Handbook of Approximation Algorithms and Metaheuristics
edited by Teofilo F. Gonzalez,
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reviewed by Jakub Mareček

In response to the development of the theory of NP-completeness in the 1970s, there appeared a number of distinct approaches to tackling NP-complete problems. Heuristics typically attempt to extend a solution to a restriction or to a relaxation to the original problem, often without much regard to guarantees of optimality in the worst-case scenario. Approximation algorithms are an attempt to derive analytical bounds on the quality of solutions obtained using heuristics in the worst case. Approximation algorithms are sometimes matched with negative, albeit often conditional, "inapproximability" results on the impossibility of the existence of algorithms with certain bounds on the quality of solutions. Metaheuristics typically involve local search, navigating the search space of solutions from one local optimum to another, along a trajectory, which is non-monotone with respect to the objective function value. A number of other communities study various special cases and alternative notions of complexity. Sadly, these communities do not seem to have much contact or overlap. It is hence a great pleasure to see the Handbook of Approximation Algorithms and Metaheuristics published by CRC.

The handbook is unique in that a good number of lengthy chapters were written by the founding fathers of the respective subfields. In Part I, "Basic Methodologies", there are chapters on greedy approaches co-authored by Guy Even and Samir Khuller, a chapter on linear programming by Yuval Rabani, a chapter on semidefinite programming by Yinyu Ye and colleagues, as well as chapters co-authored by Paul Spirakis (Randomised Approximations), Rajeev Motwani (Asymptotic Polynomial Time Approximation Schemes), Giorgio Ausiello (Approximability-Preserving Reductions), and Mario Szegedy (Hardness of Approximation). In Part II, "Local Search, Neural Networks, and Metaheuristics", there are chapters by Holger Hoos and Thomas Stützle (Empirical Analysis of Randomised Algorithms, Stochastic Local Search), Ravindra Ahuja and Jim Orlin (Very Large Neighborhood Search), Fred Glover (Principles of Tabu Search), and Emile Aarts and Jan Korst (Simulated Annealing). In Part IV, "Traditional Applications", there are chapters on packing by Ed Coffman, János Csirik, Joseph Leung, and Leah Epstein, as well as chapters co-authored by Giorgio Ausiello (Prize Collecting Traveling Salesman), Ding-Zhu Du and Andrew B. Kahng (Steiner Trees), Klaus Jansen (scheduling malleable tasks), Hiroshi Nagamochi (Vehicle Routing Problems), and Toshihide Ibaraki (Generalized Assignment Problem). These contributions may well justify buying the handbook for many readers.

There are also weaker spots. Part III, "Multiobjective Optimization, Sensitivity Analysis and Stability" seems to be rather imbalanced, although it fea-

tures an excellent chapter on the stability of approximation by Juraj Hromkovič and co-authors. Authors who contributed to Part V, "Computational Geometry and Graph Applications" and Part VI, "Large-Scale and Emerging Applications" will surely become well-known shortly, despite the fact the reviewer failed to appreciate a number of the contributions. Taken together, these three parts represent only about one half of the book.

The handbook could be compared only to a small number, if a stackful, of others. Compared to the Encyclopedia of Algorithms (Kao, 2008), which provides excellent summaries of important papers from top-tier conferences in theoretical computer science, the chapters in the handbook under review are much broader set, more comprehensive, and let the reader appreciate various authors' attitudes to problem solving, as well as their styles of writing. With so many distinguished authors of longer chapters, this liberal approach of the editor is worth praising, even if it is not the only possible one. On the other end of the spectrum, compared to the Handbook of Combinatorial Optimization (Du & Pardalos, 1999), which was published in five volumes totalling 3722 pages in 1999–2005 and retails for GBP 481.5, the handbook under review forms a reasonably coherent and meticulously edited whole. Compared with the Handbook of Metaheuristics (Glover & Kochenberger, 2003), there is a much wider range of approaches presented, although iterated local search, multi-start methods, greedy randomised adaptive search procedures, scatter search, and genetic programming receive a paragraph each, while path relinking, guided local search, and hyper-heuristics are not mentioned at all. Also, connections to constraint programming or integer programming are not made explicit. The best-written handbook covering approximation algorithms, The Algorithms and Theory of Computation Handbook (Atallah, 1998), or recent volumes on heuristic approaches palatable to theorist (Hoos & Stützle, 2004; Michiels, Aarts, & Korst, 2007), may resemble very well-written advanced undergraduate textbooks in comparison. It certainly is difficult to recommend one of the handbooks over others. It should be noted, however, that the second, much extended edition of The Algorithms and Theory of Computation Handbook is to appear in two volumes in the autumn of 2009.

Overall, the ultimate weakness of the handbook is inveterate to both fields it covers: There are no computational results reported on most approximation algorithms and there are only precious few analyses of metaheuristics. There is, nevertheless, an elite community working on practical implementations of SDP-based approximation algorithms and related heuristics (Bertsimas & Ye, 1998; Helmberg, 2000; Burer & Monteiro, 2001; Burer, Monteiro, & Zhang, 2001/02; Arora, Hazan, & Kale, 2005), although many of their papers never make it back to the theory community (Homer & Peinado, 1997; Burer & Monteiro, 2001; Burer et al., 2001/02). There are a fair few researchers in scheduling (Bertsimas & Gamarnik, 1999, e.g.), who do analyse, engineer, and test their algorithms, or at least provide empirical comparison of algorithms introduced by others (Vredeveld & Hurkens, 2002, e.g.) Some of the best people in logic

(Schäffer & Yannakakis, 1991; Buss & Krajíček, 1994) work on polynomial local search, and there is a growing interest in the theory of population-based approaches (Droste, Jansen, & Wegener, 2002). Sadly, none of these efforts are acknowledged or referenced in the handbook. Handbook of Approximation Algorithms and Metaheuristics presents both fields separately, if exhaustively.

References

Arora, S., Hazan, E., & Kale, S. (2005). Fast algorithms for approximate semidefinite programming using the multiplicative weights update method. In *Focs '05: Proceedings of the 46th Annual IEEE Symposium on Foundations of Computer Science* (pp. 339–348). Washington, DC, USA: IEEE Computer Society.

Atallah, M. J. (Ed.). (1998). *Algorithms and Theory of Computation Handbook*. Boca Raton, FL: CRC Press.

Bertsimas, D., & Gamarnik, D. (1999). Asymptotically optimal algorithms for job shop scheduling and packet routing. *J. Algorithms*, *33*(2), 296–318.

Bertsimas, D., & Ye, Y. (1998). Semidefinite relaxations, multivariate normal distributions, and order statistics. In *Handbook of combinatorial optimization, Vol. 3* (pp. 1–19). Boston, MA: Kluwer Acad. Publ.

Burer, S., & Monteiro, R. D. C. (2001). A projected gradient algorithm for solving the maxcut SDP relaxation. *Optim. Methods Softw.*, *15*(3-4), 175–200.

Burer, S., Monteiro, R. D. C., & Zhang, Y. (2001/02). Rank-two relaxation heuristics for max-cut and other binary quadratic programs. *SIAM J. Optim.*, *12*(2), 503–521.

Buss, S. R., & Krajíček, J. (1994). An application of Boolean complexity to separation problems in bounded arithmetic. *Proc. London Math. Soc. (3)*, *69*(1), 1–21.

Droste, S., Jansen, T., & Wegener, I. (2002). On the analysis of the (1+1) evolutionary algorithm. *Theor. Comput. Sci.*, *276*(1-2), 51-81.

Du, D.-Z., & Pardalos, P. M. (Eds.). (1999). *Handbook of Combinatorial Optimization*. Boston, MA: Kluwer Acad. Publ. (3722 pp.)

Glover, F. W., & Kochenberger, G. A. (Eds.). (2003). *Handbook of Metaheuristics*. Boston, MA: Kluwer Academic Publishers.

Helmberg, C. (2000). *Semidefinite programming for combinatorial optimization* (ZIB-Report No. 00-34). Konrad Zuse Zentrum fuer Informationstechnik Berlin. Available from `http://www.zib.de/Publications/abstracts/ZR-00-34` (Habilitationsschrift, TU Berlin)

Homer, S., & Peinado, M. (1997). Design and performance of parallel and distributed approximation algorithms for maxcut. *J. Parallel Distrib. Comput.*, *46*(1), 48-61.

Hoos, H., & Stützle, T. (2004). *Stochastic Local Search: Foundations & Applications*. San Francisco, CA: Morgan Kaufmann.

Kao, M.-Y. (Ed.). (2008). *Encyclopedia of Algorithms*. New York, NY: Springer. Hardcover. (1166 pp.)

Michiels, W., Aarts, E., & Korst, J. (2007). *Theoretical Aspects of Local Search*. Secaucus, NJ: Springer.

Schäffer, A. A., & Yannakakis, M. (1991). Simple local search problems that are hard to solve. *SIAM J. Comput.*, *20*(1), 56–87.

Vredeveld, T., & Hurkens, C. (2002). Experimental comparison of approxima-

tion algorithms for scheduling unrelated parallel machines. *INFORMS J. Comput.*, *14* (2), 175–189.