ABSTRACT

Optimal Truss Structure Prediction Method Using Sequential Classification and Regression Graph Neural Network

Taeyoon Lim
Dept. of Automotive Engineering
(Automotive-Computer Convergence)
Graduate School of
Hanyang University

Topology optimization is an optimal design method that can reduce weight while maintaining high stiffness under given constraints without initial design. Therefore, it is widely used in that it is possible to obtain an optimal design that does not depend on an engineer's intuition. Ground structure-based topology optimization is the primary approach used in truss topology optimization. It is also an advantageous method in terms of time because optimization is possible based on linear programming. Recently, papers have been published to ensure the manufacturability of truss structures by reducing excessive connections due to shallow bars using numerical approaches such as iterative linear programming that imposes a penalty on the length of bars. However, it is inefficient in terms of computational cost due to iterative calculation.

Consequently, this paper proposes a training method based on a graph neural network that sequentially combines a classification and regression graph neural network to predict the optimal layout of a truss structure. Similar to a graph structure, a truss structure consists of a series of interconnected bars and joints. The number of vertices and edges depends on the size and configuration of the target design domains. Artificial neural networks such as

multi-layer perceptron or convolutional neural networks cannot handle such variable-dimensional data. Therefore, a graph neural network that can train using the similarity between the truss structure and the graph was adopted.

Meanwhile, only a few potential bar candidates remain after the ground structure-based topology optimization has converged, which results in a highly imbalanced distribution of data that is difficult to predict. Therefore, three methods are proposed to solve the imbalanced problem. First, a binary classification task classified the presence or absence of remaining potential bar candidates. And then, a regression task was sequentially performed to predict the detailed value of the cross-sectional area. Second, an activation function using the exponential function in the last output layer of the model was developed. Finally, the Tweedie loss function was applied to help with training in the zero-inflated problem.

The design domains were defined as a cantilever, a simply supported beam, and an L-shape beam to evaluate that the proposed architecture can train in the non-Euclidean space, which is one of the strengths of graph neural networks. Furthermore, the proposed model was verified with three performance evaluation indicators that evaluate classification, regression, and optimality. As a result, the validity of the prediction algorithm was evaluated with a performance of over 98% for the position, cross-sectional area, and compliance of the optimal truss structure. In addition, to ensure manufacturability, the optimal truss structure can be obtained immediately without iterative linear programming when removing shallow bars. Hence, it will help to obtain the optimal truss structure quickly.