Reliability based design optimization with experiments on demand

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Simulations has to large extent replaced physical testing as the predominant mean to improve the structural integrity of mechanical designs, or even verify it. However, the computational cost associated with simulation-based optimization of mechanical designs with constraints on failure probability, *i.e.* reliability based design optimization (RBDO), can be large. A multitude of methods have been proposed to alleviate this computational burden. However, there is not a single method which is best suited for all types of problems, and thus, classes of methods suitable for specific problem types are needed. Here, a method specifically intended for RBDO of mechanically loaded structures is presented and its prerequisites and appropriateness is investigated.

The RBDO scheme employed here is a so-called single loop, single variable RBDO algorithm. It incorporates an outer loop where experiments are performed, and a inner loop with two sequential linearizations and surrogate model updates. The surrogate model is specifically designed for structural mechanics and can be shown to be exact for certain conditions, and reasonably accurate for the examples studied herein. An adaptive surrogate model fitting scheme is proposed which balances numerical stability and convergence rate as well as accuracy. Furthermore, the algorithm incorporates a novel procedure in which experiments are performed one at a time where and when they are needed. The procedure is called experiments on demand. The experiment procedure utilizes properties specific to RBDO and the problem at hand augmented by the concept of D-optimality familiar from traditional design of experiments. Also, the algorithm is designed to efficiently deal with multiple constraints.

Benchmarked against algorithms in the literature, the number of experiments needed for convergence was reduced by up to 80 % for a frequently used analytical benchmark problem and by up to 19 % for an application example. The accuracy of the reliability index is in line with the most efficient algorithm against which it was benchmarked but up to 3 % lower than the most accurate algorithm. The accuracy and efficiency of the method when applied to large scale engineering problems is expected to be in line with that stated above.

NOTE: The above stated numbers are those found with the present day algorithm and may be subject to change before final submission.