Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Mechanics & Materials Laboratory
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www.mm.ethz.ch

Master Thesis (2022)

Inverse design of truss metamaterials for dispersion relations via generative deep learning

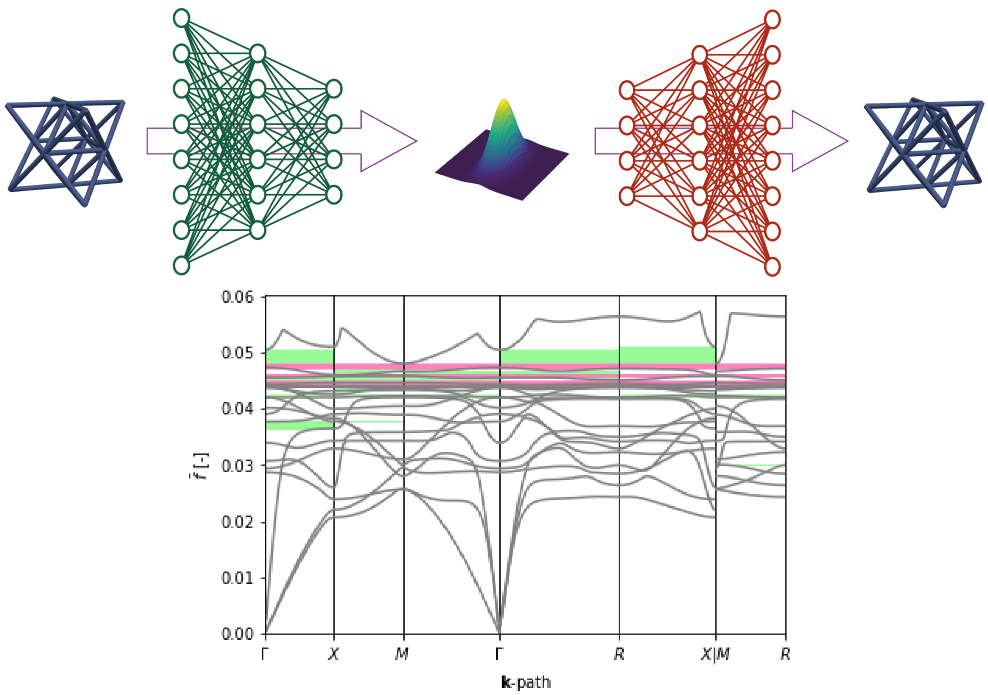

Figure 1: A diagram of the generative deep learning model used for truss metamaterials towards the data-driven design of dispersion relation.

Description:

Cellular materials have attracted massive research interest recently due to their excellent mechanical properties. Specifically, truss lattices constructed by periodic assembly of truss microstructures have shown great design freedom and significant tunability in their properties by manipulating the topology and geometry of microscale features. Recent advancements in additive manufacturing technology have largely facilitated the functional design of metamaterials across several length scales. In particular, the simplicity in numerical characterization and theorectical treatment of truss metamaterials has allowed us to explore the diverse property space in terms of a wide range of properties, including elasticity, energy absorption, and controllable nonlinear behavior, etc. Various optimization approach have been developed towards the design of truss lattices with tailored properties and functionalities. Despite all progress, key challenges persist in the inverse design: while investigating the properties of a given structure can be straightforward, identifying a candidate structure with target structures has relied on inefficient trial-and-error or classical optimization schemes that are often computationally expensive and infeasible in large-scale problems.

In light of these challenges, we aim to establish an inverse mapping between the structure topology and the dispersion relationship of truss metamaterials using generative modeling techniques in machine learning. Specifically, the dispersion relation is one of the physical basis of mechanical metamaterials and is essential for manipulating various properties, such as the bandgap. This project proposes the development of a computational design framework that realizes the generation of optimal structures for desired properties. This inverse problem is explored in a data-driven manner, e.g., to quantitatively understand appropriate architectures for a given dispersion relation. The framework will leverage (i) the in-house numerical tools to compute and analyze the dispersion relation of a diverse truss metamaterial database; (ii) machine learning techniques to explore the design space and quantitatively model the relationship between design parameters and structural properties. This efficient data-driven inverse design framework will significantly accelerate the design of metamaterials with tailored properties at minimum computation cost. The project is to some extent flexibly adjustable to your ideas and interests, e.g., proposed structures can be validated through experimental works.

Preferred skillset:

Interested students should have a background and interest in at least two of the following areas:

- computational mechanics and metamaterials
- material modeling and programming
- basic knowledge in machine learning and corresponding libraries such as PyTorch will be useful.

This project offers the willing student the opportunity to learn a great deal about computational mechanics and machine learning in the design of metamaterials.

For more information, please contact:

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