Deep-Q network for truss topology optimization with stress constraints

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Abstract

Truss topology optimization problem is widely investigated based on ground structure (GS) method. In this approach, the cross-sectional areas are considered as continuous design variables and members with lower-bound cross-sectional area are removed after optimization. However, when we consider stress constraints for multiple loading conditions, the optimization problem becomes difficult to solve, because the constraints need not be satisfied for the vanishing members.

To overcome this difficulty, Ohsaki and Katoh [1] split the problem into subproblems to find lower- and upper-bound solutions; the former sets the existence of nodes and members by continuous variables within the range from 0 to 1, and the latter by discrete 0-1 variables. Another approach is growth optimization method which starts from relatively sparse GS and add nodes and members by heuristics [2]. However, previously proposed methods do not consider the underlying characteristics of the structural model in solving the optimization problem, such as connectivity and axial stresses of the members. Hence, the quality of the solution is dependent solely on how many iterations are conducted for the optimization, not on how wisely the variables are changed. This sometimes forces the algorithms to explore the space where the optimal solution does not exist.

For more efficient searching in the space of solution, we present a new combination method of simulated annealing (SA) [3] and Deep-Q network (DQN) [4] to obtain optimal topology of trusses. The proposed process starts from learning an agent within the framework of DQN, so that it can output proper action on which member to be eliminated. Then, we conduct optimization with SA where the change of the members' cross-sectional area is determined by the agent. Our proposed method leads to comparable optimal solutions to those obtained by previous studies. Furthermore, once the agent is learned, it can be applicable to any loading conditions as long as the ground structure is the same.

In the paper, formulation process of the optimization problem is first described, then the learning with DQN and the optimization with SA are explained. Several examples of planar grid trusses are shown to evaluate the efficiency, accuracy, and extensibility of the proposed method.

References

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