MULTIFIDELITY RISK ASSESSMENTS FOR NONLINEAR SYSTEMS UNDER HIGH-DIMENSIONAL DEPENDENT RANDOM VARIABLES

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ABSTRACT

We present novel computational methods for Conditional Value-at-Risk (CVaR) estimation for nonlinear systems under high-dimensional dependent random inputs [1]. The methods are built on a novel surrogate model: a fusion of dimensionally decomposed generalized polynomial chaos expansion [2] and Kriging (called DD-GPCE-Kriging) is proposed as an accurate approximation for highly nonlinear and nonsmooth random output functions. We integrate DD-GPCE-Kriging with two sampling-based CVaR estimation methods: standard Monte Carlo simulation (MCS) and multifidelity importance sampling (MFIS). The proposed MCS-based method samples from the computationally efficient DD-GPCE-Kriging surrogate and is shown to be accurate in the presence of high-dimensional and dependent random inputs. Inevitably, sampling from a surrogate model introduces a bias. For cases of high bias, we propose the MFIS-based method, where the DD-GPCE-Kriging surrogate determines a biasing density efficiently. The high-fidelity model is then used to obtain an importance-sampling-based CVaR estimate. To further speed up the construction of the biasing density, we compute DD-GPCE-Kriging by computational cheap low-fidelity model evaluations. Numerical results for mathematical functions confirm that the DD-GPCE-Kriging-based methods provide accurate and computationally efficient CVaR estimates. The scalability of the proposed methods and their applicability to complex engineering problems are demonstrated by solving a three-dimensional composite T-joint problem with 20 (partly dependent) random inputs. In the composite problem, the proposed MFIS-based method achieves a speedup factor of 24x compared to standard MCS using the high-fidelity model, while producing an accurate CVaR estimate with a 0.98% error.

REFERENCES

[1] D. Lee and B. Kramer, Multifidelity conditional value-at-risk estimation by dimensionally decomposed generalized polynomial chaos-Kriging, *arXiv:2212.02728,* 2022.

[2] D. Lee and B. Kramer, Bi-fidelity conditional value-at-risk estimation by dimensionally decomposed generalized polynomial chaos expansion, Structural and Multidisciplinary Optimization, **66**(2), 33, 2023.