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Multi-Fidelity Sparse Polynomial Chaos and Kriging Surrogate Models for Uncertainty Quantification

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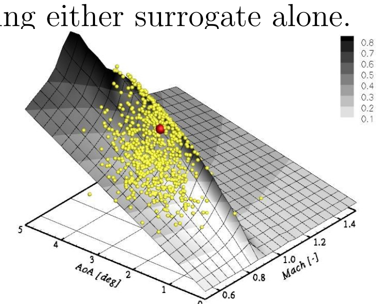
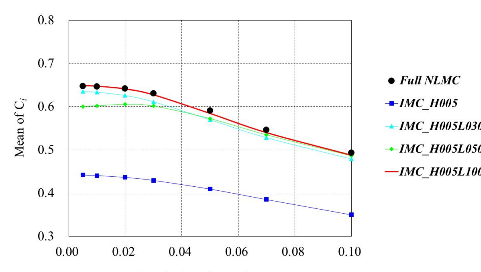
We will demonstrate the use of a multi-fidelity (MF) SPC-Kriging meta-modeling method for Uncertainty Quantification (UQ) on some benchmark cases. Sparse Polynomial Chaos (SPC) is well known for capturing the trends of the objective function, whereas kriging handles the observation values at training points well. The MF SPC-Kriging method aims at integrating the advantages of both meta-modeling methods expecting fewer training points required for constructing a reliable and fast model in lieu of the computationally expensive high-fidelity (HF) simulation [1]. UQ typically consists of three major phases: (i) characterization of the uncertainty in the input parameters; (ii) uncertainty propagation through the mathematical model; and (iii) calculation of the statistical properties of the output quantities of interest. Arguably, the computationally most expensive part of UQ is the second phase. The simplest approach is the full non-linear Monte-Carlo (NLMC) method, in which a large number of independent simulations need to be computed resulting in prohibitively large computational cost for many practical cases. Thus, to save time the use an of inexpensive MC (IMC) method where a cheaper surrogate model is interrogated instead is a very attractive option.

The left figure below shows C_l of an airfoil and $1,000$ normally distributed MC samples at (Mach,AoA)=(0.8,2.5) using $\sigma = 0.1$ in shape inputs. To the right one can see the estimate of the mean of C_l using a NLMC simulation and an IMC where a MF kriging surrogate (only constant regression) with 5 HF training points and various LF points (involving a much coarser mesh) are used to build the model [2]. We will use our previously developed MF SPC as the regression model for our MF kriging and demonstrate superior performance for UQ than using either surrogate alone.





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