Editorial — Special Issue on Surrogate Optimization

It is a great pleasure for us, as guest editors of this special issue of Optimization and Engineering on Surrogate Optimization, to present the seven papers that have been accepted under our editorship. Varying in content from application and software to algorithmic development and convergence theory, the common element of these papers is the treatment of algorithms that make no use (or selected use) of derivative information, which might be unavailable, too expensive, or misleading. Some of the approaches explicitly incorporate surrogate models of the problem functions to make the best use of their (expensive) evaluation; others use such information implicitly.

Three of the papers in our special issue concern the study of global convergence properties of algorithms for derivative-free optimization, i.e., convergence to stationarity from arbitrary points.

Pattern search is a class of direct search for derivative-free optimization with rigorously established global convergence properties. The theory of pattern search provides results under a hierarchy of assumptions for classes of algorithms which meet certain conditions on the sets of pattern generators. The first paper in our special issue is one that all of those interested in the field should be well aware of. In this paper, Audet provides a collection of cleverly constructed examples that describe pathological instances of erratic convergence for generalized pattern search. By means of these examples, it is shown, among many other facts, that pattern search can generate a non-stationary limit point under the traditional assumption of continuous differentiability and that the requirements of rationality in the definition of the pattern generators are necessary and not just sufficient.

Dennis, Price, and Coope extend frame-based direct search algorithms for nonlinear problems by using the filter globalization technique. The filter trades optimality and feasibility for constrained problems and allows an infeasible starting point. Their convergence analysis is based on Clarke's calculus. The authors identify a subsequence of iterates produced by the method such that any limit point is a KKT point under mild conditions, which include local strict differentiability of the objective function and continuous differentiability of the constraints. This permits the objective function to be non-smooth, infinite, or undefined away from these cluster points. The authors also show interesting properties when the objective function is only locally Lipschitz continuous.

Madsen and Søndergaard consider a combination of space mapping as a preprocessing tool with a classical optimization technique to ensure global convergence. The proposed combined method conserves the main benefits of both techniques. Experience suggests that space mapping is an efficient surrogate initial phase. The target optimization problems are those of the form $H \circ f$, where $H : \mathbb{R}^m \mapsto \mathbb{R}$ measures the performance of a system described by $f : \mathbb{R}^n \mapsto \mathbb{R}^m$. In this paper, H is convex and cheap to calculate and $f : \mathbb{R}^n \mapsto \mathbb{R}^m$ is smooth and expensive to evaluate. The novel aspect of the paper is that H can be non-smooth, e.g., based on ℓ_1 or ℓ_∞ type norms.

The other four papers in this special issue feature applications of derivative-free or surrogate optimization techniques to a variety of relevant design engineering problems.

The paper by Abramson describes an application of pattern search to an optimization problem arising in the design of load-bearing thermal insulation systems. The problem under consideration by the author is a mixed variable programming problem where some of the variables are categorical, meaning that they must take on values only from a predefined list or else the design cannot be evaluated. A fundamental issue here is that categorical variables cannot be relaxed as in mixed-integer nonlinear programming. The problem is successfully solved by a filter pattern search algorithm developed to handle nonlinear constraints, which in the context of the application of the paper leads to more realistic designs.

The paper by Booker, Meckesheimer, and Torng, three Boeing Company researchers, tackles the crucial issue of incorporating uncertainty into engineering design. The paper gives some evidence that surrogate based optimization can be applied effectively to traditional formulations of the problem. The results indicate that although incorporating uncertainty into the objective or constraints makes an already expensive function even more expensive, the resulting function is smoother, and even better suited to surrogate methods.

The paper by Fowler et al. is on the solution of a class of well-field design problems, which is made available to the research community by the authors. The problems are formulated as bound-constrained optimization problems, where the objective function is nonlinear, discontinuous, and presents several local minima. The implicit filtering method is a line-search based algorithm for derivative-free optimization (which searches along the so-called simplex gradient) and can be efficiently tuned to handle noise in the objective function. In this paper, it is shown that implicit filtering performed well when tested against genetic algorithms for the class of problems under consideration.

Finally, Marsden et al. apply surrogate optimization techniques to the shape design of an airfoil trailing edge in an attempt to minimize noise. The pattern search method is enhanced by the minimization of Kriging surrogate models in the so-called search step of pattern search. The constrained versions of the problem are solved using the filter scheme, although, interestingly, the surrogate models used during the search step are formed in this constrained case by means of a penalty function. The numerical results reported by the authors showed a significant reduction of acoustic power in all cases considered and revealed unexpected airfoil shapes.

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On behalf of the Guest Editors
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