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Book Review

Introduction to Applied Optimization

Urmila M. Diwekar, Series: Applied Optimization, vol. 80, Kluwer Academic Publishers, Dordrecht, ISBN 1-4020-7456-5, p. 352, Hardcover, Current price: US$109.95; Distributed by Springer Science + Business Media, New York

1. Introduction

Optimization – the art and science of making high-quality decisions – has been an essential objective of rational human activities, at least in recent history. The development of quantitative decision modeling concepts, solution algorithms, and advances in computer technology have provided researchers and practitioners with an extensive repertoire of tools to find optimized decisions. Optimization is needed in government and business organizations, across a growing range of application areas.

The stated objective of Diwekar's book is to present an introduction to optimization, with a focus on immediate applicability, and without getting into too much theoretical detail. The target audience is researchers and practitioners, as well as undergraduate and graduate students in engineering, management science, operations research, and decision science. Until recently, Diwekar was a professor of engineering at Carnegie Mellon University and at the University of Illinois. Although she is still affiliated with the University of Illinois, recently, she has started a new non-profit research institute called Vishwamitra Research Institute, Center for Uncertain Systems: Tools for Optimization and Management. (A side-note for the interested reader: Vishwamitra is one of the most important and respected sages of Hinduism.)

Diwekar's practically driven research work greatly motivates the content and style of the book. In conjunction with the introduction of key optimization subjects, the book thoroughly discusses a hazardous waste blending problem (HWBP). To sum up this obviously important problem, a nuclear plant generates radio-active waste as a by-product of its energy production activity. The issue of processing this hazardous waste in a technologically feasible, environmentally responsible, and cost-efficient manner serves as the central application example discussed throughout the subsequent chapters of the book. Increasingly more realistic, more sophisticated and (as a rule) more difficult-to-solve formulations of the HWBP lead to corresponding models and solution approaches. This approach is very useful, both educationally and from a practical point of view ("mimicking" actual – gradual – model development). The HWBP, with a view towards many other similar issues, is important enough to be of general interest for analysts and researchers, in spite of being a specific decision problem.

The book also includes a collection of other – concise, but sufficiently detailed – examples that serve to illustrate modeling and optimization concepts as they are introduced. The accompanying 134-page Solution Manual (offered to instructors) provides hints and solutions to the exercises found at the end of each chapter. The book is accompanied by a CD that includes the models developed, solved and discussed in detail. These materials together with the book offer a highly useful, ready-to-apply toolkit.

2. A brief description of the book

The front material (Table of Contents, Foreword, and Acknowledgements) is followed by Chapter 1, which serves as an introduction to the subject of optimization. The individual sections discuss problem formulation, degrees of model freedom, as well as the concepts of objective function,

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constraints, and feasible region. Next, the issue of numerical optimization is discussed, followed by an overview of the types of optimization problems presented in the book. Each chapter is concluded by a brief summary, followed by selected topical references, and a relatively small, but good collection of exercises. The exposition is enhanced by sufficiently simple but to-the-point illustrative figures, as well as by nicely presented examples, historical tales and anecdotes.

Chapter 2 is devoted to Linear Programming (LP). First, the simplex method is introduced; then the issues of infeasible and unbounded models and of multiple solutions are discussed. Sensitivity analysis, the dual simplex method and interior point algorithms are highlighted. Next, the HWBP is introduced in sufficient detail, and then it is formulated as an LP problem. This model is solved making use of the GAMS model development and solver environment. (For detailed information on GAMS, visit www.gams.com.) The chapter is concluded by a brief summary, selected references, and exercises. (This statement is valid also for all the subsequent chapters of the book, without further mention.)

Chapter 3 discusses the general area of Nonlinear Programming (NLP). The concepts of convex and concave functions are introduced first. This is followed by concise expositions on unconstrained and constrained NLP, and on necessary and sufficient local optimality conditions. The issue of global versus local optima is also highlighted. Sensitivity analysis and a brief discussion of numerical methods (sequential quadratic programming, generalized reduced gradient method, and interior point methods) conclude the exposition on NLP. Finally, the HWBP is formulated as an NLP model, and then it is solved numerically using GAMS modeling and solver facilities.

Chapter 4 is devoted to Discrete Optimization (DO) (in alternative terminology, integer programming (IP), or combinatorial optimization (CO)). Let me remark that – strictly speaking – DO does not include mixed integer-continuous problems, while all such models are formally covered by general NLP (specifically, by global optimization). Short, but useful notes on the tree and network representations of DO models are presented first. This is followed by the introduction of a generic branch-and-bound strategy for IP. Numerical methods for IP, mixed integer linear (MILP), and nonlinear (MINLP) models are also discussed briefly, including decomposition and outer approximation methods. The section on probabilistic methods introduces simulated annealing and genetic algorithms as heuristic solution approaches to difficult IP and MILP/MINLP models. Finally, the HWBP is presented in a DO model form, and then it is solved using a MINLP solver from GAMS, and (alternatively) branch-and-bound, or an iterative combination of simulated annealing and NLP.

Chapter 5 looks at the practically very relevant – and, as a rule, numerically very challenging – issue of optimization under uncertainty (stochastic programming, SP). A simple, but practical introductory example (production of chemicals under uncertainty in input material supplies) highlights the key points. This is followed by concise discussions of the (two-stage) recourse problem, chance constrained models, model decomposition, uncertainty analysis, and of various useful sampling techniques. A stochastic annealing method is introduced for combinatorial optimization under uncertainty. Finally, the HWBP is presented in a form that considers also uncertainty. This model is then solved using the stochastic annealing approach combined with NLP and an iterative sampling approach.

Chapter 6 discusses another practically important issue: multi-objective optimization (MO) with several objective functions. This chapter is based on classroom notes by Jared Cohon, a well-known MO expert (and the current president of Carnegie Mellon University). The concept of non-dominated (Pareto) solutions is introduced. The most prominent solution methods applied to solve MO problems are then briefly reviewed, classified as preference methods (to elicit the decision maker's preferences) and generating methods (to numerically find/approximate the Pareto set). Numerically, most MO solution approaches lead to iterative solutions of "traditional" optimization models in some suitable parametric form: models with weighted objectives and/or parameterized constraints regarding the individual objectives are well-known examples. The concept of goal programming is also introduced. Finally, the MO approach is illustrated by a variant of the HWBP.

Chapter 7 is devoted to the subjects of optimal control (OC) and dynamic optimization (DO), with explicit consideration given to time in the model. This chapter is co-authored by Diwekar and Benoit Morel from Carnegie Mellon University. The classical idea of calculus of variations leading to the Euler–Lagrange equations is presented. This is followed by concise expositions on the maximum principle, dynamic programming, and stochastic dynamic programming. The well-detailed illustrative example in this chapter is the reverse of blending, namely, the optimization of a separation process. The exposition nicely illustrates a sophisticated modeling and solution process, applying the concepts introduced in this chapter.

The book also includes two Appendices and an Index. Appendix A is related to Chapter 7: it describes in detail the glass property constraints used in the model version of this chapter. Appendix B defines the construction of Hammersley (quasi-random) sequences used in the efficient sampling procedure discussed in Chapter 5. Finally, the detailed Index includes all the key concepts discussed in the book, as well as page references to all authors cited in the book.

3. Conclusions and recommendations

The book is well-written, and – as indicated by the topics reviewed above – it covers fairly significant territory, in a relatively slim volume. This work is definitely a welcome addition to the existing optimization literature, given its emphasis on modeling and solution practice, as well as its, "user-friendly" style of exposition.

This book and the accompanying materials (solution manual and CD) can be recommended as a very good self-study resource. The concepts and tools presented will help scientists, researchers, and decision analysts in various fields to identify and apply models and suitable algorithms in their own work. The book will also be very useful for OR/MS, engineering and science lecturers and students with an interest in applicable optimization.

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