

Preface

Optimization in Engineering: Models and Algorithms covers the fundamentals of optimization, including linear, mixed-integer linear, nonlinear, and dynamic optimization techniques, with a clear engineering focus.

This book carefully describes classical optimization models and algorithms using an engineering problem-solving perspective. Modeling issues are emphasized using many real-world examples, related to a variety of application areas.

This textbook is intended for advanced undergraduate and graduate-level teaching in industrial engineering and other engineering specialties. It is also of use to industry practitioners, due to the inclusion of real-world applications.

This book consists of five chapters and two appendices.

Chapter 1 introduces the book, providing an overview of the major classes of optimization problems that are relevant to the engineering profession.

Chapter 2 considers linear optimization problems. The practical significance of these problems is first shown through a number of examples. Precise formulations of these example problems are provided. The geometric and algebraic features of generic linear optimization problems are then analyzed. A well-known solution algorithm is next described, which is based on the algebraic features of linear optimization problems. Sensitivity analysis and the duality properties of linear optimization problems are then described.

Chapter 3 considers mixed-integer linear optimization problems. That is, problems that are linear in the decision variables but include variables that are restricted to take on integer values. The chapter provides a number of illustrative examples, showing the practical significance of mixed-integer linear optimization. Then, a general formulation of the mixed-integer linear optimization problem is provided. Next, the use of binary variables to model various types of nonlinearities and discontinuities, while maintaining a linear model structure, is described. This use of binary variables shows the true power of mixed-integer linear optimization models. Two solution techniques for mixed-integer linear optimization problems are then explained: branch-and-bound and cutting planes. The former is developed for general mixed-integer linear optimization problems, the latter for pure-integer linear optimization problems.

Chapters 4 and 5 consider nonlinear optimization problems. Chapter 4 begins with numerous application examples demonstrating the use of nonlinear optimization. This chapter then introduces the use of optimality conditions, which is an analytical approach to solving nonlinear optimization problems. Optimality conditions are properties that an optimal solution exhibits and can be used to find candidate optimal solutions to general nonlinear optimization problems.

Chapter 5 considers a generic iterative algorithm for solving unconstrained nonlinear optimization problems. Details on the two principal steps of this generic algorithm are then provided. Next, this chapter explains two ways in which the generic algorithm can be extended to solve constrained nonlinear optimization problems. One implicitly accounts for the constraints by incorporating them into the objective function through ‘penalties’, while the other explicitly accounts for problem constraints.

Chapter 6 covers dynamic optimization techniques. This chapter begins by first introducing a simple problem that can be formulated and solved using dynamic optimization techniques. The common elements that must be identified when formulating a dynamic optimization problem are then described. These elements ‘encode’ the structure and dynamics of the system being optimized. A standard algorithm used to solve dynamic optimization problems is then described.

Appendix A reviews Taylor approximations and definite matrices while Appendix B reviews convex sets and functions. The concepts covered in these appendices are vital for Chapters 4 and 5. The appendices are provided for readers needing to refresh these topics.

The material in this book can be arranged to address the needs of undergraduate teaching in two one-semester courses. Chapters 1–3 include the material for a linear and mixed-integer linear optimization course. On the other hand, Chapters 1, 4–6 and Appendices A and B include the material for a nonlinear and dynamic optimization course. Alternatively, Chapter 1 and Sections 2.1, 3.1, 3.3, and 4.1 of Chapters 2–4 could be used in a course that introduces optimization modeling *only*, without covering solution methods or theory.

The book provides an appropriate blend of practical applications and optimization theory. This feature makes the book useful to practitioners and to students in engineering, operations research, and business. It also provides the reader with a good sense of the power of optimization and the potential difficulties in applying optimization to modeling real-world systems. The algorithms and solution methods are developed intuitively and examples are used to illustrate their use. This text is written to avoid mathematical formality while still maintaining sufficient rigor for the reader to understand the subtleties of optimization. GAMS codes for many of the examples introduced in the text are also provided. These can be readily used and expanded upon by the reader. The aim is for the reader to be able to confidently apply the modeling and solution methodologies to problem domains that go beyond the examples used in the text. Overall, the reader benefits by understanding optimization, learning how to formulate problems, solve them, and interpret solution outputs. This is done using a problem-solving engineering approach.

This book opens the door to advanced courses on both modeling and algorithm development within the industrial engineering and operations research fields.

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