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Book Reviews

Principles of Optimal Design: Modeling and Computation, 2nd edition

Panos Y. Papalambros and Douglass J. Wilde, Cambridge University Press, New York, 2000, 390 pp., $44.95

The writer of a textbook has a conflict to resolve. On the one hand it is desirable to include in the textbook material that would be of interest to the widest audience, whereas on the other hand it is desirable to insert material close to the author's heart. The first edition of Papalambros and Wilde's *Principles of Optimal Design* leaned in the direction of emphasis on material close to the heart of the authors, in particular, monotonicity analysis. The second edition improves the balance, and the result is a textbook that should be useful to a much wider audience. The new Chapter 2, Model Construction, includes popular topics, and the old specialized Chapter 6, Global Bound Construction, which also included geometric programming, is gone. There are still some popular topics that are left out or shortchanged, but this is difficult to avoid without greatly expanding the thickness and cost of the textbook. The second edition is available in paperback, and at the list price of $44.95 it is a bargain. On the day I checked on the Web, I could get it from Barnes and Noble with a coupon for $42.90 including FedEx shipping.

The second edition retains and strengthens some of the excellent features of the first. These include a wealth of good examples, solved in detail and well illustrated, as well as very nice illustrations of various concepts of optimization. The Notation section at the beginning of the book is useful, and every chapter ends with a Notes section that provides information on additional sources of material. There is also a large number of homework problems in each chapter. The book is well written and easy to follow and provides an excellent basis for a first graduate course on design optimization in Mechanical Engineering, Aerospace Engineering, or Mechanics departments.

The division of material surprised me at first. In particular, some search methods for unconstrained and constrained problems are discussed in Chapters 4 and 5, respectively. Others are given in Chapter 7, entitled Local Computation. On second thought, I could see the benefit of this arrangement, as it allows the teacher to more easily skip algorithmic descriptions. Indeed, I find that, as the years pass, I tend to teach fewer and fewer algorithms in my optimization classes because of the increasing availability of good software.

A brief description of the contents of the book follows: Chapter 1, Optimization Models, discusses the important topic of the formulation of the optimization problem. As the authors say in the preface, "a good model can make optimization almost trivial, whereas a bad one can make correct optimization difficult or impossible." Compared to the first edition, this chapter now has material on multicriterion optimization as well as expanded coverage of hierarchical models.

Chapter 2, Model Construction, is a new chapter that includes material on fitting models from data, originally in Chapter 1, but now with kriging methods and neural networks added. The chapter also includes a good treatment of natural and practical constraints. Chapter 3, Model Boundedness, begins with a very thorough discussion of the effects of constraints on optima and continues with monotonicity analysis.

Chapter 4, Interior Optima, provides mostly theoretical aspects of unconstrained optimization, including optimality conditions and the concept of convexity. Numerical methods in this chapter are limited to steepest descent and Newton's method, as well as a general discussion of trust region algorithms. More methods are discussed in Chapter 7. Chapter 5, Boundary Optima, includes optimality conditions but also the gradient projection and generalized reduced gradient methods, as well as linear programming. I would have liked to see more in this chapter on sensitivity of optimal solutions to problem parameters. Chapter 6, Parametric and Discrete Optima, is mostly about the use of monotonicity theory for model reduction, like Chapter 5 from the first edition. There is much more on discrete variables but not with standard methods, like branch and bound for linear problems, or stochastic methods, such as genetic algorithms.

Chapter 7, Local Computation, includes search algorithms for constrained and unconstrained optimization. Compared to the first edition, it includes trust regions and convex approximations. The absence of the conjugate gradient method is conspicuous (even though quasi-Newton is there). I would have also liked to see methods that do not require derivatives, such as pattern search methods. Chapter 8, Principles and Practice, describes the calculation of derivatives, scaling, problem formulations, checklists, and a road map of where to find things in the book, as well as lists of software and Internet sites.

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Multiple Gravity Assist Interplanetary Trajectories

A. V. Labunsky, O. V. Papkov, and K. G. Sukhanov, Gordon and Breach Science Publishers, Amsterdam, 1998, 292 pp., $132.00

This book presents the results of 20 years of experience of the three Russian authors on the design of interplanetary missions. The book is focused on the development of algorithms and their application for the preliminary design of such missions. Although, as one would expect, the majority of the references are Russian, this book is not restricted to work performed only in Russia but also reflects research in other countries, primarily the United States. This reviewer, although knowledgeable of orbital mechanics, has never worked in the area of the design of interplanetary missions. As a result I may approach the book differently from those who work in the area.

The book consists of seven chapters. The first three and the last chapters are focused on the development of algorithms. The practical application of these methods is presented in Chapters 4–6. Mathematical modeling of interplanetary trajectories using gravity assist and the efficiency of such maneuvers are the focus of Chapter 1. Two subjects are addressed in Chapter 2. First, a method for the preliminary analysis of possible multipurpose trajectories is developed. This method uses simplified models for the celestial bodies to determine the feasibility of the trajectories. This is a combination graphical-analytical method that is based mostly on minimum energy trajectories. Using this method as a basis, a universal method for designing multipurpose orbits is addressed in the latter half of Chapter 2. Because there are several thousand objects registered in the solar system, a novel technique for coding the bodies and possible trajectories is developed. Almost any trajectory in the solar system can be specified using a chain of these codes. The trajectories consist of segments of the Keplerian orbit about the sun and Keplerian orbits in the vicinity of the other bodies that the spacecraft passes by for gravity assist. The result is a multipurpose trajectory that is of minimum energy. Chapter 3 addresses the problem of applying real-world constraints, such as those imposed by ground tracking and control, to the methods developed in Chapter 2.

Chapters 4–6 apply these methods to the preliminary design of feasible trajectories to planets, comets, asteroids, etc. Chapter 4 treats the problem of trajectories to the planets, and trajectories to the natural satellites of planets are the focus of Chapter 5; Chapter 6 addresses trajectories to small bodies of the solar system. Chapter 7 completes the analysis by addressing the problem of navigation of a satellite in the near planetary flight segment. Presented are methods for designing different types of trajectories such as orbiting the planet, landing on the planet, and gravity assist to other bodies. A unified approach using the so-called B-plane of the flyby planet is used for solving these problems.

Contained in this book is a wealth of information on preliminary design of interplanetary gravity assist trajectories. The authors are commended for the quality of their research and the contribution they have made to this field. However, using this book is not easy at times. A nomenclature section would have helped significantly. The notation and variable definitions are not consistent. Let me explain by several examples. In Chapter 1 the authors use the notation "h" to denote orbital energy. Then plots are presented as a function of "H" that has units of km^2/sec^2, which is energy, but the quantity "H" is never defined. They also use the undefined notation "sh$H$" and "ch$H$." It is somewhat obvious from the equation that these are hyperbolic sine and cosine, but the reviewer has not seen this notation before. Also, the quantity "H" is not defined. It is obviously not the same "H" as before because this one has no dimensions, but neither is defined. Another notation not seen before is $\overline{rv}$. In one equation this is a dot product yielding a scalar, but in another place it is a cross product yielding a vector. Finally, many of the results are presented, not developed. It is left to the reader to derive the result. Even with these limitations the researcher in this field may want this book on his shelf as a reference source. It does provide a comprehensive treatment of the subject.

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