Sampling-based Approach for Design Optimization in the Presence of Interval Variables

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ABSTRACT

This paper proposes a methodology for sampling-based design optimization in the presence of interval variables. It is assumed in this study that accurate surrogate models are available. Then, during the design optimization with interval variables only, calculation of constraints with the worst combination of interval variables, namely the worst case constraints, and their sensitivities with respect to interval variables at design point are required. Similarly, during the design optimization with both random and interval variables, calculation of probabilistic constraints with the worst combination of interval variables, namely the worst case probabilistic constraints, and their sensitivities with respect to both random and interval variables at a design point are required. The behavior of the worst combination of interval variables called the worst case interval variables is first defined by the Dirac delta function. Then, using the Dirac delta function, sensitivities of both the worst case constraint and probabilistic constraint with respect to the worst case interval variables are derived at a design point. Finally, the worst case constraints and probabilistic constraints are obtained through the worst case performance search and the worst case probability of failure search, respectively, both utilizing calculation of sensitivity. Monte Carlo simulation (MCS) is used as one of the sampling-based methods in this study.

The important merit of the proposed method is that it does not require gradients of performance functions and transformation from X-space to U-space for reliability analysis after the worst case interval variables is obtained, thus there is no approximation or restriction in calculating the sensitivities of the worst case constraints and probabilistic constraints. Also, the probability of failure is directly used to obtain the worst case probabilistic constraints, which is more reasonable than existing methods due to the fact that the worst case interval variables for probability of failure does not always coincide with that for performance function. Furthermore, sensitivity of constraint with respect deterministic variables can be also calculated using the proposed method when gradients of performance functions are not available. Numerical results indicate that the proposed method can search the worst case probability of failure in both low- and high-dimensional problems and that it can perform design optimization with mixture of random and interval variables utilizing the worst case probability of failure search.

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