Jaya: An Advanced Optimization Algorithm and its Engineering Applications

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Dedicated to my parents (Lakshmi Narayana and Jayamma), dearest wife (Sujatha Rao) and beloved daughter (Jaya Lakshmi)

Foreword

It is a well-known fact that the traditional or classical optimization techniques impose some limitations on solving complex optimization problems. These limitations are mainly interrelated to their inherent search mechanisms. In order to overcome some of the deficiencies of the classical optimization procedures, metaheuristic optimization techniques (also called the advanced optimization techniques), mainly originated from artificial intelligence research, have been developed by the researchers. These algorithms are problem- and model-independent, and most of them are efficient and flexible. Research on these techniques is very active, and many new metaheuristics and improved versions of the older ones are continually appearing in the scientific literature.

In recent years, the field of optimization is witnessing a number of intelligent optimization algorithms, almost all of them based on a metaphor of some natural or man-made process. However, in this book, Prof. Ravipudi Venkata Rao describes a new optimization algorithm named as "Jaya" which is not based on any metaphor. The algorithm always tries to get closer to success (i.e., reaching the best solution) and tries to avoid failure (i.e., moving away from the worst solution). The algorithm strives to become victorious by reaching the best solution, and hence it is named as Jaya (a Sanskrit word meaning triumph or victory). The algorithm has been developed for the global optimization problems and can be used for solving the continuous and discrete optimization problems involving single objective or multiple or many objectives.

In addition to the basic Jaya algorithm, different variants of Jaya algorithm are described in this book. The applications of Jaya algorithm and its variants to different fields of engineering and sciences are also described. The readers may find that, in addition to being simple and powerful, the Jaya algorithm does not need any algorithm-specific parameters for its working, and hence it eliminates the disadvantages of many existing advanced optimization algorithms which face the burden of tuning of algorithm-specific parameters. Improper tuning of the algorithm-specific parameters may lead to local optima or inferior results.

The Jaya algorithm is gaining good reputation among the optimization research community. I believe that the researchers, scientists, engineers, and practitioners belonging to different disciplines of engineering and sciences (physical, life, and social) will find Jaya algorithm as a powerful tool to optimize the systems and processes. I hope the book will be a delight to the readers.

http://www.imiue.mech.pk.edu.pl

Kraków, Poland

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Preface

Keeping in view of the limitations of the traditional optimization techniques, the researchers have developed a number of advanced optimization algorithms popularly known as metaheuristics. The population-based metaheuristic algorithms have two important groups: Evolutionary Algorithms (EA) and swarm intelligence (SI)-based algorithms. Some of the recognized evolutionary algorithms are Genetic Algorithm (GA), Evolutionary Strategy (ES), Evolutionary Programming (EP), Differential Evolution (DE), etc. Some of the well-known swarm intelligence based algorithms are Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Artificial Bee Colony (ABC), Firefly (FF) algorithm, Cuckoo search algorithm (CSA), etc. Besides the evolutionary and swarm intelligence based algorithms, there are some other algorithms which work on the principles of different natural phenomena and some of them are Harmony Search (HS) algorithm, Gravitational Search Algorithm (GSA), Biogeography-Based Optimization (BBO) algorithm, League championship algorithm (LCA), etc.

All the abovementioned algorithms are population-based optimization methods and have some limitations in one or the other aspect. The main limitation of all the algorithms is that different parameters (i.e., algorithm-specific parameters) are required for proper working of these algorithms. Proper tuning of these parameters is essential for the searching of the optimum solution by these algorithms. A change in the algorithm-specific parameters changes the effectiveness of the algorithm. The improper tuning of algorithm-specific parameters either increases the computational effort or yields the local optimal solution. Considering this fact, in the year 2011, I had introduced the teaching–learning-based optimization (TLBO) algorithm which does not require any algorithm-specific parameters. The TLBO algorithm requires only common controlling parameters like population size and number of generations for its working. The TLBO algorithm has gained wide acceptance among the optimization researchers.

Keeping in view of the success of the TLBO algorithm, another algorithm-specific parameter-less algorithm was proposed by me in 2016 and was named as Jaya algorithm. However, unlike two phases (i.e., teacher phase and the learner phase) of the TLBO algorithm, the Jaya algorithm has only one phase. The Jaya algorithm is

simple in concept and has shown better performance as compared to other optimization algorithms. This algorithm can be used to obtain global solutions for continuous as well as discrete optimization problems with less computational effort and high consistency. In this book, *a posteriori* multi-objective versions of TLBO algorithm and Jaya algorithm are presented and applied to solve the single- and multi-objective optimization problems. In addition, improved versions of Jaya algorithm named as *Elitist Jaya*, *Quasi-Oppositional Jaya*, *Self-Adaptive Jaya*, *Self-Adaptive Multi-Population Jaya*, *Self-Adaptive Multi-Population Elitist Jaya, Multi-objective Jaya*, and *Multi-objective Quasi-Oppositional Jaya* are developed and applied to solve the engineering optimization problems.

The Jaya algorithm is gaining wide acceptance in the optimization research community in different fields of science and engineering. The major applications, as of March 2018, are found in the fields of electrical engineering, mechanical design, thermal engineering, manufacturing engineering, civil engineering, structural engineering, computer engineering, electronics engineering, biotechnology, and economics. Many research papers have been published in various reputed international journals of Elsevier, Springer-Verlag, Taylor & Francis and IEEE Transactions in addition to those published in the proceedings of international conferences. The number of research papers is continuously increasing at a faster rate. The algorithm has carved a niche for itself in the field of advanced optimization, and many more researchers may find this as a potential optimization algorithm.

This book provides a detailed understanding of the Jaya algorithm and its versions. Also, it provides the applications of Jaya algorithm and its versions in different fields of engineering. The computer codes of Jaya and its versions are also included in the book and these will be useful to the readers. The book is expected to be useful to various engineering professionals as it presents the powerful Jaya algorithm to make their tasks easier, logical, efficient, and effective. The book is intended for engineers, practitioners, managers, institutes involved in the optimization related projects, applied research workers, academics and graduate students in mechanical, manufacturing, electrical, computer, civil, and structural engineering. As such, this book is expected to become a valuable reference for those wishing to do research by making use of advanced optimization techniques for solving single- or multi-objective combinatorial design optimization problems.

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While every attempt has been made to ensure that no errors (printing or otherwise) enter the book, the possibility of these creeping into the book is always there. I will be grateful to the readers if these errors are pointed out. Suggestions for further improvement of the book will be thankfully acknowledged.

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