Improved Two-Phase Projection Topology Optimization

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Projection-based algorithms for continuum topology optimization have received considerable attention in recent years due to their ability to control minimum length scale in a computationally efficient manner. This not only provides a means for imposing manufacturing length scale constraints, but also circumvents numerical instabilities of solution mesh dependence and checkerboard patterns. Standard radial projection, however, imposes length scale on only a single material phase, potentially allowing small-scale features in the second phase to develop. This may lead to sharp corners and/or very small holes when the solid (load-carrying) phase is projected, or one-node hinge chains when only the void phase is projected.

Two-phase length scale control is therefore needed to prevent these potential design issues. Ideally, the designer would be able to impose different minimum length scales on both the structural (load-carrying) and void phases as required by the manufacturing process and/or application specifications. A previously proposed algorithm towards this goal required a design variable associated with each phase to be located at every design variable location, thereby doubling the number of design variables over standard topology optimization [1]. This work proposes a two-phase projection algorithm that remedies this shortcoming. Every design variable has the capability to project either the solid or the void phase, but nonlinear, design dependent weighting functions are created to prevent both phases from being projected. The functions are constructed intentionally to resemble level set methods, where the sign of the design variable dictates the feature to be projected. Despite this resemblance to level sets, the algorithm follows the material distribution approach with sensitivities computed via the adjoint method and MMA used as the gradient-based optimizer. The algorithm is demonstrated on benchmark minimum compliance and compliant inverter problems, and is shown to satisfy length scale constraints imposed on both phases.

References:

[1] Guest, J. K. "Topology Optimization with Multiple Phase Projection," *Comput. Methods Appl. Mech. Engrg.,* Vol. 199, 2009, pp. 123-235.