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Efficient Approximation and Online Algorithms

Recent Progress on Classical Combinatorial Optimization Problems and New Applications

Springer

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Preface

In this book, we present some recent advances in the field of *combinatorial optimization* focusing on the design of *efficient approximation and on-line algorithms*. Combinatorial optimization and polynomial time approximation are very closely related: given an $\mathcal{NP}$-hard combinatorial optimization problem, i.e., a problem for which no polynomial time algorithm exists unless $\mathcal{P} = \mathcal{NP}$, one important approach used by computer scientists is to consider polynomial time algorithms that do not produce optimum solutions, but solutions that are provably close to the optimum. A natural partition of combinatorial optimization problems into two classes is then of both practical and theoretical interest: the problems that are *fully approximable*, i.e., those for which there is an approximation algorithm that can approach the optimum with any arbitrary precision in terms of relative error and the problems that are *partly approximable*, i.e., those for which it is possible to approach the optimum only until a fixed factor unless $\mathcal{P} = \mathcal{NP}$. For some of these problems, especially those that are motivated by practical applications, the input may not be completely known in advance, but revealed during time. In this case, known as the *on-line* case, the goal is to design algorithms that are able to produce solutions that are close to the *best* possible solution that can be produced by any *off-line* algorithm, i.e., an algorithm that knows the input in advance.

These issues have been treated in some recent texts [1], but in the last few years a huge amount of new results have been produced in the area of approximation and on-line algorithms. This book is devoted to the study of some classical problems of scheduling, of packing, and of graph theory, but also new optimization problems arising in various applications such as networks, data mining or classification. One central idea in the book is to use a linear program relaxation of the problem, randomization and rounding techniques.

The book is divided into 11 chapters. The chapters are self-contained and may be read in any order.

In Chap. 1, the goal is the introduction of a theoretical framework for dealing with data mining applications. Some of the most studied problems in this area as well as algorithmic tools are presented. Chap. 2 presents a survey concerning local search and approximation. Local search has been widely used in the core of many heuristic algorithms and produces excellent practical results for many combinatorial optimization problems. The objective here is to com-

[1] V. Vazirani, *Approximation Algorithms, Springer Verlag, Berlin, 2001*; G. Ausiello et al, *Complexity and Approximation: Combinatorial Optimization Problems and Their Approximability, Springer Verlag, 1999*; D. S. Hochbaum, editor, *Approximation Algorithms for NP-Hard Problems, PWS Publishing Company, 1997*; A. Borodin, R. El-Yaniv, *On-line Computation and Competitive Analysis, Cambridge University Press, 1998*, A. Fiat and G. J. Woeginger, editors, *Online Algorithms: The State of the Art, LNCS 1442. Springer-Verlag, Berlin, 1998.*

pare from a theoretical point of view the quality of local optimum solutions with respect to a global optimum solution using the notion of the approximation factor and to review the most important results in this direction. Chap. 3 surveys the *wavelength routing problem* in the case where the underlying optical network is a tree. The goal is to establish the requested communication connections but using the smallest total number of wavelengths. In the case of trees this problem is reduced to the problem of finding a set of transmitter-receiver paths and assigning a wavelength to each path so that no two paths of the same wavelength share the same fiber link. Approximation and on-line algorithms, as well as hardness results and lower bound, are presented. In Chap. 4, a *call admission control problem* is considered in which the objective is the maximization of the number of accepted communication requests. This problem is formalized as an *edge-disjoint-path problem* in (non)-oriented graphs and the most important (non)-approximability results, for arbitrary graphs, as well as for some particular graph classes, are presented. Furthermore, combinatorial and linear programming algorithms are reviewed for a generalization of the problem, the *unsplittable flow problem*. Chap. 5 is focused on a special class of graphs, the intersection graphs of disks. Approximation and on-line algorithms are presented for the maximum independent set and coloring problems in this class. In Chap. 6, a general technique for solving min-max and max-min resource sharing problems is presented and it is applied to two applications: scheduling unrelated machines and strip packing. In Chap. 7, a simple analysis is proposed for the on-line problem of scheduling preemptively a set of tasks in a multiprocessor setting in order to minimize the flow time (total time of the tasks in the system). In Chap. 8, approximation results are presented for a general classification problem, the *labeling problem* which arises in several contexts and aims to classify related objects by assigning to each of them one label. In Chap. 9, a very efficient tool for designing approximation algorithms for scheduling problems is presented, the *list scheduling in order of α-points*, and it is illustrated for the single machine problem where the objective function is the sum of weighted completion times. Chap. 10 is devoted to the study of one classical optimization problem, the k-median problem from the approximation point of view. The main algorithmic approaches existing in the literature as well as the hardness results are presented. Chap. 11 focuses on a powerful tool for the analysis of randomized approximation algorithms, the Lovász-Local-Lemma which is illustrated in two applications: the job shop scheduling problem and resource-constrained scheduling.

We take the opportunity to thank all the authors and the reviewers for their important contribution to this book. We gratefully acknowledge the support from the EU Thematic Network APPOL I+II (Approximation and Online Algorithms). We also thank Ute Iaquinto and Parvaneh Karimi Massouleh from the University of Kiel for their help.

September 2005 Evripidis Bampis, Klaus Jansen, and Claire Kenyon

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