ABSTRACT

Curved Geometries for Generative Metamaterial Design

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Mechanical metamaterials, with their architected structures and tailored mechanical properties, have garnered significant attention for applications ranging from lightweight structures to energy absorption and actuation. Recent advances in machine learning (ML) have introduced powerful tools for the design and optimization of these metamaterials, particularly through generative models capable of addressing the inverse
problem: designing geometries that yield desired mechanical behaviors.
These methods not only enhance the efficiency of exploring the design space but also open new possibilities for creating complex, multi-functional metamaterials with properties that extend beyond traditional design paradigms.
In part due to progress in machine learning, lattice-based mechanical metamaterials are experiencing a renaissance, as increasingly complex topologies can now be efficiently created and analyzed. However, there is an alternative way to achieve unorthodox mechanical behavior even in relatively simple lattices. While classically, the nodes of lattices are connected by straight beams, current fabrication methods enable the incorporation of curved elements into the metamaterial architecture. From a mechanical standpoint, curved beams exhibit an intriguing behavior—tensile and bending deformations become coupled. We demonstrate how the unique mechanics of curved beams can be exploited to facilitate unusual behavior in corresponding metamaterials and how generative approaches can assist in this process [1]. Specifically, we examine the effect of curved geometry on metamaterial behavior in both static and dynamic regimes and analyze the balance between the accuracy of property matching and the variability of designs for different generative approaches.

[1] G. Felsch, N. Ghavidelnia, D. Schwarz, V. Slesarenko, CMAME, 410 116032 (2023).