Evidence-theory-based epistemic uncertainty modeling and reliability analysis

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Abstract:

Uncertainties associated with manufacturing imperfection, usage variation and imprecise knowledge widely exist in practical engineering problems. Uncertainty can be categorized as aleatory and epistemic types, in which the former derives from inherent variability of a physical system and the latter arises from lack of knowledge. Compared to aleatory type, treatments of epistemic uncertainty is much more difficult in aspects of uncertainty quantification, propagation and design.

Among the existing approaches, evidence theory employs a much more flexible framework to quantify epistemic uncertainty, and can be viewed as a generalization of probabilistic and non-probabilistic methods. Recently, it has been introduced to deal with structural uncertainty propagation and reliability-based design optimization. However, computational efficiency is still a challenging problem to limit its practical applicability due to the coupling of the discrete nature of uncertainty modeling and complex structures especially with computational intensive simulation model. To cooperate these disadvantages, we developed several related practical approaches for uncertainty propagation and reliability: (1) A comparative study of metamodeling techniques is performed for reliability analysis using evidence theory; (2) A structural static and dynamic response analysis method is presented by integrated evidence theory with finite element method; (3) An efficient evidence-based reliability analysis method is proposed by introducing a non-probabilistic reliability index; (4) A evidence-theory model considering parameter dependency is proposed and applied to structural reliability analysis. Additionally, the corresponding methods are applied to several vehicle design problems.

Keywords: reliability analysis, epistemic uncertainty, evidence theory, vehicle engineering