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Robust optimization of unconstrained problems using efficient response surface building strategy

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Abstract

Robust optimization involving expensive computer simulations usually leads to prohibitively high computational costs. A viable alternative is to employ surrogate modeling, where optimization is performed on a cheaper response surface fitted using intelligently placed sample points. However, the best placement depends on the characteristics of the underlying function, which makes the sampling strategy itself a challenging problem. Amongst the different techniques for response surface building, the statistical framework-based technique of Kriging holds distinctive appeal due to the availability of an estimated error in the interpolation between the sample points. This provides the groundwork for the development of *expected improvement* and *efficient global optimization (EGO)* procedures, which allow the adaptive placement of sample points at locations most likely to lead to the global optimum. In deterministic optimization EGO has been successfully applied, but an efficient equivalent approach for robust optimization is still lacking.

The main focus of this work is on the application of unconstrained robust optimization using efficient global optimization to problems affected by implementation errors, i.e. uncertainties that directly affect the design variables of the problem. This choice is motivated by practical problems encountered in the design of integrated photonic devices, and also applies to similar problems involving micro fabrication. It is assumed that no probability distribution information is available concerning the uncertainty set and only uncertainty bounds are known. Under this scenario, a robust global optimum can be found by minimizing the maximum realizable value of the objective with respect to the uncertainty set. Additionally, design problems may be affected by parametric uncertainties, a term referring to the perturbation in problem data. In this work, we aim to include parametric uncertainties as well to realize a computationally cheap robust optimization approach based on surrogate models which can handle all types of uncertainties.

In our proposed method, robust optimization is applied based on a two-stage process. At the first stage, a response surface of the nominal function is fitted to an initial coarse sampling of the design space. Based on this response surface, in each iteration the *worst-case cost* metamodel is built by finding the maximum realizable value of the objective with respect to the uncertainty set. The combined error of the nominal and the worst-case metamodels is used to come up with a sound criterion for the expected improvement for robust optimization. Robust efficient global optimization is applied using this modified expected improvement measure, which provides new optimal sampling point locations. Iteratively, this process leads to the robust optimum of the design problem while keeping the number of expensive simulations at a minimum. The efficiency and effectiveness of our proposed approach is investigated using various robust optimization test problems. Initial sampling is performed via Latin hypercube sampling, a typical space-filling strategy. We verify the capability of the proposed algorithm to locate the global robust optimum by varying the initial LHS sampling randomly. Hundred runs of the considered test problems show steady and reliable convergence, indicating the effectiveness of the approach.