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Hans Kellerer, Ulrich Pferschy, David Pisinger, *Knapsack Problems*, Springer, Berlin, 2004, ISBN 3-540-40286-1, 546pp., € 99,95.

I cannot help but start this review with an analogy between the knapsack problem and the traveling salesman problem (TSP), the two most studied problems of combinatorial optimization. Both problems are easy to explain even to a stranger, both are hard to solve. Each of these problems is important in its own right as well as due to numerous applications.

Each of the two problems forms an excellent testing ground to verify various algorithmic ideas. It is not by chance that the seminal TSP book compiled in 1985 by Lawler et al. [4] has “A guided tour of combinatorial optimization” in the title. The knapsack problem has also got its own canonical text, the famous 1990 monograph by Martello and Toth [5]. These two classical books not only give a wonderful introduction to the techniques of combinatorial optimization and their applications; they have also stimulated further research of the travelling salesman and knapsack problems, respectively. The increased volume of publications in the area and algorithmic advances that have taken place in recent years have called for another attempt to overview the developments. In 2002, the operations research community warmly received the new TSP book edited by Gutin and Punnen [1]. And now, a new book on the knapsack problem is in print.

I love both TSP books and admire the work done by their editors. Still, I feel it is advantageous that unlike their TSP counterparts, both knapsack books are not edited volumes but monographs. This makes it possible to guarantee a smoother delivery, to maintain consistent notation, to organize the flow of material appropriately, e.g., in order of increasing its complexity, etc.

The book under review is not simply written by people who know everything there is to know on the topic. All three authors have recently made essential contributions to the knapsack research. To mention just a few, Kellerer and Pferschy have reduced the running time and space requirements for the fully polynomial time approximation scheme for the knapsack problem [2,3]. Pisinger has improved the performance of dynamic programming algorithms using the word RAM model of computation [6].

The book under review consists of fifteen chapters. The list of quoted references exceeds 500 titles. Before looking at the structure of the book in more detail, let me make a formal statement of the knapsack problem, since this will facilitate the discussion of variants of the basic model. In its pure form, the knapsack problem is usually written as the following problem of Boolean linear programming:

$$\begin{aligned} &\text{maximize} && \sum_{j=1}^{n} p_j x_j, \\ &\text{subject to} && \sum_{j=1}^{n} w_j x_j \leqslant c, \\ &x_j \in \{0,1\}, && j = 1, \ldots, n. \end{aligned} \tag{1}$$

Each of n items has a profit value p_j and a weight w_j. For item j the decision variable x_j is equal to 1 if the item is placed into the knapsack of total capacity c, and the aim is to maximize the total profit of the items in the knapsack.

The first three chapters of the book give a gentle, step-by-step introduction to the problems of the knapsack family and associated algorithmic techniques. The material of these chapters should be suitable for undergraduate students and also prepares the reader for the more technical chapters.

Chapter 1 introduces the knapsack problem and its most important variants and generalizations. In particular, it draws attention to the all-capacities knapsack problem and to the design of algorithms that are capable of solving the problem for all or several capacities c up to a given upper bound $c_{\max}$.

Various basic algorithmic ideas are introduced in Chapter 2. Here the authors are not after the most efficient implementation of solution algorithms, but rather concentrate on the principal features of exact dynamic programming and branch-and-bound procedures, as well as those of approximation algorithms and schemes.

More advanced algorithmic concepts are discussed in Chapter 3. These include various techniques of fast implementation of dynamic programming algorithms that allow space and running time reductions. Special attention is paid to the so-called word RAM algorithms that allow parallelism at bit level. Methods like Lagrangian relaxation and decomposition are presented and the structure of the knapsack polytope is discussed.

The remaining chapters of the book provide a deeper analysis of modern techniques for designing exact and approximation algorithms for the knapsack problem, its generalizations and applications. For this often quite technical material, the authors successfully maintain a consistent style: sufficient intuition and strict justification of an algorithm, its formal statement in a pseudocode, and usually computational results. This part of the book is meant for a more prepared audience and will be appreciated by post-graduate students, active researchers in operations research and computer science, numerate managerial consultants, and experienced practitioners.

Chapters 4–8 give full treatment of the main problems of the knapsack family: the subset sum problem ($p_j = w_j$ for all items); the classical knapsack problem of the form (1); the bounded knapsack problem ($0 \leqslant x_j \leqslant b_j$ and integer) and the unbounded knapsack problem (the decision variables are arbitrary non-negative integers). For each of these problems the reader will find descriptions of economical dynamic programming algorithms and branch-and-bound methods, analysis of approximation algorithms and schemes, as well as reports on extensive computational experiments.

Starting from Chapter 9, the book turns to multidimensional variants of the knapsack problem. Chapter 9 is devoted to the multidimensional knapsack problem in which there is more than one linear constraint. The multiple knapsack problem (each item has to be assigned to at most one knapsack) is the topic of Chapter 10. The multiple-choice knapsack problem in which the items are partitioned into classes and exactly one item of each class has to be put into the knapsack is discussed in Chapter 11. For each of these problems a detailed exposition of exact and approximate solution techniques is given.

Chapter 12 addresses the quadratic knapsack problem in which the linear objective function of the classical model is replaced by a quadratic function. Here the main emphasis is on derivation of upper bounds on the optimal problem value; the discussed approaches include linearization, Lagrangian relaxation and decomposition and semi-definite relaxation. The results of computational experiments on the quality of various upper bounds are reported.

Chapter 13 reviews other variants of the knapsack problems that have not been addressed in the previous parts of the books. Probabilistic models related to the knapsack problem are analyzed in Chapter 14. Here, various structural results are presented, and the issues of expected performance and of expected running time of algorithms are discussed.

The concluding Chapter 15 contains a useful collection of applications of various problems of the knapsack family to cutting, finance, codes, combinatorial auctions etc.

To summarize: The book by Kellerer, Pferschy and Pisinger covers all major aspects of research on the knapsack problem, puts together interesting material, and delivers it expertly. I congratulate the authors on accomplishing an excellent job. The new knapsack book has all the potential to become another classical text on this classical problem.

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Stanley B. Gershwin, Yves Dallery, Chrissoleon T. Papadopoulos, J. MacGregor Smith (Eds.), *Analysis and Modeling of Manufacturing Systems*, International Series in Operations Research and Management Science, 2003, Kluwer Academic Publishers, Boston, Dordrecht, London, ISBN: 1-4020-7303-8, 429pp., € 139.00/ $ 135.50/ £87.00

This book provide results from research in analysis and modeling of manufacturing systems, as an outgrowth of the Second Aegean International Conference of Analysis and Modeling of Manufacturing Systems. The book, which has 16 chapters written by various authors, is dedicated to John A. Buzacott, who has been a leading influence on the topic. It is mentioned in the preface by Gershwin that all chapters had undergone a refereeing process by anonymous reviewers, making the collection a high-quality one. The contents of the collection are interesting mainly for researchers.

The problems that are analyzed in different chapters are as follows: Capacitated repairable inventory systems (Chapter 1, by Avsar and Zijm), distribution resource planning (Chapter 2, by Feigin, Katircioglu and Yao), modeling uncertainty in tool adjustment (Chapter 3, by Glenn and Pollack), continuous merge system (Chapter 4, by Helber and Mehrtens), multi-armed bandit problem (Chapter 5, by Hongler and Dusonchet), production planning of short-life cycle products (Chapter 6, by Ishikura), automated flow line with repair crew interference (Chapter 7, by Kuhn), modeling stations with multiple failure modes (Chapter 8 and Chapter 9, both by Levantesi, Matta and Tolio), due-date performance measuring (Chapter 10, by Li and Meerkov), two-valve flow control (Chapter 11, by Ozdogru and Altiok), determining supply-chain lead time (Chapter 12, Raghavan and Viswanadham), base-stock control (Chapter 13, by Sbiti, Mascolo, Bennani and Amghar), designing a manufacturing cell (Chapter 14, by Spiliopoulos and Sofianopoulou), pull control (Chapter 15, by Tan), and dynamic scheduling (Chapter 16, by Veatch).

It is difficult to cluster the chapters, as they represent a number of very challenging research areas. However, to give the reader some insight on the individual chapters, we group chapters in terms of their specified network structure, and in terms of the solution and analysis technique employed.

Almost all of the studies can be grouped with respect to their network structure. The systems that are analyzed by these studies are described below in four network structures; flow, convergent, divergent, and general systems: Flow systems (Chapter 7—with repair crew interference, Chapter 8—a reasonably general two-station problem, Chapters 9–11); convergent systems—assembly network (Chapter 3—with three stations, Chapter 4—with three stations, Chapter 13—base-stock controlled); divergent systems—arborescent networks (Chapter 1—allowing returns for repair, Chapter 2—classical distribution problem); and general networks (Chapter 12—overview of computational issues in lead-time related issues of a supply chain, Chapter 15—exploiting the possibility of reduction to flow type structures, Chapter 16).

It is almost impossible to cluster the chapters into some well-defined groups of solution and analysis techniques. However, it is possible to identify several chapters that deal with performance evaluation of manufacturing systems in the classical sense. These studies represent manufacturing systems as queuing network structures and employ various methods to analyze the system. Among such chapters one can mention Chapters 1, 7, 9, 10, 13 that use approximate decomposition algorithms, Chapters 8, 15 that solves their associated problem with an exact algorithm, and Chapters 4, 11, 16, using fluid approximations. Additionally, in Chapter 12 the authors utilize a queuing network package program. In Chapter 2, the authors employ standard stochastic inventory concepts (with approximations from the renewal theory) to describe

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