

Preface

This book is written for students and researchers in the field of industrial engineering, computer science, operations research, management science, electrical engineering, and applied mathematics. The aim is to introduce the reader to a *subset* of topics on simulation-based optimization of large-scale and complex stochastic (random) systems. Our goal is *not* to cover all the topics studied under this broad field. Rather, it is to expose the reader to a *selected* set of topics that have recently produced breakthroughs in this area. As such, much of the material focusses on some of the key recent advances.

Those working on problems involving *stochastic discrete-event* systems and optimization may find useful material here. Furthermore, the book is self-contained, but only to an extent; a background in elementary college calculus (basics of differential and integral calculus) and linear algebra (matrices and vectors) is expected. Much of the book attempts to cover the topics from an intuitive perspective that appeals to the engineer.

In this book, we have referred to any stochastic optimization problem related to a discrete-event system that can be solved with computer simulation as a **simulation-optimization** problem. Our focus is on those simulation-optimization techniques that do not require any a priori knowledge of the structure of the objective function (loss function), i.e., closed form of the objective function or the underlying probabilistic structure. In this sense, the techniques we cover are **model-free**. The techniques we cover do, however, require all the information typically required to construct a simulation model of the discrete-event system.

Although the science underlying simulation-based optimization has a rigorous mathematical foundation, our development in the initial chapters is based on intuitively appealing explanations of the major concepts. It is only in Chaps. 9–11 that we adopt a somewhat more rigorous approach, but even there our aim is to prove only those results that provide intuitive insights for the reader.

Broadly speaking, the book has two parts: (1) parametric (static) optimization and (2) control (dynamic) optimization. While the sections on control optimization are longer and a greater portion of the book is devoted to control optimization, the intent is not in any way to diminish the significance of parametric optimization. The field of control optimization with simulation has benefited from work in numerous communities, e.g., computer science and electrical engineering, which perhaps explains the higher volume of work done in that field. But the field of parametric optimization has also attracting significant interest in recent times and it is likely that it will expand in the coming years.

By *parametric* optimization, we refer to static optimization in which the goal is to find the values of *parameters* that maximize or minimize a function (the objective or loss function), usually a function of those parameters. By *control* optimization, we refer to those dynamic optimization problems in which the goal is to find an optimal *control* (action) in each state visited by a system. The book's goal is to describe these models and the associated optimization techniques in the context of stochastic (random) systems. While the book presents some classical paradigms to develop the background, the focus is on recent research in both parametric and control optimization. For example, exciting, recently developed techniques such as *simultaneous perturbation* (parametric optimization) and *reinforcement learning* (control optimization) are two of the main topics covered. We also note that in the context of control optimization, we focus only on those systems which can be modeled by Markov or semi-Markov processes.

A common thread running through the book is naturally that of simulation. Optimization techniques considered in this book require simulation as opposed to explicit mathematical models. Some special features of this book are:

1. An accessible introduction to **reinforcement learning** and parametric optimization techniques.
2. A step-by-step description of several algorithms of simulation-based optimization.

3. A clear and simple introduction to the methodology of **neural networks**.
4. A special account of semi-Markov control via simulation.
5. A **gentle** introduction to convergence analysis of some of techniques.
6. **Computer programs** for many algorithms of simulation-based optimization, which are online.

The background material in discrete-event simulation from Chap. 2 is at a very elementary level and can be skipped without loss of continuity by readers familiar with this topic; we provide it here for those readers (possibly not from operations research) who may not have been exposed to it. Links to computer programs have been provided in the appendix for those who want to apply their own ideas or perhaps test their own algorithms on some test-beds. Convergence-related material in Chaps. 9–11 is for those interested in the mathematical roots of this science; it is intended only as a form of an introduction to mathematically sophisticated material found in other advanced texts.

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