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Vine copula modeling of high-dimensional inputs 
in uncertainty quantification problems

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The quantification of uncertainty (UQ) in the response of a system subject to a stochastic input requires to build a map of the input-output relationship, and to study how the components/parameters of the input influence the output.

Advanced UQ methods based on spectral decomposition, such as polynomial chaos expansions (PCE, [1]), accomplish this task under the assumption that the components of the input are statistically independent, or that they can be mapped onto independent variables by means of isoprobabilistic transformations like Rosenblatt or Nataf [2]. Such transformations, however, are in general difficult to compute, both analytically and numerically, especially in large dimensions.

In this contribution we propose an effective approach to model the input’s dependence structure (copula) via vine copulas. Vine copulas consist of a factorization of a joint copula into pair copulas of its components [3, 4]. The advantage of this approach is two-fold: it grants great flexibility in modeling the pairwise dependencies of the data, while at the same time providing a natural framework to transform the input model into the independent unit hypercube via the Rosenblatt transform. The latter can be used to build a map of the input onto the output by, e.g., PCE.

We further investigate how to embed this approach into surrogate-based frameworks for UQ. Specifically, once the vine model of the input data is defined, it can be used to create space-filling samples of the its joint distribution (e.g. with latin hypercube sampling or pseudorandom series), via the inverse Rosenblatt transform. The resulting sample enables one to perform a large class of UQ analyses (e.g. reliability analysis or propagation by polynomial chaos expansions) at limited computational cost.

References


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