Surrogate models for uncertainty quantification and reliability analysis

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Taking into account uncertainties in the design of complex industrial systems and civil infrastructures has received much attention in the last decade. Indeed, although the physical modelling of such systems has made tremendous progress, there are always discrepancies between ideal *in silico* designed systems and real-world manufactured ones.

Starting from a realistic computational model (a.k.a simulator) which reproduces the behaviour of the considered system and allows the engineer to predict its performance, uncertainty quantification aims at modeling the various sources of uncertainty (including natural variability and lack of knowledge) affecting the parameters of the model, propagate these uncertainties and get relevant statistics on the output quantities of interest (e.g. performance indicators). Due to the high-fidelity and related computational cost of simulators, the use of Monte Carlo methods for uncertainty propagation and reliability analysis is not a viable solution.

In the last decade, surrogate models of various kinds have been developed to bypass this issue. Roughly speaking, a surrogate model is built from a limited number of runs of the simulator at selected values of the input parameters (the so-called experimental design) and some learning algorithm. In this keynote lecture, an overview of the most efficient surrogate modelling techniques will be given: polynomial chaos expansions (including sparse approaches suitable to high-dimensional problems), Kriging (a.k.a Gaussian process modelling) and their combination into PC-Kriging. Low-rank tensor approximations will also be introduced. The advantages of the various approaches for sensitivity analysis and reliability (estimation of small failure probabilities) will be discussed. Numerous examples from structural mechanics, hydrogeology, computational electromagnetism, etc. addressed using the UQLab software will be presented to show the efficiency and versatility of these methods.