Non-parametric stochastic subset optimization for reliability-based design optimization

G. Jia[1], and A. A. Taflanidis[2]

[1]Department of Civil & Environmental Engineering & Earth Sciences, University of Notre Dame, Notre Dame, IN 46556, gjia1@nd.edu

[2]Department of Civil & Environmental Engineering & Earth Sciences, University of Notre Dame, Notre Dame, IN 46556, a.taflanidis@nd.edu

Keywords: *Reliability-based design optimization; Non-parametric stochastic subset optimization; Kernel density estimation.*

Abstract

The Non-Parametric Stochastic Subset Optimization (NP-SSO) is a recently developed algorithm appropriate for design optimization problems that use the system reliability as objective function and involve computationally expensive numerical models. This paper discusses its extension to solve reliability-based design optimization (RBDO) problems involving the system reliability as a design constraint.

The basic concept of NP-SSO is the formulation of an augmented design problem where the design variables are artificially considered as uncertain with uniform distributions. Then the system reliability is proportional to an auxiliary probability density function of the design variables. NP-SSO is based on simulation of samples from this density and approximate the system reliability through kernel density estimation (KDE) using these samples. The RBDO problem is then solved using this approximation for evaluating the reliability constraints. Thus, through a single analysis, NP-SSO provides information for the system reliability over the entire design domain, contributing to great efficiency.

To improve the computational efficiency, an iterative approach is proposed; at the end of each iteration, a new reduced search domain is identified, until the algorithm converges to the feasible design domain satisfying the reliability constraints. A non-parametric characterization of the search domain at each iteration and eventually the feasible domain using a framework based on KDE with multivariate boundary kernels (KDE-MBK) and support vector machine (SVM) is established. To further improve the efficiency of the stochastic sampling stage, which is the most computationally demanding component of NP-SSO, an adaptive kernel sampling density (AKSD) approach is proposed, making use of information in samples across iterations to formulate optimal proposal densities. The approach is illustrated in an example considering optimization of a floor isolation system for protection of critical structural contents.