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ADAPTIVE MESH REFINEMENT AND EFFICIENT PRECONDITIONING FOR TOPOLOGY OPTIMIZATION WITH DISCRETE GEOMETRIC COMPONENTS

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Abstract: Traditional density-based and level set methods for topology optimization render very efficient, organic designs. These designs, however, are often difficult to fabricate with available manufacturing processes. The geometry projection method recently advanced by our group accommodates a specific but common fabrication technique, namely assembly of stock material such as bars and plates. This method maps parameterized geometric primitives onto a fixed finite element mesh for the primal and sensitivity analyses, and renders optimal topologies that distinctly consist of these primitives. Since the ensuing optimal designs more closely resemble the final fabricated structure, this approach leads to significant savings in resources otherwise spent in translating an organic topology into a manufacturable concept. Moreover, the resulting designs are more structurally efficient than the translated organic designs. In addition to these advantages, the availability of a parametric primitives provides a direct computer aided design (CAD) representation. Practical structures made of stock material typically exhibit a low volume fraction with respect to the volume of the design region they occupy. The geometry projection requires that the element size is such that there is more than one element across the thinnest dimension of the primitive for accuracy and robustness of the sensitivity analysis. If a uniform element size mesh is used, this requirement leads to very high numbers of elements for practical applications (e.g., welded plate structures), making the cost of the optimization impractical. A strategy to alleviate this computational cost is to use adaptive mesh refinement. A fine mesh that satisfies the element size requirements of the geometry projection is only needed within a vicinity of the boundaries of the geometric components. Elsewhere, we can employ a much coarser mesh. In our method, for every design produced by the optimizer, we perform adaptive refinement and coarsening of the mesh using the projected density as a refinement indicator. We use quadrilateral and hexahedral elements in 2-D and 3-D respectively, and the refinement strategy consists of iterative subdivision/combination of elements, which results in hanging nodes. Through numerical examples, we demonstrate the effectiveness of the proposed method and show that, when used in conjunction with efficient geometric multigrid preconditioners, the proposed strategy drastically increases the efficiency of the optimization for industry-size problems.