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Recursive Polynomial Chaos Co-Kriging for Reliability-based Design Optimisation

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ABSTRACT

This work proposes to combine multi-fidelity Co-Kriging with Polynomial Chaos regression for reliability-based design optimisation. In many engineering fields, complex design optimisation problems are tackled by multi-fidelity optimisation. Simple models are built to understand the landscape of the design space. This approximate landscape is then refined by running high-fidelity simulations in the most promising regions. Various approaches exist to propagate the information from the low-fidelity simulations to the high-fidelity models. Recently, Co-Kriging has obtained increased attention to fuse together the information from many computationally-cheap simulations and a limited number of high-accuracy simulations [Forrester et al.]. In essence, Co-Kriging builds a Kriging (or Gaussian process regression) model based on the low-fidelity observations. This low-fidelity surrogate model is used to construct an accurate high-fidelity surrogate by considering the covariances of both low- and high-fidelity observations. This multi-fidelity model can provide a sufficiently accurate surrogate model at a relatively-low computational cost. Two recent advancements of Co-Kriging have made the surrogate technique appealing for solving computationally expensive problems under uncertainty. On the one hand, Co-Kriging was extended to fuse the information of arbitrary number of hierarchical fidelity levels and rewritten into a recursive formulation [Le Gratiet, L. and Garnier, J.]. On the other hand, Polynomial Chaos was integrated into the Kriging technique to provide and efficient quantile estimation of a problem under uncertainty [Schöbi et al.]. These two advancement are combined in this work to solve complex reliability-based design optimisation problems under uncertainty. The recursive formulation facilitates the information fusion of an arbitrary number of fidelity levels. The integration of Polynomial Chaos combines the advantages of Polynomial Chaos and Kriging. The

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global trend is efficiently approximated by Polynomial Chaos while Kriging captures the local variations of the landscape. Moreover, Polynomial Chaos enables the fast estimation of quantile values which are used as reliability measures of the optimisation problem under uncertainty [Schöbi, R. and Sudret, B.]. Therefore, the recursive Polynomial Chaos Co-Kriging (RePCoK) provides an efficient manner to build an accurate surrogate model by utilising the information from observations of various fidelity. The technique reduces the number of required high-fidelity computations; however, the computational effort required for the training of the surrogate model is increased. Thus, RePCoK is proposed for problems where the computational cost of the high-fidelity observations are many orders of magnitude higher than the computational cost of the surrogate model training. The performance and characteristics of the proposed technique are presented through the optimisation of common test functions as well as a reliability-based design optimisation of a simplified aerospace problem.

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