ABSTRACT

Optimal Stiffness Topology Prediction with Unstructured Triangular Mesh Using Recursive Training of Graph Neural Network

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Topology optimization is the method of finding optimal material distribution satisfying given constraint in design domain. It is widely used to obtain the configuration of material that are difficult to think in the early stage of engineering design. However, topology optimization has disadvantage of computational cost due to large number of design variables and repetitive finite element analysis. Therefore, many studies have been conducted to predict optimal topology with deep learning model taking advantage of giving output in short time once the model is trained. However, previous studies used convolutional neural network, which inevitably limited their scope to structured mesh and rectangular design domain.

This paper proposes recursive training strategy with graph neural network in order to apply deep learning to general topology optimization problems composed of various design domain and element. To predict density based topology optimization results, the centroid of elements are converted to vertices of graph. Also, the input vertex features are set to the initial value of topology optimization with its displacement and stress to prevent sparse vertex feature matrix and to clarify the position of force. We composed three different models with graph convolution layers, graphSAGE layers and graph attention layers each and trained to predict the optimal topology through End-to-End learning. Batch normalization, dropout and L2 regularization are used to alleviate overfitting and residual connection is applied to enhance the performance of models. With the model composed of graph attention layers which showed lowest validation error, coefficient of determination between compliance showed the value of 0.8855 and outlier percentage 10.57%. To improve the coefficient of determination and outlier percentage, we used recursive training strategy using the intermediate material density during topology optimization. The intermediate material densities are stored with same number of sequences by the cumulative sum values of material density change. We used identical model architecture of graph attention model in End-to-End learning for comparison. The training was conducted with recursive manner using previous predicted sequence output to input vertex feature for next sequence prediction. Recursive training method showed coefficient of determination of 0.9687 and outlier percentage 3.43%, which implies the recursive training method is better when predicting optimal topology compared to End-to-End training method.