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INTEGRATING DESIGN ALGORITHMS FOR EFFICIENT OPTIMIZATION

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Abstract

Real-world design studies often involve integrating different design algorithms to solve practical engineering problems. The designers and engineers have routinely solved such engineering design problems using a multitude of design algorithms and available software tools. VisualDOC is one such software which can be used for such design studies. It includes algorithms for optimization, probabilistic analysis (reliability and robustness), design of experiments, and response surface modeling. These algorithms can be coupled together to perform different kinds of design studies. In this paper, we present novel methods for integrating algorithms that not only facilitate performing complex design studies but also significantly reduce the associated computational cost. This study focuses on strategies to coordinate execution and data transfer. The strategies proposed in this paper are designed to be used with well-known design methods from literature that are available in VisualDOC. The first algorithm integration method presented in this paper is for reliability-based design optimization. Probability of failure (or reliability) of any response can be estimated using mean value approximation (MVA) which relies on first order Taylor series approximation. A gradient-based optimization method relies on finite forward differences to find a search direction which in turn also depends upon the first derivative of the responses (objectives and constraints). In this paper, it is shown that coordinating the execution of optimization and probability estimation and sharing the design points for Taylor series approximation can significantly speed-up the optimization process (reduce the number of function evaluations). The second case study presents response-surface approximated optimization. Using response surfaces as surrogates for actual analysis has been used to reduce computational cost associated with optimization and several such methodologies exist in literature. Response-surface based optimization typically results in an approximate optimum, the accuracy of which is dependent upon the quality of the approximation. In this paper, we show that VisualDOC can be used to model a design process in which the response surface is iteratively refined as the optimization proceeds, and using a multi-step optimization strategy where the approximation is replaced with the actual analysis late in the optimization process can result in actual optimum solution at a significantly reduced computational cost. In this strategy, most of the search process if performed using the surrogate model which is iteratively refined, and when there is no improvement in the optimum using the surrogate model, it is replaced with the actual analysis which results in the actual optimum (nearest local optimum) solution. The third case study focuses on performing multi-objective optimization using single-objective optimization algorithms. It is shown how the process integration capabilities of VisualDOC can be used to systematically scalarize a multi-objective problem and solve it using weight-based, epsilon-constraint, and normal-constraint methods to obtain an approximation to the Pareto-optimal frontier. Such scalarization methods only work with convex problems and are typically faster than multi-objective optimization methods like genetic algorithms. These novel case studies presented in this paper show that it is possible to speed-up the optimization process by properly integrating design algorithms.