Franz Rothlauf: Design of Modern Heuristics

Dario Landa-Silva

Springer

Springer

BOOK REVIEW

Franz Rothlauf: Design of Modern Heuristics
Springer, 2011, ISBN 978-3-540-72961-7

Dario Landa-Silva

Design of Modern Heuristics focuses on the application of heuristic search methods to tackle optimization problems and on explaining design aspects such as representation of solutions, variation operators, fitness functions, generation of initial solutions and search strategies. Although the emphasis is on combinatorial optimization problems such as travelling salesman, knapsack and minimum spanning tree, some of the concepts and techniques are also discussed in the context of continuous optimization problems. The book provides a brief but substantial introduction to the design of modern heuristic search methods. By this, Rothlauf refers mainly to algorithms that make iterative improvements to solutions by means of local search and recombination operators. That is, algorithms such as variable neighbourhood search, iterated local search, simulated annealing and genetic algorithms. Students involved in projects related to heuristic search would benefit enormously from reading it early in their studies. It provides a solid foundation which helps the reader to understand and interpret the vast number of published research articles on the development and the application of heuristic search techniques for optimization.

Part 1 gives the fundamentals. It helps the reader to understand the key concepts, principles and methods of optimization. The first chapter sets out very clearly the aim and the scope of the book and makes a high-level comparison between classical optimization and heuristic algorithms. However the introduction assumes that the reader is familiar with the fundamentals of search and optimization. Chapter one emphasizes the three key design choices discussed in the rest of the book: using exact or heuristic algorithms, which type of heuristic approach to implement, and how to incorporate problem domain knowledge into the heuristic algorithm. The second chapter provides clear and concise definitions of key concepts in search and computational complexity such as search space, local search, fitness landscapes,

D. Landa-Silva (✉)
School of Computer Science, University of Nottingham, Nottingham, UK
e-mail: dario.landasilva@nottingham.ac.uk

locality, ruggedness and decomposability. The third chapter provides overviews of various optimization techniques including analytical methods like simplex and interior-point methods and enumeration. Then it looks at heuristic methods including approximation algorithms, branch and bound, cutting planes and modern heuristics (simulated annealing is discussed in particular). Chapter three also looks at relaxation and rounding techniques in the context of solving mathematical programming models. Such relaxation and rounding methods are used to obtain an integer solution from a non-integer one and the limitations of such approaches are clearly explained and illustrated. The discussion of approximation algorithms and their relation to heuristic search is particularly valuable. The strengths and the limitations of the various optimization techniques are also discussed. Part one of the book ends by proposing five design aspects for modern heuristic algorithms: representation of solutions, variation operators, fitness function, generation of initial solutions and search strategy. Overall, part one of the book provides a concise but also rigorous overview of optimization techniques while clearly establishing the context for the application of modern heuristic search algorithms.

Chapters four to six in part two are the core of the book and focus on defining and discussing design aspects of modern heuristic algorithms. The reader is taken on a journey to understand four design aspects that are common to most heuristic algorithms and to understand some of the choices available to implement these types of algorithms for optimization. Section 4.1 gives a good discussion of the difficulties that users face when selecting a modern heuristic algorithm to tackle their real-world optimization problems. The rest of the chapter discusses the role and importance of solution representation, search operators, search operators, fitness function and initialization of solutions. Although not comprehensive, chapter four describes the important goals when designing these four components of a heuristic algorithm implementation. In order to fully grasp chapter four, less knowledgeable readers will also benefit from reading articles on specific applications of heuristic algorithms. Chapter five focuses on the search strategy. The discussion is organized into local search versus recombination-based search and after explaining their rationale and mechanisms, examples of modern heuristics that use each are outlined. This chapter provides summaries of different modern heuristic methods but the presentation could have been more effective by focusing on explaining the different search strategies and then referring to specific algorithms as examples. Chapter six goes further, discussing solution representations and search operators from the perspective of the locality property (i.e. the relationship between distance in the decision space and distance in the objective space between solutions) in local search. Chapter six also discusses ways to bias the search towards better solutions. Constructive heuristics, redundant representations, and knowledge of the problem domain are among the other issues discussed in this chapter. Overall, part two of the book is very good as it encourages the reader to think about the important choices when designing modern heuristic algorithms and the possible impact that such choices could have on the successful application of these algorithms to their optimization problems.

Part three consists of two chapters each of them presenting a case study to illustrate some of the issues discussed in part two of the book. Chapter seven is an

example of how locality and the genotype-phenotype mapping have an effect on the search ability of grammatical evolution and genetic programming. Chapter eight is a comprehensive case study that uses spanning tree problems to illustrate how knowledge of the problem domain can be incorporated to bias the search. Overall, part three, in particular chapter eight, is excellent and will help readers to grasp the issues discussed earlier in the book.

The book ends with a summary where Rothlauf clearly identifies the six key topics that are covered in the book: (1) guidelines to chose optimization methods according to the problem difficulty, (2) the role of locality and decomposability, (3) common design elements of modern heuristic algorithms, (4) role of intensification and diversification and ways to combine and control them when designing heuristics, (5) case study on basic design principles, and (6) case study on using problem domain knowledge to bias the search.

To conclude *Design of Modern Heuristics* is a must read book for anyone interested in modern heuristic algorithms development as it encourages the reader to focus on design decisions and not on implementation mechanisms. It is an excellent entry point to modern heuristic algorithms but although rigorous and substantial, the coverage of the topic is also brief and concise. This book is a valuable addition to the literature and should be considered key reading for students entering the exciting field of modern heuristic algorithms. One small criticism is the use of 'modern heuristics' to label the class of heuristic search techniques that use intensification and diversification, as the term modern will inevitably be perceived by some as meaning instead recent.