The objective of robust design optimization is to improve the quality of a product or process by minimizing the deteriorating effects of variable or uncertain parameters. In addition to this original formulation of robust parameter design by G. Taguchi several other approaches based on decision-theoretic formulations have been introduced to attain a robust design, e.g. the minimax principle which minimizes the worst case effected by variability and the Bayes principle to optimize the expectation of the objective. Both approaches require a lot of function evaluations either to find the worst case or to calculate numerically the integral of the expectation. In cases where a large number of function evaluations is prohibitive, e.g. extensive and time-consuming computer simulations, an optimization method using metamodels is suggested. Within this framework a surrogate model of the objective function is constructed using the results of a finite element analysis at selected sampling points. On such a metamodel evaluations which represent estimates for the true function are very cheap to get and thus the abovementioned
criteria can easily be evaluated. In this paper a review of common metamodeling techniques is given with a focus on spatial correlation and response surface methods. The so-called kriging has emerged as well suited for the analysis of computer experiments as it is able to interpolate the output of the simulations. This is an important feature regarding the fact that deterministic computer simulations are not subject to random error: equal input parameters yield equal responses up to floating-point precision. Hence we expect our metamodel to represent the output data exactly at the sampled points. On the other hand, response surface methods are often successfully used in engineering applications due to their easy implementation and application. However, response surfaces usually only approximate the values at the sampled points. The selection of the sampling points used to build the surrogate model can be implemented via classical design of experiments (DOE) including the crossed or combined array. In the context of kriging models Latin hypercube designs have been widely used for instance because of their space filling property. This assures a balanced predictive performance of the kriging model throughout the investigated design space. Using the procedure presented above results in an estimate for the robust design. Verifying this design via the underlying computer simulation will show whether the claimed accuracy of the metamodel compared to the computer code is met or further improvements of the surrogate model are necessary. Regarding the latter case an approach for the selection of additional sampling points to sequentially augment the significance of the metamodel is needed. In the literature various update algorithms are available related to the different metamodeling techniques. Depending on objective and the formulation of the error estimate several alternatives are presented in this paper. Using the updated metamodels a new optimization can be run yielding an improved estimate of the robust optimum. This sequence will be continued until the stopping criterion is met.

Stichworte: robust design, optimization, metamodel, design of experiments, computer experiments


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