

# Preface

The costs of extensive computational simulations used for engineering designs can be very expensive, and thus can be a serious bottleneck for the design process in many applications. Nowadays prototyping is heavily involved in design and verification using computer models, and such computational approaches can have many advantages such as the reduction of the overall design costs and design cycles as well as finding good solutions to ‘what-if’ scenarios. However, the computation costs incurred by extensive computational time can still be very high. Though the speed of the computer power has steadily increased over past the decades, computationally extensive tasks are still a challenging issue. One of the reasons is the ever-increasing demand of the high-accuracy, high-fidelity models for simulating complex systems. For many applications such as those in aerospace engineering, microwave engineering and biological applications, a single simulation task can take hours, even days or weeks on modern computers. While in other applications such as combinatorial optimization problems, the evaluations of every possible combination can be prohibitive because such numbers of combinations can be astronomical. For continuous problems such as computational fluid dynamics and electromagnetic wave simulation, some forms of efficient approximations such as surrogate-based models are needed, while for combinatorial problems, efficient algorithms should be used, though there are no efficient algorithms for genuinely NP-hard problems.

In addition, other challenges associated with such problems include numerical noise in the simulation data, multimodality with multiple local optimum designs due to high nonlinearity, as well as multiple (potentially conflicting) objectives. All these make computationally expensive design tasks even more challenging. Thus, it is timely to edit a book to address such problems with the focus on the latest developments.

From the computational point of view, three key issues should be emphasized: approximation models, optimization algorithms and multi-objectives. Approximation models often use the so-called surrogates that can reliably represent

the expensive, simulation-based model of the system/device of interest. If such surrogates are designed properly, they can speed up the simulation significantly. However, such surrogates tend to work for the local, smooth design landscape, and for multimodal problems, good approximations are not easy to construct. This book will include some of the latest developments in this area when dealing with nonlinear problems with complex design objectives.

Even with efficient, computational models, efficient optimization algorithms are also crucial to ensure design optimization that can be carried out successfully in a practically acceptable time scale. Traditional algorithms such as the trust-region method, the interior-point method and gradient-based algorithms can work well for local search, but for multimodal global optimization, heuristic and meta-heuristic algorithms start to demonstrate their efficiency. Swarm intelligence based approaches will be introduced and reviewed in this book.

In almost all engineering applications, there are multiple design objectives and these objectives can often be conflicting, resulting in very complex objective landscapes in the design space. In addition, complex constraints can often modify the search regions significantly and thus make it even more challenging for search algorithms. Furthermore, the computational costs for multi-objective optimization will increase multifold, compared to the counterpart of single objective optimization problems. For example, multi-objective optimization can be very challenging in image processing applications, and we will also briefly touch this area in this book.

This edited book provides a timely snapshot of some of the latest developments in surrogate-based models, optimization algorithms and multi-objective design applications. Topics include surrogate models in engineering design, surrogate-based and PDE-constrained models in climate applications, shape-preserving response predictions, simulation-driven design for antenna designs, space dimension reduction for multi-objective design, large-scale optimization via swarm intelligence, clustering of radar images, classification of laser point clouds, knowledge-based modelling by artificial neural networks and others. However, as the length of the book is limited, it is not our intention to cover everything. As a result, many topics that are very active in the field may not be covered at all. But we hope all the topics we have covered can form a basis with enough literature for further research in the relevant areas.

The editors hope that topics covered in this book will allow the readers to gain understanding of basic mechanisms of surrogate modeling process and surrogate-based optimization algorithms, to follow the trend of swarm intelligence and image processing, and to see the ways of dealing with multi-objective optimization. Ultimately, this may help to reduce the costs of the design process aided by computer simulations. Therefore, this book can serve as a timely reference to researchers, lecturers and engineers in engineering design, modelling and optimization as well as industry.

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