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Exploring the Pareto frontier in level set-based topology optimization

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Abstract

Structural optimization has been successfully used in many industries, such as automotive industries. In particular, topology optimization, first proposed by Bendsøe and Kikuchi [1], has the most potential for exploring ideal and optimized structures among the three primary structural optimization types: sizing, shape, and topology optimization. Topology optimization is currently applied to a variety of complex problems, including multiobjective optimization problems. To facilitate the handling of multiobjective topology optimization problems, a scalarization technique is often used, in which a multiobjective optimization problem is converted to a single objective optimization problem, but adjustment of the scalarization parameters depends on a cumbersome iterative process. On the other hand, obtaining a comprehensive Pareto optimal solution set, also termed a non-dominated solution set, is especially advantageous because design engineers can easily choose a particular solution that best meets their needs. Furthermore, Pareto optimal solution information can aid the analysis of trade-off conditions among the objective functions [2]. Here, we propose a new multiobjective topology optimization method based on a level set method that facilitates obtaining a comprehensive set of Pareto optimal solutions. The proposed method adopts a population-based approach in which many search points are updated considering their relative positions and the distribution of the non-dominated solutions. Specifically, each search point's level set function, whose iso-surface implicitly represents the structural boundaries of the design solution at that point, is updated by solving a reaction-diffusion equation that incorporates a weighted sum of the topological derivative of each objective functional. The weighting coefficients are adaptively given during the optimization process by considering the distribution of the search points and the non-dominated solutions. Furthermore, a point selection scheme and a point replacement scheme are introduced. The former selects promising points that should be updated and the latter replaces poor points with non-dominated solutions. Both schemes are based on the use of non-domination ranking and crowded comparisons. Finally, to illustrate its effectiveness, the proposed method is applied to example problems, including a robust optimization problem for compliant mechanisms.

References

[1] M.P. Bendsøe and N. Kikuchi, Generating optimal topologies in structural design using a homogenization method, Computer Methods in Applied Mechanics and Engineering, 71 (2), 197-224, 1988.

[2] A. Oyama, T. Nonomura and K. Fujii, Data Mining of Pareto-Optimal Transonic Airfoil Shapes Using Proper Orthogonal Decomposition, Journal of Aircraft, 47 (5), 1756-1762, 2010.