Unified uncertainty analysis under probability, evidence, fuzzy and interval uncertainties

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Abstract

The uncertainty analysis of structures generally involves uncertain parameters of different types. In order to derive predictions regarding uncertain structural responses, it is crucial to represent the uncertainty appropriately according to the underlying information available. This paper presents a unified framework for uncertainty analysis under probability, evidence, fuzzy and interval variables, by which the quantities with sufficient data, sparse data, and subjective information can be simultaneously considered. A Taylor expansion-based unified uncertainty analysis (T-UUA) method is first proposed for small uncertainty problems. By temporarily neglecting the evidence, fuzzy and interval variables, the probability-evidence-interval-fuzzy model is degraded into a random problem, in which the expectations and variances of responses can be obtained as functions in terms of evidence, interval and fuzzy uncertainties. Then, through dealing with the evidence variables, the previous expectations and variances are further expressed as a summation of functions in terms of fuzzy and interval variables with basic probability assignments (BPAs). The fuzziness is then discretized by using α-cut technique and thus the expectations and variances are further expressed as functions of only intervals. Afterwards, by reconsidering the interval uncertainties, the bounds of the expectations and variances are computed via combining Taylor expansion with interval arithmetic. In addition, a dimensional reduction (DR)/efficient global optimization (EGO)-based unified uncertainty analysis (DR/EGO-UUA) method is also presented to solve the large uncertainty problems. The framework of DR/EGO-UUA is similar as T-UUA. However, in DR/EGO-UUA, the second moments of responses are computed by DR integrations, and their upper and lower bounds are calculated by the EGO. Finally, three numerical examples are investigated to demonstrate the effectiveness of the proposed methods.

Key words: Unified uncertainty analysis; Evidence theory; Fuzzy; Interval; Dimensional reduction; Efficient global optimization