Application of Line Sampling for Reliability Sensitivity Estimation

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ABSTRACT

Probability theory offers the possibility to account for the unavoidable effects of variability present in engineering systems on their observed or predicted performances. Specifically, uncertainty associated with loading, structural properties, and boundary conditions can be accounted for using random variables, random fields, or stochastic processes. Usually, random fields and stochastic processes are discretized by means of a finite set of (correlated) random variables. Then, with the aid of appropriate stochastic techniques, the variability associated with the input variables, represented by a countable set of discrete random variables, can be propagated to the system responses in order to characterize its performance. Thus, the variability in the system responses can be quantified, depending on the propagation method, in terms of different indicators such as second order statistics (mean and standard deviation), probability distributions and confidence intervals, or/and probability of exceedance (also known as failure probability) when risk assessment is of interest.

The estimation of the failure probability has been the subject of active research, see e.g. [3], due to its significance to the risk and safety of structures. Furthermore, quantifying the sensitivity of these failure probabilities with respect to the input variables and associated statistics has also been of interest [4]. In fact, sensitivity analysis is significant to the assessment of structural reliability. It aims at identifying and differentiating the influence of input random variables and their associated statistics on the system performance. From a computational perspective, this is usually carried out in terms of the partial derivatives of the failure probability with respect to the parameters characterizing the probability distribution of the random variables, i.e. mean values and standard deviations. Sensitivity analysis is also important to risk and safety designs. For example, sensitivities of the failure probability with respect to the statistics (e.g. a change in the expected value) of the size of a structural member can provide useful information to increase the safety level in the structural performance.

This paper presents an approach that contributes to the reliability sensitivity estimation. In particular, it proposes a strategy for estimating the reliability sensitivity by applying Line Sampling (LS). Recall that LS is an efficient simulation method that allows estimating small failure probabilities for linear and weakly nonlinear problems [1]. The proposed approach for estimating reliability sensitivity requires the same information used for probability estimation as well as a few additional system analyses. It should be noted that the application of LS for probability sensitivity estimation has already been addressed elsewhere. However, the novelty of this contribution lies on expanding the range of applicability of the strategy suggested in [2] to more general and realistic cases.

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