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Utilization of Gaussian Kernel Reliability Analyses in the Gradient-based Transformed Space for Design Optimization with Arbitrarily Distributed Design Uncertainties

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Abstract

Several Reliability-Based Design Optimization (RBDO) algorithms have been developed to solve engineering optimization problems under design uncertainties. Some existing methods transform the random design space to standard normal design space to estimate the reliability assessment for the evaluation of the failure probability. When the random variable is arbitrarily distributed and cannot be properly fitted to any known form of probability density function, the existing RBDO methods, however, cannot perform reliability analysis either in the original design space or in the standard normal space. This paper proposes a novel method, Ensemble of Gradient-based Transformed Reliability Analyses (EGTRA), to evaluate the failure probability of arbitrarily distributed random variables in the original design space. The arbitrary distribution of the random variable is approximated by a merger of multiple Gaussian kernel functions. Each Gaussian kernel function is transformed to a single-variate coordinate that is directed toward the gradient of the constraint function. The failure probability is then estimated by the ensemble of each kernel reliability analysis. This paper further derives a linearly approximated probabilistic constraint at the design point with allowable reliability level in the original design space using the aforementioned fundamentals and techniques. Numerical examples with generated random distributions show EGTRA is capable of solving the RBDO problems with arbitrarily distributed uncertainties in the original design space.

Keywords: gradient-based transformation; gaussian kernel density estimation; reliability-based design optimization; arbitrarily distributed design uncertainty.