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Inverse design of nonlinear shell metamaterials via diffusion language models

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Introduction

The design of mechanical metamaterials with tailored properties has been of great interest for the last few decades [1]. Although deep generative models have opened a new paradigm in the design and optimization of metamaterials, their incorporation into shell-based metamaterials remains challenging due to the structural complexity and the lack of a comprehensive parameterization for the vast design space of shell lattices [2,3]. We here present an inverse design framework for nonlinear shell metamaterials using diffusion language models [4,5]. By leveraging a string-based parameterization, we construct a comprehensive design space of triply periodic surfaces, enabling an efficient, low-dimensional representation of a diverse family of shell lattices spanning a broad range of mechanical properties. We then demonstrate the effectiveness of the guided diffusion model in generating shell designs that achieve desired stress-strain responses under compression in the large-strain regime, including buckling and contact. Furthermore, we show that the generative modeling framework effectively captures the one-to-many mapping from properties to geometries, producing a diverse array of microstructures tailored for given nonlinear responses. Experimental and simulation results further validate the effectiveness of the proposed inverse design approach, highlighting its potential for advancing the design of novel materials with complex, tailored properties.

References

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