Efficient Sparse Polynomial Chaos Expansion Methodology for Computationally-expensive deterministic models

Tamara Al-Bittar [1], and Abdul-Hamid Soubra[1]

[1] University of Nantes, Bd. de l'université, BP 152, 44603 Saint-Nazaire cedex, France; E-mails: Tamara.Al-Bittar@univ-nantes.fr; Abed.Soubra@univ-nantes.fr

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Abstract

An efficient approach to deal with uncertainties propagation in case of high-dimensional problems (i.e. with a great number of random variables or eigenmodes) was recently presented by Blatman and Sudret. This methodology makes use of a sparse polynomial chaos expansion (SPCE) for the system response which significantly reduces the computational cost with respect to the classical full polynomial chaos expansion (PCE). Notice however that when dealing with computationally-expensive deterministic models, the time cost remains important even with the use of the SPCE. In this paper, a combined use of the SPCE methodology and the global sensitivity analysis is proposed to solve such a problem. In this method, a small PCE order was firstly used to detect the most influential eigenmodes using a global sensitivity analysis based on Sobol indices. The reason why a small PCE order was used is based on of the fact that higher PCE orders leads to the same influential eigenmodes. Once the most influential eigenmodes were detected, a higher PCE order that makes use of only the most influential eigenmodes was used. This significantly reduces the computation time. The use of a high PCE order is necessary to lead to an improved fit of the PCE since the leave-one-out error estimate Q^2 increases with the PCE order. Notice that the deterministic computations performed during the global sensitivity analysis (where all the eigenmodes were considered in the analysis) are used herein in the computation of the SPCE. In case where this number of deterministic computations is not sufficient, other additional deterministic computations (with the same number of eigenmodes used before) can be performed. This methodology was applied to the computation of the PDF of the ultimate bearing capacity of a strip footing resting on a spatially varying (c, φ) soil where c and φ are modeled as two anisotropic non-Gaussians cross-correlated random fields for which the number of eigenmodes can dramatically increase when the autocorrelation distances significantly decrease.

References

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