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Janusz Kacprzyk, Polish Academy of Sciences, Warsaw, Poland
e-mail: kacprzyk@ibspan.waw.pl

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Xin-She Yang
Editor

Nature-Inspired Algorithms and Applied Optimization

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Editor
Xin-She Yang
School of Science and Technology
Middlesex University
London
UK

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Preface

Nature-inspired algorithms, especially those based on swarm intelligence, have been successfully applied to solve a variety of optimization problems in real-world applications, and thus their popularity has also increased significantly in recent years. The applications of nature-inspired optimization algorithms have been very diverse, from engineering optimization to feature selection and from scheduling to vehicle routing. Consequently, significant progress has been made with several thousand new research papers published in these areas in the past few years.

This edited book reviews and summarizes the state-of-the-art developments in nature-inspired algorithms with an emphasis on applied optimization in real-world applications. The algorithms covered in this book includes ant colony optimization, bat algorithm, cuckoo search, directional bat algorithm, differential evolution, firefly algorithm, flower pollination algorithm, genetic algorithm, particle swarm optimization, simulated annealing and others. The application topics include classification, feature selection, computational geometry curve-fitting, economic load dispatch, knapsack problems, mass damper tuning, modelling to generate alternatives, hypercomplex representations, vehicle routing with time windows, wireless networks, wireless butterfly networks and others.

In addition, some rigorous theoretical analyses of nature-inspired algorithms have also been presented. An overview of mathematical tools used for analyzing nature-inspired algorithms is presented to provide an informal but relatively comprehensive summary. In addition, no free lunch theorems are reviewed in the context of metaheuristic optimization, and a convergence analysis of the cuckoo search algorithm has been carried out using Markov chain theory. All these can form a solid foundation for the in-depth understanding of the working mechanisms for such powerful algorithms.

It is worth pointing out that the developments in nature-inspired computing are so rapid that it is estimated that there are more than 150 algorithms and variants in the current literature. Thus, it is not possible and not our intention to review all of them. Instead, we have focused on the diversity and different characteristics of algorithmic structures and their capabilities in solving a wider range of problems in various disciplines.

Despite the success and popularity of nature-inspired algorithms, there are still some questions and issues that require further research. In addition to the lack of a rigorous mathematical framework for analyzing such algorithms, an important area of research is parameter tuning and parameter control. As almost all algorithms have algorithm-dependent parameters, their settings will largely influence the performance of the algorithm under consideration. However, how to efficiently tune an algorithm and vary/control its parameters is still unresolved. At the same time, it is also difficult to achieve a fine balance of exploration and exploitation for a given algorithm and a given set of problems. Furthermore, though no free lunch theorems hold for averaged performance for all problem sets, free lunches can potentially exist for a finite set of problems. After all, for a given type of problems, some algorithms (especially those uses the landscape-specific knowledge of the problem of interest) are more effective than others. Therefore, how to incorporate problem-specific knowledge effectively requires further studies.

Though there are many case studies in real-world applications, the scales of such applications are relatively moderate, and the number of design variables is typically about a few dozens to a few hundred. In reality, many applications can have thousands or even millions of design variables, such large-scale problems can be very challenging to solve because they are usually computationally expensive. It is not quite clear how to scale up the present techniques to tackle large-scale, computationally extensive optimization problems. Therefore, there is a strong need to review carefully the state-of-the-art developments concerning bio-inspired computation, swarm intelligence and optimization techniques in general so as to identify important research challenges, to inspire further research and to encourage innovative approaches that can ultimately help to develop effective tools for solving hard optimization problems in real-world applications.

This book is a timely attempt to achieve such objectives with emphasis on applied optimization. As a timely snapshot of the latest developments, this book will be interested by students, researchers and professionals in many disciplines, and can thus serve as an ideal reference for graduates and researchers in computer science, evolutionary computing, machine learning, computational intelligence and engineering, as well as engineers in various disciplines and industrial applications.

I would like to thank the reviewers for their constructive comments on the manuscripts of all the chapters during the peer-review process. I also would like to thank the editors, especially Drs. Thomas Ditzinger and Ravi Vengadachalam, and staff at Springer for their help and professionalism.

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Contents

Contributors

Zaid Abdi Alkareem Alyasseri School of Computer Sciences, Universiti Sains Malaysia (USM), Pulau Pinang, Malaysia; ECE Department - Faculty of Engineering, University of Kufa, Najaf, Iraq

Mohammed Azmi Al-Betar Department of Information Technology, Al-Huson University College, Al-Balqa Applied University, Irbid, Al-Huson, Jordan

Mohammed A. Awadallah Department of Computer Science, Al-Aqsa University, Gaza, Palestine

Gebrail Bekdaş Department of Civil Engineering, Istanbul University, Avcılar, Istanbul, Turkey

Roberto Carballedo Deusto Institute of Technology (DeustoTech), University of Deusto, Bilbao, Spain

Asma Chakri Industrial Mechanics Laboratory, Department of Mechanical Engineering, University Badji Mokhtar of Annaba (UBMA), Annaba, Algeria

Javier Del Ser TECNALIA, Derio, Spain; University of the Basque Country (UPV/EHU), Bilbao, Spain; Basque Center for Applied Mathematics (BCAM), Bilbao, Spain

E. Emary Faculty of Computers and Information, Cairo University, Giza, Egypt

Iztok Fister Jr. Faculty of Electrical Engineering and Computer Science, University of Maribor, Maribor, Slovenia

A.H. Gandomi School of Business, Stevens Institute of Technology, Hoboken, NJ, USA

Akemi Gálvez Faculty of Sciences, Department of Information Science, Toho University, Funabashi, Japan; Department of Applied Mathematics and Computational Sciences, University of Cantabria, Santander, Spain

Xing-Shi He College of Science, Xi'an Polytechnic University, Xi'an, China

J. Michael Herrmann The University of Edinburgh, Edinburgh, Scotland

Andrés Iglesias Faculty of Sciences, Department of Information Science, Toho University, Funabashi, Japan; Department of Applied Mathematics and Computational Sciences, University of Cantabria, Santander, Spain

T. Jayabarathi School of Electrical Engineering, VIT University, Vellore, India

Thomas Joyce The University of Edinburgh, Edinburgh, Scotland

Aylin Ece Kayabekir Department of Civil Engineering, Istanbul University, Avcılar, Istanbul, Turkey

Ahamad Tajudin Khader School of Computer Sciences, Universiti Sains Malaysia (USM), Pulau Pinang, Malaysia

Pedro Lopez-Garcia Deusto Institute of Technology (DeustoTech), University of Deusto, Bilbao, Spain

Carlos Loucera Department of Communications Engineering, Universidad de Cantabria, Santander, Spain

Sinan Melih Nigdeli Department of Civil Engineering, Istanbul University, Avcılar, Istanbul, Turkey

Eneko Osaba Deusto Institute of Technology (DeustoTech), University of Deusto, Bilbao, Spain

João Paulo Papa School of Sciences, São Paulo State University, Bauru, Brazil

T. Raghunathan School of Electrical Engineering, VIT University, Vellore, India

Haroun Ragueb Energy and Mechanical Engineering Laboratory, Department of Mechanical Engineering, Faculty of Engineering Sciences, University M'hamed Bougara of Boumerdes (UMBB) Avenue of Independence, Boumerdes, Algeria

Gustavo Henrique de Rosa Department of Computing, São Paulo State University, Bauru, Brazil

Quoc-Tuan Vien Middlesex University, London, UK

Fan Wang College of Science, Xi'an Polytechnic University, Xi'an, People's Republic of China

Yan Wang College of Science, Xi'an Polytechnic University, Xi'an, People's Republic of China

Xin-She Yang School of Science and Technology, Middlesex University, London, UK

Julian Scott Yeomans OMIS Area, Schulich School of Business, York University, Toronto, ON, Canada

Hossam M. Zawbaa Faculty of Computers and Information, Beni-Suef University, Beni Suef, Egypt