Topology Optimization with Multiple Materials, Multiple Constraints, and Multiple Load Cases

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Abstract:

Topology optimization is a practical tool that allows for improved structural designs. However, most work in this field has been restricted to single material with linear material behavior, limited volume constraint settings, and single load case. To address these issues, we propose an efficient multi-material topology optimization formulation considering material nonlinearity. The proposed formulation handles an arbitrary number of candidate materials with flexible material properties, features freely specified material layers, and includes a generalized volume constraint setting. To efficiently handle such arbitrary volume constraints, we derive a novel design update scheme that performs robust updates of the design variables associated with each volume constraint independently. The derivation is based on the separable feature of the dual problem of the convex approximated primal subproblem with respect to the Lagrange multipliers, and we show that the update of design variables in each volume constraint only depends on the corresponding Lagrange multiplier. To obtain designs under many load cases, we also present a randomized approach that efficiently optimizes structures under hundreds of load cases. This approach only uses 5 or 6 stochastic sample load cases, instead of hundreds, to obtain similar optimized designs (for both continuum and truss topology optimization). Through examples using combinations of Ogden-based, bilinear, and linear materials, we demonstrate that the proposed topology optimization frameworks with the aforementioned update scheme and randomized algorithm lead to design tools that not only find the optimal topology but also select the proper type and amount of material with drastically reduced computational cost.

Biographical sketch:

Shelly Zhang is currently a doctoral candidate in the School of Civil and Environmental Engineering at Georgia Tech. She received her bachelor's and master's degrees in structural engineering from the University of Illinois at Urbana Champaign. Her major research interests are in multi-material and nonlinear topology optimization, stochastic approximation, uncertainty quantification, multi-scale metamaterials, and 3D/4D printing. During her doctoral studies, she was a summer structural engineer in the Chicago office of the Skidmore, Owings and Merrill LLP (SOM), where she applied some of her research to unique building design projects.