Interval quasi-Monte Carlo method for reliability assessment with imprecise probability

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Abstract

Reliability analysis of structures is often performed on the basis of limited data. Under this circumstance, there are practical difficulties in identifying unique distributions as input for a probabilistic analysis. But the selection of realistic probabilistic input is critical for the quality of the results of the reliability analysis. This problem can be addressed by using an entire set of plausible distribution functions rather than one single distribution for random variables based on limited data. The uncertain nature of the available information is then reflected in the probabilistic input. An imprecise probability distribution can be modeled by a probability box (p-box), i.e., the bounds of the cumulative distribution function for the random variable. Reliability analysis with probability boxes can be conducted using sampling-based methods. However, direct sampling of p-boxes requires a large number of samples to control the sampling uncertainty. The total computational cost can be very high as each simulation may involve an expensive range-finding problem.

This study proposes an interval quasi-Monte Carlo simulation method to compute the bounds of failure probabilities. We focus on the reduction of sampling uncertainty in the propagation of p-boxes with quasi-Monte Carlo methods. This reduction of sampling uncertainty helps to reduce the simulation effort for desired tolerance of the result variance. The method is based on deterministic low-discrepancy sequences, which are distributed more uniformly than the (pseudo) random points in direct Monte Carlo simulation. The efficiency and accuracy of the present method is illustrated using two examples. The reliability implications of different approaches for construction of probability boxes are also investigated through the example.