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Author: Dr. Saranthip Koh
United States, topopt@jhu.edu

Prof. James Guest
United States, jkguest@gmail.com

TOPOLOGY OPTIMIZATION FOR 3D PRINTING WITH SELECTIVE PLACEMENT OF CNT YARN REINFORCEMENT

Abstract

Additive Manufacturing (AM) technologies are rapidly advancing with machine processing resolutions continuously improving, feedstock material options expanding, and new capabilities arising. The vast majority of AM processes create monolithic components, meaning material can be deposited (or powder melted and solidified) to create freeform shapes of varying thickness and of a generally continuous material phase (or phases in multi-material systems). Many engineered components and materials, however, gain strength and functionality through strategic placement of distinct, discrete objects, such as reinforcing fibers. Often these objects are selected 'off-the-shelf' and thus come in fixed size and shape, and are not permitted to overlap due to physical contact or functional requirements. Recent technological advances have brought this concept to additive manufacturing, with techniques such as pick-and-place and deposition of reinforcing fibers making their way into 3D printing hardware. To fully leverage these tremendous capabilities, engineers must rethink the way they approach component design. Topology optimization can enhance this process and offer a systematic approach to exploring the now expanded design space afforded by these new technologies. Classical topology optimization approaches, however, are not capable of designing structures composed of discrete objects. Herein an approach based on Discrete Object Projection (DOP) is presented for simultaneously optimizing component topology and the distribution of discrete reinforcing objects within the topology. Specifically we are motivated by research at NASA LaRC and focus on the case of reinforcing yarns, where a 3D printer may deposit either a polymer material or a carbon nanotube (CNT) yarn encased in polymer at a given location. As in typical projection-based approaches, all geometric constraints, including length scales of the objects, spacing between the objects, and length scales of the component are achieved through the projection functions without additional constraints. The proposed algorithm is demonstrated on structural designs where the simultaneous optimization of structure topology and reinforcing CNT yarn are shown to offer significant mass savings over single material solutions.