

Bernd Gärtner · Jiří Matoušek

# Approximation Algorithms and Semidefinite Programming

# Approximation Algorithms And Semidefinite Programming

**Vijay V. Vazirani**

## **Approximation Algorithms And Semidefinite Programming:**

*Approximation Algorithms and Semidefinite Programming* Bernd Gärtner, Jiri Matousek, 2012-01-10 Semidefinite programs constitute one of the largest classes of optimization problems that can be solved with reasonable efficiency both in theory and practice. They play a key role in a variety of research areas such as combinatorial optimization, approximation algorithms, computational complexity, graph theory, geometry, real algebraic geometry, and quantum computing. This book is an introduction to selected aspects of semidefinite programming and its use in approximation algorithms. It covers the basics but also a significant amount of recent and more advanced material. There are many computational problems such as MAXCUT for which one cannot reasonably expect to obtain an exact solution efficiently and in such case one has to settle for approximate solutions. For MAXCUT and its relatives, exciting recent results suggest that semidefinite programming is probably the ultimate tool. Indeed, assuming the Unique Games Conjecture a plausible but as yet unproven hypothesis, it was shown that for these problems known algorithms based on semidefinite programming deliver the best possible approximation ratios among all polynomial time algorithms. This book follows the semidefinite side of these developments, presenting some of the main ideas behind approximation algorithms based on semidefinite programming. It develops the basic theory of semidefinite programming, presents one of the known efficient algorithms in detail, and describes the principles of some others. It also includes applications focusing on approximation algorithms.

*Aspects of Semidefinite Programming* E. de Klerk, 2002-03-31 Semidefinite programming has been described as linear programming for the year 2000. It is an exciting new branch of mathematical programming due to important applications in control theory, combinatorial optimization, and other fields. Moreover, the successful interior point algorithms for linear programming can be extended to semidefinite programming. In this monograph the basic theory of interior point algorithms is explained. This includes the latest results on the properties of the central path as well as the analysis of the most important classes of algorithms. Several classic applications of semidefinite programming are also described in detail. These include the Lovasz theta function and the MAX CUT approximation algorithm by Goemans and Williamson.

**Audience:** Researchers or graduate students in optimization or related fields who wish to learn more about the theory and applications of semidefinite programming.

**The Design of Approximation Algorithms** David P. Williamson, David B. Shmoys, 2011-04-26 Discrete optimization problems are everywhere, from traditional operations research planning (scheduling, facility location and network design) to computer science (databases, advertising, issues in viral marketing). Yet most such problems are NP-hard, unless P=NP, there are no efficient algorithms to find optimal solutions. This book shows how to design approximation algorithms: efficient algorithms that find provably near-optimal solutions. The book is organized around central algorithmic techniques for designing approximation algorithms, including greedy and local search algorithms, dynamic programming, linear and semidefinite programming, and randomization. Each chapter in the first section is devoted to a single algorithmic technique applied to several problems. The second section is devoted to more advanced topics, including local search, constrained optimization, and semidefinite programming.

several different problems with more sophisticated treatment in the second section The book also covers methods for proving that optimization problems are hard to approximate Designed as a textbook for graduate level algorithm courses it will also serve as a reference for researchers interested in the heuristic solution of discrete optimization problems

### **Aspects of**

**Semidefinite Programming** E. de Klerk,2013-04-16 Semidefinite programming has been described as linear programming for the year 2000 It is an exciting new branch of mathematical programming due to important applications in control theory combinatorial optimization and other fields Moreover the successful interior point algorithms for linear programming can be extended to semidefinite programming In this monograph the basic theory of interior point algorithms is explained This includes the latest results on the properties of the central path as well as the analysis of the most important classes of algorithms Several classic applications of semidefinite programming are also described in detail These include the Lovasz theta function and the MAX CUT approximation algorithm by Goemans and Williamson Audience Researchers or graduate students in optimization or related fields who wish to learn more about the theory and applications of semidefinite programming

### **An Introduction to Semidefinite Programming and Its Applications to Approximation Algorithms**

Thomas Hofmeister,Martin Hühne,1997 **On the Optimality of Some Semidefinite Programming-based**

**Approximation Algorithms Under the Unique Games Conjecture** Seth R. Flaxman,2008 *Handbook of Approximation Algorithms and Metaheuristics* Teofilo F. Gonzalez,2007-05-15 Delineating the tremendous growth in this area the Handbook of Approximation Algorithms and Metaheuristics covers fundamental theoretical topics as well as advanced practical applications It is the first book to comprehensively study both approximation algorithms and metaheuristics Starting with basic approaches the handbook presents the methodologies to design and analyze efficient approximation algorithms for a large class of problems and to establish inapproximability results for another class of problems It also discusses local search neural networks and metaheuristics as well as multiobjective problems sensitivity analysis and stability After laying this foundation the book applies the methodologies to classical problems in combinatorial optimization computational geometry and graph problems In addition it explores large scale and emerging applications in networks bioinformatics VLSI game theory and data analysis Undoubtedly sparking further developments in the field this handbook provides the essential techniques to apply approximation algorithms and metaheuristics to a wide range of problems in computer science operations research computer engineering and economics Armed with this information researchers can design and analyze efficient algorithms to generate near optimal solutions for a wide range of computational intractable problems

*Sublinear Computation Paradigm* Naoki Katoh,Yuya Higashikawa,Hiro Ito,Atsuki Nagao,Tetsuo Shiba,Adnan Sljoka,Kazuyuki Tanaka,Yushi Uno,2021-10-19 This open access book gives an overview of cutting edge work on a new paradigm called the sublinear computation paradigm which was proposed in the large multiyear academic research project Foundations of Innovative Algorithms for Big Data That project ran from October 2014 to March 2020 in Japan To handle the unprecedented

explosion of big data sets in research industry and other areas of society there is an urgent need to develop novel methods and approaches for big data analysis To meet this need innovative changes in algorithm theory for big data are being pursued For example polynomial time algorithms have thus far been regarded as fast but if a quadratic time algorithm is applied to a petabyte scale or larger big data set problems are encountered in terms of computational resources or running time To deal with this critical computational and algorithmic bottleneck linear sublinear and constant time algorithms are required The sublinear computation paradigm is proposed here in order to support innovation in the big data era A foundation of innovative algorithms has been created by developing computational procedures data structures and modelling techniques for big data The project is organized into three teams that focus on sublinear algorithms sublinear data structures and sublinear modelling The work has provided high level academic research results of strong computational and algorithmic interest which are presented in this book The book consists of five parts Part I which consists of a single chapter on the concept of the sublinear computation paradigm Parts II III and IV review results on sublinear algorithms sublinear data structures and sublinear modelling respectively Part V presents application results The information presented here will inspire the researchers who work in the field of modern algorithms

**Approximation Algorithms for Combinatorial Optimization** Klaus Jansen, Jose Rolim, 1998-07 Computer simulation has become a basic tool in many branches of physics such as statistical physics particle physics or materials science The application of efficient algorithms is at least as important as good hardware in large scale computation This volume contains didactic lectures on such techniques based on physical insight The emphasis is on Monte Carlo methods introduction cluster algorithms reweighting and multihistogram techniques umbrella sampling efficient data analysis and optimization methods but aspects of supercomputing the solution of stochastic differential equations and molecular dynamics are also discussed The book addresses graduate students and researchers in theoretical and computational physics

**Efficient Approximation Algorithms for Some Semidefinite Programs** Hsueh-I. Lu, 1997 **Integer Programming and Combinatorial Optimization** Michael Jünger, Volker Kaibel, 2005-06 This book constitutes the refereed proceedings of the 11th International Conference on Integer Programming and Combinatorial Optimization IPCO 2005 held in Berlin Germany in June 2005 The 34 revised full papers presented were carefully reviewed and selected from 119 submissions Among the topics addressed are mixed integer programming graph theory graph algorithms approximation linear programming approximability packing scheduling computational geometry randomization network algorithms sequencing TSP and travelling salesman problem

**Coping with NP-hardness** Michael Langberg, 2003 **Fast Approximation Algorithms for Graph Partitioning Using Spectral and Semidefinite-Programming Techniques** Lorenzo Orecchia, 2011 Graph partitioning problems are a central topic of research in the study of approximation algorithms They are of interest to theoretical computer scientists for their far reaching connections to spectral graph theory metric embeddings and inapproximability theory And they are also important

for many practitioners as algorithms for graph partitioning are often fundamental primitives in the solution of other problems such as image segmentation clustering and social network analysis While many theoretical approximation algorithms exist for graph partitioning they often rely on multicommodity flow computations that run quadratic time in the worst case and are too time consuming for the massive graphs that are prevalent in today's applications In this thesis we study the design of approximation algorithms that yield strong approximation ratios while running in subquadratic time and relying on computational procedures that are often fast in practice Our algorithms employ spectral and st flow operations to explore the cuts of a graph in a very efficient way A crucial ingredient in their design is the usage of random walks that capture the sparse cuts of a graph better than single eigenvectors The analysis of our methods is particularly simple as it relies on a semidefinite programming formulation of the graph partitioning problem of choice Indeed we can develop our algorithms as primal dual methods for solving a semidefinite program and show that certain random walks arise naturally from this approach

**Derandomizing Semidefinite Programming Based Approximation Algorithms** Sanjeev Mahajan, H. Ramesh, 1996 Abstract Remarkable breakthroughs have been made recently in obtaining approximate solutions to some fundamental NP Complete problems namely Max Cut Max k Cut Max Sat Max Dicut Max Bisection k Vertex Coloring Independent Set etc These breakthroughs all involve polynomial time randomized algorithms based upon Semidefinite Programming a technique pioneered by Goemans and Williamson 8 In this paper we give techniques to derandomize the above class of randomized algorithms thus obtaining polynomial time deterministic algorithms with the same approximation ratios for the above problems At the heart of our technique is the use of spherical symmetry to convert a nested sequence of n integrations which cannot be approximated sufficiently well in polynomial time to a nested sequence of just a constant number of integrations which can be approximated sufficiently well in polynomial time

**Approximation Algorithms** Vijay V. Vazirani, 2002-12-05 Covering the basic techniques used in the latest research work the author consolidates progress made so far including some very recent and promising results and conveys the beauty and excitement of work in the field He gives clear lucid explanations of key results and ideas with intuitive proofs and provides critical examples and numerous illustrations to help elucidate the algorithms Many of the results presented have been simplified and new insights provided Of interest to theoretical computer scientists operations researchers and discrete mathematicians

**Lectures on Proof Verification and Approximation Algorithms** Ernst W. Mayr, Hans Jürgen Prömel, Angelika Steger, 2006-06-08 During the last few years we have seen quite spectacular progress in the area of approximation algorithms for several fundamental optimization problems we now actually know matching upper and lower bounds for their approximability This textbook like tutorial is a coherent and essentially self contained presentation of the enormous recent progress facilitated by the interplay between the theory of probabilistically checkable proofs and approximation algorithms The basic concepts methods and results are presented in a unified way to provide a smooth introduction for newcomers These lectures are particularly useful

for advanced courses or reading groups on the topic **Approximation Algorithms for Combinatorial Optimization** Klaus Jansen, Stefano Leonardi, Vijay Vazirani, 2003-06-30 This book constitutes the refereed proceedings of the 5th International Workshop on Approximation Algorithms for Combinatorial Optimization Problems APPROX 2002 held in Rome Italy in September 2002 The 20 revised full papers presented were carefully reviewed and selected from 54 submissions Among the topics addressed are design and analysis of approximation algorithms inapproximability results online problems randomization techniques average case analysis approximation classes scheduling problems routing and flow problems coloring and partitioning cuts and connectivity packing and covering geometric problems network design and applications to game theory and other fields Integer Programming and Combinatorial Optimization, 2002 **Approximation Algorithms for NP-hard Problems** Dorit S. Hochbaum, 1997 This is the first book to fully address the study of approximation algorithms as a tool for coping with intractable problems With chapters contributed by leading researchers in the field this book introduces unifying techniques in the analysis of approximation algorithms APPROXIMATION ALGORITHMS FOR NP HARD PROBLEMS is intended for computer scientists and operations researchers interested in specific algorithm implementations as well as design tools for algorithms Among the techniques discussed the use of linear programming primal dual techniques in worst case analysis semidefinite programming computational geometry techniques randomized algorithms average case analysis probabilistically checkable proofs and inapproximability and the Markov Chain Monte Carlo method The text includes a variety of pedagogical features definitions exercises open problems glossary of problems index and notes on how best to use the book *Proceedings of the Twelfth Annual ACM-SIAM Symposium on Discrete Algorithms* SIAM Activity Group on Discrete Mathematics, 2001-01-01 Contains 130 papers which were selected based on originality technical contribution and relevance Although the papers were not formally refereed every attempt was made to verify the main claims It is expected that most will appear in more complete form in scientific journals The proceedings also includes the paper presented by invited plenary speaker Ronald Graham as well as a portion of the papers presented by invited plenary speakers Udi Manber and Christos Papadimitriou

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