Preface

Optimization is a branch of applied mathematics and numerical analysis. Almost every problem in engineering, science, economics, and life can be formulated as an optimization or a search problem. While some of the problems can be simple that can be solved by traditional optimization methods based on mathematical analysis, most of the problems are very hard to be solved using analysis-based approaches. Fortunately, we can solve these hard optimization problems by inspirations from nature, since we know that nature is a system of vast complexity and it always generates a near-optimum solution.

Natural computing is concerned with computing inspired by nature, as well as with computations taking place in nature. Well-known examples of natural computing are evolutionary computation, neural computation, cellular automata, swarm intelligence, molecular computing, quantum computation, artificial immune systems, and membrane computing. Together, they constitute the discipline of computational intelligence.

Among all the nature-inspired computational paradigms, evolutionary computation is most influential. It is a computational method for obtaining the best possible solutions in a huge solution space based on Darwin's survival-of-the-fittest principle. Evolutionary algorithms are a class of effective global optimization techniques for many hard problems.

More and more biologically inspired methods have been proposed in the past two decades. The most prominent ones are particle swarm optimization, ant colony optimization, and immune algorithm. These methods are widely used due to their particular features compared with evolutional computation. All these biologically inspired methods are population-based. Computation is performed by autonomous agents, and these agents exchange information by social behaviors. The memetic algorithm models the behavior of knowledge propagation of animals.

There are also many other nature-inspired metaheuristics for search and optimization. These include methods inspired by physical laws, chemical reaction, biological phenomena, social behaviors, and animal thinking.

Metaheuristics are a class of intelligent self-learning algorithms for finding near-optimum solutions to hard optimization problems, mimicking intelligent processes and behaviors observed from nature, sociology, thinking, and other disciplines. Metaheuristics may be nature-inspired paradigms, stochastic, or

probabilistic algorithms. Metaheuristics-based search and optimization are widely used for fully automated decision-making and problem-solving.

In this book, we provide a comprehensive introduction to nature-inspired metaheuristical methods for search and optimization. While each metaheuristics-based method has its specific strength for particular cases, according to no free lunch theorem, it has actually the same performance as that of random search in consideration of the entire set of search and optimization problems. Thus, when talking about the performance of an optimization method, it is actually based on the same benchmarking examples that are representatives of some particular class of problems.

This book is intended as an accessible introduction to metaheuristic optimization for a broad audience. It provides an understanding of some fundamental insights on metaheuristic optimization, and serves as a helpful starting point for those interested in more in-depth studies of metaheuristic optimization. The computational paradigms described in this book are of general purpose in nature. This book can be used as a textbook for advanced undergraduate students and graduate students. All those interested in search and optimization can benefit from this book. Readers interested in a particular topic will benefit from the appropriate chapter.

A roadmap for navigating through the book is given as follows. Except the introductory Chapter 1, the contents of the book can be grossly divided into five categories and an appendix.

- Evolution-based approach is covered in Chapters 3–8:
  Chapter 3. Genetic Algorithms
  Chapter 4. Genetic Programming
  Chapter 5. Evolutionary Strategies
  Chapter 6. Differential Evolution
  Chapter 7. Estimation of Distribution Algorithms
  Chapter 8. Topics in Evolutionary Algorithms
- Swarm intelligence-based approach is covered in Chapters 9–15:
  Chapter 9. Particle Swarm Optimization
  Chapter 10. Artificial Immune Systems
  Chapter 11. Ant Colony Optimization
  Chapter 12. Bee Metaheuristics
  Chapter 13. Bacterial Foraging Algorithm
  Chapter 14. Harmony Search
  Chapter 15. Swarm Intelligence
- Sciences-based approach is covered in Chapters 2, 16–18:
  Chapter 2. Simulated Annealing
  Chapter 16. Biomolecular Computing
  Chapter 17. Quantum Computing
  Chapter 18. Metaheuristics Based on Sciences
- Human-based approach is covered in Chapters 19–21:

Chapter 19. Memetic Algorithms
Chapter 20. Tabu Search and Scatter Search
Chapter 21. Search Based on Human Behaviors

- General optimization problems are treated in Chapters 22–23:
  Chapter 22. Dynamic, Multimodal, and Constrained Optimizations
  Chapter 23. Multiobjective Optimization
- The appendix contains auxiliary benchmarks helpful to test new and existing algorithms.

In this book, hundreds of different metaheuristic methods are introduced. However, due to space limitation, we only give detailed description to a large number of the most popular metaheuristic methods. Some computational examples for representative metaheuristic methods are given. The MATLAB codes for these examples are available at the book website. We have also collected some MATLAB codes for some other metaheuristics. These codes are of general purpose in nature. The reader needs just to run these codes with their own objective functions.

For instructors, this book has been designed to serve as a textbook for courses on evolutionary algorithms or nature-inspired optimization. This book can be taught in 12 two-hour sessions. We recommend that Chapters 1–11, 19, 22 and 23 should be taught. In order to acquire a mastery of these popular metaheuristic algorithms, some programming exercises using the benchmark functions given in the appendix should be assigned to the students. The MATLAB codes provided with the book are useful for learning the algorithms.

For readers, we suggest that you start with Chapter 1, which covers basic concepts in optimization and metaheuristics. When you have digested the basics, you can delve into one or more specific metaheuristic paradigms that you are interested in or that satisfy your specific problems. The MATLAB codes accompanying the book are very useful for learning those popular algorithms, and they can be directly used for solving your specific problems. The benchmark functions are also very useful for researchers for evaluating their own algorithms.

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