Deep learning methods for structure and metamaterial design

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Abstract

Structure design is an ancient and yet a modern topic. The advent of micro/nano fabrication techniques and additive manufacturing methods has enabled the fabrication of micro/nanostructures with complex topologies, which further fuels the development of metamaterials whose properties are controlled by the internal structures of their building blocks. The design of these structural materials is complicated by multiple requirements which often impose conflicting constraints on the design. Topological optimization based methods offer attractive approaches for such design problems, and successful applications have been demonstrated. However, a major challenge of topological optimization is its efficiency. During the design process, structure constantly evolves and forward calculations must be performed at each iteration. Another major challenge in the current topological optimization techniques is the control of the shape of the optimal layout. Shape control is necessary due to, for example, the need for including a few explicit shapes in the design, manufacturing constraints such as minimum feature size, aesthetic consideration and connection/installation requirements. The lack of efficient design methods that are able to control geometrical features of the designs greatly hinders the development of metamaterials.

In this talk, we will present our work on using deep neural networks such as GAN, VAE and CNN to either accelerate topological optimization process or to conduct inverse design directly [1,2]. In recent years, machine-learning techniques have shown remarkable success in various disciplines. We show that neural networks can also be applied to solving inverse design problems, and shape control can be easily handled in this approach. Examples involving inverse design of metamaterials and surface diffusion will be illustrated to demonstrate the performance of the proposed methods.

Keywords: **Inverse design, variational auto-encoder, generative adversarial network, convolutional neural network, metamaterial**

References

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