Graduate Student Research Seminar

Fall 2022

Deep Reinforcement Learning for the Design of Mechanical Metamaterials with Targeted nonlinear Deformation Responses

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Monday, October 31st

3:00 pm (EST) – 132 Fluor Daniel Building

Abstract

Mechanical metamaterials are a class of artificial materials whose unique global properties originate from the structural geometry and material composition of their unit cell. Typically, mechanical metamaterials unit cells are designed such that, when tessellated, they exhibit unique mechanical properties such as zero or negative Poisson's ratio, vanishing shear modulus, negative stiffness, and negative compressibility. Beyond these applications, mechanical metamaterials can be used to create a set of artificial materials with tailorable nonlinear deformation responses. Computational methods such as gradient-based topology optimization (TO) and size/shape optimization (SSO) are commonly implemented to design this set of metamaterials. However, both methods are limited by the threat of severe suboptimal solution convergence or a lack of generalizability. Therefore, this research investigates implementing deep reinforcement learning (DRL), a subset of deep machine learning that teaches an agent to complete a task or set of tasks through accumulating experiences in an interactive environment, to design mechanical metamaterials with strategic nonlinear deformation responses. A DRL environment was built to allow an agent to additively design mechanical metamaterial unit cells that exhibit deformation responses of varying nonlinearity in both tension and compression. The agent learned to design the unit cells by sequentially adding material to a discrete design domain and being rewarded according to the similarity of the unit cell's surrogate-model-predicted deformation response and a random desired deformation response. After proper training, the agent succeeded in designing several unit cells to match previously unseen tensile and compressive deformation responses. The results show that DRL can accurately design mechanical metamaterials with a more diverse range of deformation nonlinearity than TO or SSO. This work takes a step towards validating the design and generalization capabilities of using DRL as a high-level design tool to improve the capabilities of several engineering design processes.

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