A Geometry Projection Method for Continuum-Based Topology Optimization of Frames with Member Length Constraints

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Abstract

We present a method for the continuum-based topology optimization of structures made of discrete elements. In particular, we examine the optimization of structures made of bars of fixed width and semicircular ends. Here, we extend the previous work by the authors to consider length constraints on the bars in order to avoid the presence of very short or very long bars and hence improve manufacturability with stock material. The design space for the optimization consists of the locations of the endpoints of the bar's medial axes and their out-of-plane thicknesses. To circumvent re-meshing upon design changes, we project the design onto a fixed analysis grid using a differentiable geometry mapping that results in a density field indicating the fraction of solid material anywhere in the design space, as in density-based topology optimization methods. The out-of-plane thickness is penalized so that the optimizer is capable of removing bars during the optimization. The differentiability of the projection allows for the computation via the chain rule of design sensitivities of responses of interest, and therefore it allows for the use of robust and efficient gradient-based optimization methods. Our method considers the case where bars overlap at their joints (i.e. their thicknesses are added at the joint) and when they do not; and in the former, we compute the volume fraction directly from the geometric parameters and not from the density field. Also, our proposed method naturally accommodates the imposition of several fixed length scales. We demonstrate the proposed approach on classical problems of compliance-based topology optimization.