

Improving Multi-fidelity Surrogate Modelling by Updating the Uncertainty Estimation

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ABSTRACT

Achieving the optimum solution in a simulation-driven design optimization framework can be computationally intensive due to the requirement for realistic simulations. To address this challenge, surrogate models are widely applied in engineering optimization. These models have great potential to speed up the process by modelling the response of the problem based on a limited number of adaptively assigned candidates. Moreover, multi-fidelity approaches further accelerate optimization by combining the exploration capability of many low-fidelity simulations with the exploitation ability of several high(er)-fidelity ones. The adaptive sampling methodology dominates the efficiency of a multi-fidelity framework, as it determines the selection of the next candidate for evaluation. At this stage, using a reliable uncertainty estimation is essential, as it plays a major role in accurately capturing the response of the problem, which guides the model in focusing on the most promising regions for exploration, thereby contributing to the efficiency of the surrogate. Existing surrogate models, such as Gaussian process regression and Stochastic Radial Basis Functions, provide uncertainty estimations. However, they exhibit weaknesses in challenging conditions, such as when there is a lack of data or the presence of noise, which highlights the need for an update in the uncertainty estimation approach. Therefore, a novel strategy is proposed, which models the uncertainty as the sum of contributions from two sources: interpolation and multi-fidelity corrections. The approach is presented for single-fidelity and then extended to multi-fidelity surrogate modelling, which performs more reliable uncertainty estimation even in the most challenging cases. In this study, the new approach will be tested on a multi-fidelity analytical benchmark.

Keywords: multi-fidelity, uncertainty modelling, error estimation, noise filtering, small-data