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# Multiobjective Robust Optimization of Plane Frame using Order Statistics

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**Abstract** Optimization of truss-like structure under uncertainty has been widely receiving attention from researchers in the last 30 years, and two main models are generally used to describe the uncertain characteristic, i.e., the probabilistic and non-probabilistic models [1, 2]. When the probabilistic model is used in the optimization procedure, the uncertain parameter is considered as random variable with known or partially known distribution, and the objective is usually to minimize the structural response under failure probability constraints or the weighted sum of statistical moments of structural response, which are referred to as reliability-based structural optimization (RBSO) and robust structural optimization (RSO),respectively. In RBSO many attempts are made to decouple the double-loop algorithms, but the computation cost is still very large when multiple failure modes are involved in the failure probability constraint. As for RSO, the calculation of statistical moments and its corresponding derivatives would become cumbersome if more than one type of random variables are involved. In addition, both RSO and RBSO may lead to inaccurate estimation if the distributions of random variables are not appropriately defined.

On the other hand, the non-probabilistic model provides an alternative to consider uncertainty in structural optimization, where the optimization problem is often formulated as minimizing the structural response within the predefined set of uncertain parameters. This problem is also called RSO problem. However, the search for the exact worst value of structural response will lead to prohibitive cost even for simple interval variables. Moreover, it will be useful for the designer if the structure which minimize the response at different levels of robustness can be found, and the problem becomes a multiobjective optimization problem. Recently the second and the third authors proposed an order statistics approach for multiobjective structural optimization under uncertainty [3], in which the exact worst value of structural response is relaxed to the quantile response and the robustness level of the approximated worst response value is defined by the order statistics. It has been shown that solutions with different robustness levels at the same confidence can be simultaneously obtained, and the values of optimal design variables depend on the level of robustness.

This study extends the method in Ref. [3] to present a multiobjective shape and topology optimization for plane frame structure under uncertain parameters. The frame structure is discretized by the Euler-Bernoulli beam elements and each element is assumed to have solid circular cross section; hence, the cross-sectional properties can be determined by cross-sectional area only. The uncertainty is considered in structural stiffness and described as interval variables, in which the variation range is given from the corresponding nominal value. Moreover, the optimization problem without involving uncertainty is also included in order to enhance the convergence of the optimization procedure, and several *k*-th worst values in order statistics are selected for determining various robustness level in the multiobjective optimization problem. Pareto solutions are found for several plane frames, and the optimization problem is solved by a multiobjective genetic algorithm in MATLAB 2018a with appropriately selected crossover rate. After obtaining the optimal shapes and topologies with different robustness level, the final topology of the structure is modified by removing the elements whose cross-sectional areas are small. The solutions with different robustness level are compared and investigated to verify the effectiveness of the proposed method.

## References

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