Discrete Object Projection – New Restriction Capabilities in Topology Optimization

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We look to expand the reach of continuum topology optimization to include the design of 'structures' that gain functionality or are specifically manufactured from discrete, non-overlapping objects. While significant advancements have been made in restricting the geometric properties of topology-optimized structures, including restricting the minimum and maximum length scale of features, continuum topology optimization is still largely limited to monolithic structures. A wide variety of structures and materials, however, gain their stiffness or functionality from discrete objects, such as fiber-reinforced composites. At WCSMO9, the author proposed a projection-based methodology for optimizing the distribution of discrete objects (2d inclusions) across a design domain [1]. The previously proposed methodology was limited to objects of fixed size and shape, defined a priori by the designer.

This work significantly extends the capabilities of the existing projection algorithm by enabling simultaneous optimization object sizes, shapes, and/or locations. The algorithm is then further extended to three dimensions, enabling the design of structures composed of objects with directional dependency, such as fibers. These latest advancements are achieved through introduction of additional design variables that are independently and strategically projected onto element space. The interaction of these functions is constructed such that the objects are non-overlapping and near binary (0-1), without the need for additional constraints. As in traditional topology optimization, gradient-based optimizers are used with sensitivity information estimated via the adjoint method, solved using finite element analysis. The algorithm is demonstrated on benchmark problems in structural and material design, including cases where the objects are stiff inclusions embedded in a compliant matrix material, and vice-versa.

References

[1] Guest J.K. (2011). A Projection-Based Topology Optimization Approach to Distributing Discrete Features in Structures and Materials. *Proceedings 9th World Congress on Structural and Multidisciplinary Optimization*, Shizuoka, Japan, pp. 1-10.