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Multifidelity Monte Carlo estimation with multiple surrogate models

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We present an optimal model management strategy that exploits multifidelity surrogate models to accelerate the estimation of statistics of outputs of computationally expensive high-fidelity models. Existing acceleration methods typically exploit a multilevel hierarchy of surrogate models that follow a known rate of error decay and computational costs; however, a general collection of surrogate models, which may include projection-based reduced models, data-fit models, support vector machines, and simplified-physics models, does not necessarily give rise to such a hierarchy. Our multifidelity approach provides a framework to combine an arbitrary number of surrogate models of any type. Instead of relying on error and cost rates, an optimization problem balances the number of model evaluations across the high-fidelity and surrogate models with respect to error and costs. We show that a unique analytic solution of the model management optimization problem exists under mild conditions on the models. Our multifidelity method makes occasional recourse to the high-fidelity model; in doing so it provides an unbiased estimator of the statistics of the high-fidelity model, even in the absence of error bounds and error estimators for the surrogate models. Numerical experiments with linear and nonlinear examples show that speedups by orders of magnitude are obtained compared to Monte Carlo estimation that invokes a single model only.