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Review of the book "Derivative-Free and Blackbox Optimization" by C. Audet and W. Hare, Springer Series in Operations Research and Financial Engineering, 2017, 302 pages, DOI 10.1007/978-3-319-68913-5

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In the interest of full disclosure, the reader is advised that I am biased positively towards the book considered here as I have collaborated with its first author several times during the last 19 years. In fact, the two of us served as guest editors of the last special issue on derivative-free and blackbox optimization appeared in this journal [1].

As an engineer, my primary appreciation of this book pertains to its invaluable contribution to the field of engineering design optimization. Numerical optimization problems in the modern era of computer-aided engineering design rely almost exclusively on simulation models to evaluate objective and constraint functions. Therefore, gradients may either not exist or require unreasonable and unjustifiable effort to be approximated with adequate precision if automatic differentiation is not an option. This is frequently the case with so called blackboxes, i.e., computational[1] models that the user does not have access to. The only resort then is to use derivative-free optimization algorithms.

Despite the renewed interest and considerable research activity in the field of derivative-free optimization in the past two and a half decades, this is only the second book that treats the subject from a rigorous mathematical point of view, the first one being [2]. The contrast to the large body of literature on heuristic methods, notably genetic algorithms, is astonishing. The latter are extremely popular in the community of engineering design practitioners because they are straightforward to understand and implement and always yield results, which is what engineers are rightfully after as opposed to convergence properties. However, the confusion of obtaining a good engineering design solution (which is often legitimately sufficient) with converging to an optimal one has propagated to a misconception of dangerously large proportions.

This book offers an excellent opportunity for informing the engineering design community on the availability of mathematically rigorous alternatives to heuristics that not only work at least as well, if not much better, but are also sophisticatedly simple while armed with convergence properties. The authors have managed to present rich material very elegantly, making a highly enjoyable read. The structure, layout, and color-code of the book facilitate both the digestion of technical information and the selected omission of more advanced yet not esoteric parts according to the reader's background or needs. In other words, while the content of the book is mostly based on relativey recent nonetheless mature research results, it is a wonderful textbook that can be used entirely or partially to support optimization courses.

The authors begin with an excellent introduction to the *raison d'être* of derivative-free optimization emphasizing that it is not a competitor of gradient-based methods and providing classification and application examples, mathematical background, and detailed analysis of early search algorithms (exhaustive search, grid search, and coordinate search). Then, they proceed with a complete presentation of two major heuristic methods (genetic algorithms and the Nelder-Meade Simplex), including convergence studies. This sets the foundation for comparing them with the modern direct search methods (generalized pattern search and mesh adaptive direct search) presented in Part 3 of the book, which includes neccesary nonsmooth analysis fundamentals. In Part 4, the authors discuss how linear or quadratic models can be built and used in model-based descent and trust-region methods. The chapters of Part 5 consider three important topics: i) different types of variables and constraints as well as the handling of the latter using a progressive barrier method; ii) the use of surrogates to address practical computational cost issues; and iii) biobjective optimization. This part of the book merely whets the reader's appetite, which is not unreasonable given that a detailed treatment would have doubled the size of the book. A detailed discussion on categorical variables would have been very useful, if not only to stimulate further research. Surrogate optimization is a topic of tremendous importance in engineering design and warrants its own book. It is very important to stress that surrogates should only be used to assist the optimization process as opposed to making algortihmic decisions based directly on surrogate evaluations. And multi-objective optimization is one more example of a topic deserving future research especially to provide an alternative to multi-objective genetic algorithms. The authors conclude with an extremely valuable appendix on proper data collection, analysis, and visualization

[1] We use the terms "computational" and "simulation" interchangeably to characterize a model.

techniques for comparing optimization algorithms as well as an extensive benchmarking project that combines material from the entire book.

The parts of the book, as well as most of their chapters, have been composed to be self-contained. This modularity enables the use of selected portions of the book as text for multiple courses with different learning objectives. Throughout the book, the authors use a challenging representative problem from rheology to illustrate the presented methods and demonstrate their performance. All chapters come with several exercises of varying difficulty level and very useful propositions for computational projects. Solutions to some of the exercises are provided in an appendix.

In conclusion, the authors have achieved gloriously their stated goal of "*providing a clear grasp of the foundational concepts in derivative-free and blackbox optimization.*" My only regret about this book is that it was not published as part of Springer's Series in Engineering instead of that in Operations Research and Financial Engineering. I wish that it will find its way somehow to the desks of engineering design optimization practitioners.

References

[1] C. Audet and M. Kokkolaras. Blackbox and derivative-free optimization: theory, algorithms and applications. Optimization and Engineering, 17(1):1–2, 2016.

[2] A.R. Conn, K. Scheinberg, and L.N. Vicente. Introduction to Derivative-Free Optimization. MOS-SIAM Series on Optimization. SIAM, Philadelphia, 2009.