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RESEARCH PAPER

The traveling salesman problem: a book review

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Abstract We review the recent book authored by David L. Applegate, Robert E. Bixby, Vašek Chvátal and William J. Cook, The traveling salesman problem: a computational study, Princeton Series in Applied Mathematics. Princeton University Press 2007, Hardback price $45.00 / £26.95, 606pp, ISBN 978-0-691-12993-8.

Keywords TSP · Branch-and-cut · Separation · Computer implementation

MSC classification (2000) 90C05 · 90C27 · 90C35 · 90C57

The *Traveling Salesman Problem* (TSP) is the problem of finding a tour through a specified set of cities that minimizes the total travel distance; or, more formally, the problem of finding a Hamiltonian circuit of minimum cost in an edge-weighted graph. It is probably the most well-known $\mathcal{NP}$-hard combinatorial optimization problem, and arises in many practical applications, either directly or as a sub-problem. Despite the fact that three excellent books devoted to the TSP have been published in the past (Lawler et al. 1985; Reinelt 1994; Gutin and Punnen 2002), this new work by Applegate, Bixby, Chvátal and Cook has been eagerly awaited by researchers in the field. (As a personal memory, a young second reviewer had the chance of having a preliminary version of separation chapters 8, 9 and 11 as lecture notes in a Ph.D. course taught by Vašek Chvátal: Zinal (Switzerland), March 2–6, 1999!)

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For those who do not know, Applegate et al. are the creators of CONCORDE, a state-of-the-art exact algorithm for the symmetric TSP. Using CONCORDE, Applegate et al. have solved breathtakingly large real-world TSP instances, with tens of thousands of cities, to proven optimality. This book explains the workings of CONCORDE in great detail, not only presenting the algorithms involved but also describing useful data structures and other implementation 'tricks'. The fact that the CONCORDE source code is freely available makes the picture very complete. However, the book is much more than a mere description of a software package: it also contains copious material on the history, applications and theory of the TSP.

The structure of the book is as follows. Chapter 1 defines the TSP and gives some historical background from which the reader is also able to review fundamental steps in the history of Combinatorial Optimization. Chapter 2 describes various practical applications. Chapter 3 is dedicated to the famous 1954 paper by Dantzig, Fulkerson and Johnson, which introduced the cutting plane approach to the TSP. Chapter 4 reviews the literature on various other algorithmic approaches, such as branch-and-bound, dynamic programming, local search heuristics, and branch-and-cut. Chapter 5 returns to the cutting plane method, giving more details on the underlying polyhedral theory. Chapters 6 to 11 give detailed descriptions of the various *separation routines* that are implemented in CONCORDE. Chapters 12 to 15 cover the other key ingredients of CONCORDE, such as pricing routines, branching rules and primal heuristics. Chapter 16 presents some comprehensive (and extremely impressive) computational results. Finally, Chapter 17 summarizes some recent developments in the field and makes suggestions for further research.

We like this book very much. It contains a wealth of interesting information on the TSP, gives useful pointers to the literature and, as mentioned before, presents convincing computational results. Moreover, it is written in a light and highly readable style. (It is even humorous in places.) There are also lots of useful figures that, as well as looking very pretty, aid understanding. For this reason, we expect the book to be suitable for graduate students as well as experienced researchers.

So far, our review has been unequivocably favorable. Does the book have any errors or important omissions? Well, we have not found any errors, although we found one typo. We have to say, however, that the book does not contain a fully comprehensive review of the literature related to the application of the branch-and-cut method to the TSP. Several classes of valid inequalities (such as Naddef's crown and binested inequalities) are not mentioned, and nor are several relevant algorithms, such as the fast minimum cut algorithms of Hao–Orlin and Nagamochi–Ono–Ibaraki, or the new blossom separation algorithm of Letchford–Reinelt–Theis. Furthermore, the considerable literature on the *asymmetric* TSP is given only scant treatment. The reason for all of these omissions appears to be that Applegate et al. are concentrating on the inequalities and algorithms that are actually used within CONCORDE. In any case, we would recommend that interested readers supplement their reading with recent survey papers such as Junger et al. (1995, 1997), Naddef (2002).

Despite this minor drawback, this is a useful, informative and highly readable text which, at the current price, is an absolute bargain.

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