

Comprehensive Metaheuristics Algorithms and Applications

Edited by

Seyedali Mirjalili

Center for Artificial Intelligence Research and Optimization,
Torrens University Australia, Brisbane, QLD, Australia
University Research and Innovation Center, Obuda University, Budapest, Hungary

Amir H. Gandomi

University of Technology Sydney, Sydney, Australia
University Research and Innovation Center, Obuda University, Budapest, Hungary



ACADEMIC PRESS

An imprint of Elsevier

Academic Press is an imprint of Elsevier
125 London Wall, London EC2Y 5AS, United Kingdom
525 B Street, Suite 1650, San Diego, CA 92101, United States
50 Hampshire Street, 5th Floor, Cambridge, MA 02139, United States
The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, United Kingdom

Copyright © 2023 Elsevier Inc. All rights reserved.

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher. Details on how to seek permission, further information about the Publisher's permissions policies and our arrangements with organizations such as the Copyright Clearance Center and the Copyright Licensing Agency, can be found at our website: www.elsevier.com/permissions.

This book and the individual contributions contained in it are protected under copyright by the Publisher (other than as may be noted herein).

Notices

Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors, assume any liability for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

ISBN 978-0-323-91781-0

For information on all Academic Press publications
visit our website at <https://www.elsevier.com/books-and-journals>

Publisher: Mara E. Conner
Acquisitions Editor: Chris Katsaropoulos
Editorial Project Manager: Clark M. Espinosa
Production Project Manager: Sreejith Viswanathan
Cover Designer: Vicky Pearson Esser

Typeset by STRAIVE, India



Contents

Contributors xvii

CHAPTER 1 Chaos theory in metaheuristics 1

Bahaeddin Turkoglu, Sait Ali Uymaz, and Ersin Kaya

1	Introduction.....	1
2	Chaos system and chaotic maps.....	2
2.1	Chebyshev map	3
2.2	Circle map	3
2.3	Gaussian and gauss-mouse map	4
2.4	Iterative map.....	4
2.5	Logistic map.....	5
2.6	Piecewise map.....	5
2.7	Sine map.....	7
2.8	Singer map.....	8
2.9	Sinusoidal map	8
2.10	Tent map.....	8
3	Chaotic strategies in metaheuristic optimization.....	10
3.1	Studies using different chaotic strategies in metaheuristics.....	11
4	An application with chaotic system	13
	References.....	16

CHAPTER 2 Metaheuristic approaches for solving multiobjective optimization problems 21

Selim Yilmaz and Sevil Sen

1	Introduction.....	21
1.1	Definitions	22
2	Related works	23
3	An overview of electric fish optimization	25
3.1	Initialization of population.....	25
3.2	Active and passive electrolocation phases	26
4	Multiobjective electric fish optimization algorithm	27
4.1	Population initialization	27
4.2	Frequency update	28
4.3	Active and passive electrolocation phases	30
5	Experiments	32
5.1	Benchmark problems	32
5.2	Performance metrics.....	32
5.3	Competitor algorithms	34

5	Conclusion and future work	374
	References.....	375
CHAPTER 20	Metaheuristics for clustering problems.....	379
	<i>Farhad Soleimanian Gharehchopogh, Benyamin Abdollahzadeh, Nima Khodadadi, and Seyedali Mirjalili</i>	
1	Introduction.....	379
2	Data clustering problem	380
3	Data clustering using metaheuristic algorithms.....	381
4	Results and discussion.....	382
	4.1 Results of conventional metaheuristics	382
	4.2 Results of recent metaheuristics	384
5	Conclusion and future works.....	391
	References.....	391
CHAPTER 21	Employment of bio-inspired algorithms in the field of antenna array optimization: A review	393
	<i>Krishanu Kundu and Narendra Nath Pathak</i>	
1	Introduction.....	393
2	Flower pollination algorithm.....	394
3	Cat Swarm Optimization.....	397
	3.1 Searching mode.....	397
	3.2 Tracking mode	397
4	Gravitational Search Algorithm	399
5	Case study.....	402
6	Conclusion	403
	References.....	403
CHAPTER 22	Foundations of combinatorial optimization, heuristics, and metaheuristics.....	407
	<i>Bochra Rabbouch, Hana Rabbouch, Foued Saâdaoui, and Rafea Mraïhi</i>	
1	Introduction.....	407
2	Combinatorial optimization problems.....	407
3	Analysis of algorithms.....	408
4	Complexity of algorithms.....	410
5	Modeling a CO problem.....	411
	5.1 Graph theory concepts	411
	5.2 Mathematical optimization model	412
	5.3 Constraint programming	416

Employment of bio-inspired algorithms in the field of antenna array optimization: A review

Krishanu Kundu^a and Narendra Nath Pathak^b

^aDepartment of Electronics and Communication Engineering, G.L. Bajaj Institute of Technology & Management, Greater Noida, Uttar Pradesh, India, ^bDepartment of Electronics and Communication Engineering, Dr. B.C. Roy Engineering College, Durgapur, West Bengal, India

1. Introduction

Numerous variants of Evolutionary Algorithms (EAs) have been developed in the past few decades. The concept of EAs was first presented by Alan Turing in 1948. EAs are based on the characteristics and evolution of several biological species. Much research has been carried on Genetic Algorithms (GAs) [1,2] as well as Evolutionary Programming (EP) approaches [3,4]. EAs can provide effective solutions for single as well as multiobjective optimization problems. The GA was invented by John Holland in 1962. This algorithm is based on genetics and the concept of evolution. Genetics is based on inheritance and deviation of biological properties. According to GA, a set of chosen individuals evolves toward an optimal solution with respect to the selective pressure of the fitness function. The Tabu Search (TS) algorithm was developed by Fred Glover in 1986 [5]. The tendency of local search to get stuck in the region consisting of numerous equal-fit solutions is GA's greatest disadvantage. TS eliminates this drawback. Ant Colony Optimization (ACO) was developed by Marco Dorigo in 1992 [6]. It is inspired by the foraging behavior of ants and their usage of pheromones to exchange information. Ants deposit pheromones on the ground to mark favorable paths. The idea is that the rest of the colony members will follow these demarcated paths to reach the destination (food source) more conveniently. A similar mechanism is used in ACO to solve optimization problems. Significant progress in the history of EAs occurred with the invention of Particle Swarm Optimization (PSO) by James Kennedy in 1995 [7]. This algorithm is inspired by the swarm intelligence of birds as well as fish. Another vector-based EA known as Differential Evolution (DE) was industrialized in 1997 [8]. The Harmony Search (HS) algorithm was introduced by Geem et al. in 2001 [9]. This algorithm is based on music, as finding harmony is the same as finding optimality in an optimization process. For optimization of Internet-hosting centers, Nakrani and Tovey suggested a new algorithm called the Honey Bee Algorithm (HBA) in 2004 [10]. Yang invented the Virtual Bee Algorithm (VBA) in 2005 [11]. In the same year, Karaboga developed Artificial Bee Colony (ABC) [12]. In 2006, Chu and Tsai discovered Cat Swarm Optimization (CSO), which is inspired by the seeking and tracing behavior of cats [13]. In 2008 [14], Yang proposed the Firefly Algorithm (FA), taking inspiration from the flashing behavior

COMPREHENSIVE METAHEURISTICS

Algorithms and Applications

Edited by **Seyedali Mirjalili, and Amir H. Gandomi**

Metaheuristics are general-purpose problem-solving Artificial Intelligence (AI) techniques that can be used to solve any sort of optimization problems, subject to the proper configuration. *Comprehensive Metaheuristics: Algorithms and Applications* presents the foundational underpinnings of metaheuristics and the broad scope of algorithms and real-world applications across a variety of research fields.

The book begins by presenting fundamentals, mathematical prerequisites, and conceptual approaches to provide readers with a solid foundation of understanding. After presenting multi-objective optimization, constrained optimization, and problem formation for metaheuristics, world-renowned authors give readers in-depth understanding of the full spectrum of algorithms and techniques. Algorithms and techniques covered in Part 1 include Genetic Algorithm, Particle Swarm Optimization, Krill Herd Algorithm, Cuckoo Search Algorithm, Bat Algorithm, Grey Wolf Optimizer, Salp Swarm Optimizer, Dragonfly Algorithm, Grasshopper Optimization Algorithm, Whale Optimization Algorithm, Equilibrium Optimizer, Marine Predator Algorithm, Arithmetic Optimization Algorithm, and Differential Evolution. Scientists, researchers, academicians, and practitioners who are interested in optimizing a process or procedure to achieve a goal will benefit from the case studies of real-world applications from different domains presented in Part 2 of the book.

This book takes a much-needed holistic approach, combining the most widely used metaheuristic algorithms with an in-depth treatise on multi-disciplinary applications of metaheuristics. Each algorithm is thoroughly analyzed to observe its behavior, providing a detailed tutorial on how to solve problems using metaheuristics. New case studies and research problem statements are also discussed, which will help researchers in their application of the concepts, algorithms, and techniques of metaheuristics.

Key Features

- World-renowned researchers and practitioners in metaheuristics present techniques, algorithms, and applications based on real-world case studies
- The book presents methodology for formulating optimization problems for metaheuristics
- The book teaches readers to analyze and tune the performance of a metaheuristic and integrate metaheuristics into other AI techniques
- All source code from the applications and algorithms is available online

About the Editors

Seyedali Mirjalili is a Professor at Torrens University Australia and the founding director of the Center for Artificial Intelligence Research and Optimization. He has published more than 300 journal articles with an H-index of 80. He has been listed on the top 1% of highly cited researchers and named one of the most influential researchers in the world by Web of Science since 2019. In 2021, The Australian newspaper named him the top researcher in Australia in artificial intelligence, evolutionary computation, and fuzzy systems. Professor Mirjalili is a senior member of the Institute of Electrical and Electronics Engineers (IEEE) and an editor of leading AI journals including *Neurocomputing*, *Applied Soft Computing*, *Advances in Engineering Software*, *Computers in Biology and Medicine*, *Healthcare Analytics*, *Applied Intelligence*, and *Decision Analytics*. His research interests are optimization, evolutionary computation, meta-heuristics, machine learning, and data science.

Amir H. Gandomi is Professor of Data Science and an Australian Research Council (ARC) Discovery Early Career Researcher Award (DECRA) fellow at the Faculty of Engineering and Information Technology, University of Technology Sydney (UTS). Prior to joining UTS, Prof. Gandomi was an assistant professor at Stevens Institute of Technology, USA, and a distinguished research fellow at the BEACON Center for the Study of Evolution in Action, Michigan State University, United States. Prof. Gandomi has published 330+ journal papers and 12 books which collectively have been cited 33,000+ times (H-index = 82). He has been named as one of the most influential scientific minds and received the Highly Cited Researcher award (top 1% publications and 0.1% researchers) from Web of Science for six consecutive years, 2017 to 2022. He also ranked 17th in GP bibliography among more than 15,000 researchers. He has received multiple prestigious awards for his research excellence and impact, such as the 2022 Walter L. Huber Prize, the highest level mid-career research award in all areas of civil engineering. His research interests are global optimisation and (big) data analytics using machine learning and evolutionary computations in particular.



ACADEMIC PRESS

An imprint of Elsevier

elsevier.com/books-and-journals

ISBN 978-0-323-91781-0



9 780323 917810