Topology Optimization Through Machine Learning

Md Imrul Reza Shishir[1] and Alireza Tabarraei[2*]

[1] Department of Mechanical Engineering & Engineering Science, University of North Carolina at Charlotte, Charlotte, NC 28223, United States of America, mshishir@uncc.edu

[2] Department of Mechanical Engineering & Engineering Science, University of North Carolina at Charlotte, Charlotte, NC 28223, United States of America, atabarra@uncc.edu

Key Words: *Topology optimization, machine learning, thermo-mechanical problems, Fourier projection*

Topology Optimization (TO) is a powerful computational design method for automatically generating a structural layout to determine the optimal material layout in a design domain with maximum performance under relevant design specifications. In recent years, considerable research efforts have been made in the advancement of topology optimization procedures. Various topology optimization strategies have been developed including density-based methods (i.e; Solid Isotropic Material with Penalization (SIMP), Rational Approximation of Material Properties (RAMP)), level set methods, evolutionary methods, phase field, and topological sensitivity methods [1]. The standard finite element analysis (FEA) is normally implemented to calculate the unknown structural responses in topology optimization.

Although structural topology optimization has great potential for creating innovative structural designs without a prior knowledge, it is a time-consuming task. This is because in traditional topology optimization frameworks a fine finite element mesh must be used to represent the material distribution with acceptable resolution, and this will inevitably lead to intensive computational effort for evaluating structural responses and carrying out numerical optimization [2]. Machine learning techniques have been recently used to speed up the topology optimization process through data-driven training and image processing.

In this study, we investigate the application of neural network (NN) and convolution neural network (CNN) to conduct topology optimization directly from the finite element solver. In this approach, a neural network is used to represent the density field function independent of finite element mesh. A Fourier space projection has been implemented within the machine learning model to control the minimum and maximum length scales to meet the manufacturing and other functional requirements. We have adapted the high-performance Google automatic differentiation (AD) library JAX to build an end-to-end differentiable network model. The sensitivity computations are automated by using the built-in backpropagation functionality in JAX. The performance of the proposed framework is demonstrated by solving several elastic and thermoelastic compliance minimization problems and comparing the results with the optimized structures obtained from other optimization techniques.

REFERENCES

[1] Sigmund, Ole, and Kurt Maute. "Topology optimization approaches." Structural and Multidisciplinary Optimization (2013) **48**, no. 6: 1031-1055.

[2] Lei, Xin, Chang Liu, Zongliang Du, Weisheng Zhang, and Xu Guo. Machine learning-driven real-time topology optimization under moving morphable component-based framework. *Journal of Applied Mechanics*, (2019) **86**, no. 1: 011004.