations. Therefore, most results, especially for time-harmonic dynamic problems, reported in the literature use direct solvers, limiting the studies and the results to academic 2D examples. Our work extends and demonstrates topology optimization to large-scale 3D linear elastic problems excited by time-harmonic loads. Their discretizations yield large, complex linear systems that are notoriously difficult to precondition and solve. To this end, we reformulate the discrete linear systems in equivalent real-valued two-by-two block systems, which are relatively easy to precondition and solve. To speed up the solution process and improve the constructed preconditioners, we reuse the history of the physical system's solution during the optimization and use part of the lowest-frequency eigenmodes obtained through randomization. Several solution strategies are demonstrated for 2D and 3D topology optimization problems implemented using the MFEM finite element discretization library, focusing on scalability and the impact of material contrast.

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