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Multi-Fidelity Simulations for Multidisciplinary Design Optimization

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Design optimization is a strategic factor in industrial design: it is an essential component to produce more efficient, better performing and more sustainable products.

At this end, it is normally necessary to evaluate a large number of candidate solutions, at the variation of the design parameters, until the optimal criteria are satisfied. If the availability of process automation platforms and of increasing computational resources help today to achieve objectives that were not feasible few years ago, it is still particularly important to elaborate efficient optimization methodologies, in order to obtain the optimal results with the lowest number of design evaluations, to save costs and time.

In that sense, the adoption of meta-models, i.e. mathematical or statistical models able to approximate the response of the system in function of the design parameters on the basis of a dataset of design simulations, help the designers to reach their objectives, since the overall cost is generally lower than the one necessary to evaluate each single design proposed by the optimization algorithm by a numerical simulation. By the way, the impact of the number of design simulations for the meta-model training can still be relevant in many cases, in particular if the simulation model is a high-fidelity (HF) one. How it is therefore possible to train efficient meta-models, with a lower computational cost? And in particular, how can low-fidelity (LF) models can be used in the training process, in conjunction with the HF ones, to reduce the overall computational time?

In this paper, we present three different multi-fidelity methodologies to answer to these questions, all of them perfectly compatible with a process automation platform and therefore directly applicable to industrial practice. The first two methods, based respectively on Co-Kriging and on Dataset Reducer DOE, aims to build a scalar field meta-model, using two or more series of samples of different fidelity, respectively in a single step (data are “blended” together) or in two consecutive steps (LF samples are used to determine where to define the HF samples). The last method, based on the application of ROM (reduced-order-models) to a multi-fidelity set of samples, is instead used to build a vector field meta-model, i.e. to replace the original CFD simulation mode, with another equivalent model, by the computation of the principal components of the original field.