Slawomir Koziel and Xin-She Yang (Eds.)

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Preface

Computational modelling is becoming the third paradigm of modern sciences, as predicted by the Nobel Prize winner Ken Wilson in 1980s at Cornell University. This so-called third paradigm complements theory and experiment to problem solving. In fact, a substantial amount of research activities in engineering, science and industry today involves mathematical modelling, data analysis, computer simulations, and optimization. The main variations of such activities among different disciplines are the type of problem of interest and the degree as well as extent of the modelling activities. This is especially true in the subjects ranging from engineering design to industry.

Computational optimization is an important paradigm itself with a wide range of applications. In almost all applications in engineering and industry, we almost always try to optimize something - whether to minimize the cost and energy consumption, or to maximize the profit, output, performance and efficiency. In reality, resources, time and money are always limited; consequently, optimization is far more important. The optimal use of available resources of any sort requires a paradigm shift in scientific thinking, which is because most real-world applications have far more complicated factors and parameters as well as constraints to affect the system behaviour. Subsequently, it is not always possible to find the optimal solutions. In practice, we have to settle for suboptimal solutions or even feasible ones that are satisfactory, robust, and practically achievable in a reasonable time scale.

This search for optimality is complicated further by the fact that uncertainty almost always presents in the real-world systems. For example, materials properties always have a certain degree of inhomogeneity. The available materials which are not up to the standards of the design will affect the chosen design significantly. Therefore, we seek not only the optimal design but also robust design in engineering and industry. Another complication to optimization is that most problems are nonlinear and often NP-hard. That is, the solution time for finding optimal solutions is exponential in terms of problem size. In fact, many engineering applications are NP-hard indeed. Thus, the challenge is to find a workable method to tackle the problem and to search for optimal solutions, though such optimality is not always achievable.

Contemporary engineering design is heavily based on computer simulations. This introduces additional difficulties to optimization. Growing demand for accuracy and ever-increasing complexity of structures and systems results in the simulation process being more and more time consuming. Even with an efficient optimization algorithm, the evaluations of the objective functions are often time-consuming. In many engineering fields, the evaluation of a single design can take as long as several hours up to several days or even weeks. On the other hand, simulation-based objective functions are inherently noisy, which makes the optimization process even more difficult. Still, simulation-driven design becomes a must for a growing number of areas, which creates a need for robust and efficient optimization methodologies that can yield satisfactory designs even at the presence of analytically intractable objectives and limited computational resources.

In most engineering design and industrial applications, the objective cannot be expressed in explicit analytical form, as the dependence of the objective on design variables is complex and implicit. This black-box type of optimization often requires a numerical, often computationally expensive, simulator such as computational fluid dynamics and finite element analysis. Furthermore, almost all optimization algorithms are iterative, and require numerous function evaluations. Therefore, any technique that improves the efficiency of simulators or reduces the function evaluation count is crucially important. Surrogate-based and knowledge-based optimization uses certain approximations to the objective so as to reduce the cost of objective evaluations. The approximations are often local, while the quality of approximations is evolving as the iterations proceed. Applications of optimization in engineering and industry are diverse. The contents are quite representative and cover all major topics of computational optimization and modelling.

This book is contributed from worldwide experts who are working in these exciting areas, and each chapter is practically self-contained. This book strives to review and discuss the latest developments concerning optimization and modelling with a focus on methods and algorithms of computational optimization, and also covers relevant applications in science, engineering and industry.

We would like to thank our editors, Drs Thomas Ditzinger and Holger Schaepe, and staff at Springer for their help and professionalism. Last but not least, we thank our families for their help and support.

Slawomir Koziel
Xin-She Yang
2011

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