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A Sequential Optimization and Mixed Uncertainty Analysis Method Based on Taylor Series Approximation

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Abstract

In this paper reliability-based optimization (RBO) under both aleatory and epistemic uncertainties is studied based on combined probability and evidence theory. Traditionally the mixed uncertainty analysis is directly nested in optimization which is computationally prohibitive. In [1] a sequential optimization and mixed uncertainty analysis (SOMUA) method is proposed to decompose the RBO problem into separate deterministic optimization and mixed uncertainty analysis sub-problems, which are solved sequentially and alternately till convergence. SOMUA transforms the RBO problem into its quasi-equivalent deterministic formulation based on the inverse Most Probable Point (iMPP) of objective and constraint functions in each focal element. As the iMPP identification calculation is complex, the computational cost grows rapidly with the increase of focal elements.

To improve the efficiency of SOMUA, in this paper it is proposed to use Taylor approximation to transform deterministic optimization. In each cycle, uncertainty analysis is conducted at the deterministic optimum to obtain its MPP in each focal element. Then the epistemic uncertainties are assigned the values of MPP under the assumption that the worst case will happen with these values. Since the epistemic uncertainties are fixed, only random uncertainties are left. Thus the uncertain distributions of the objective and constraint functions are also random, which can be approximated by Taylor series approximation methods. According to application, the first or second order Taylor series can be flexibly used for accuracy.

The efficacy of the proposed method is demonstrated with two test problems. It shows that the computational cost can be greatly reduced. However, the optimum may be very close to but not as good as that of SOMUA for highly nonlinear problems, which needs further research.

References

[1] W. Yao, X.Q. Chen, Y.Y. Huang, G. Zafer, M. van Tooren, A sequential optimization and mixed uncertainty analysis method for reliability-based optimization, AIAA Journal, 51(9), 2266-2277, 2013.