

Preface

Evolutionary algorithms (EAs), as well as other bio-inspired heuristics, are widely used to solve numerical optimization problems. However, in their original versions, they are limited to unconstrained search spaces i.e they do not include a mechanism to incorporate feasibility information into the fitness function. On the other hand, real-world problems usually have constraints in their models. Therefore, a considerable amount of research has been dedicated to design and implement constraint-handling techniques. The use of (exterior) penalty functions is one of the most popular methods to deal with constrained search spaces when using EAs. However, other alternative methods have been proposed such as: special encodings and operators, decoders, the use of multiobjective concepts, among others.

An efficient and adequate constraint-handling technique is a key element in the design of competitive evolutionary algorithms to solve complex optimization problems. In this way, this subject deserves special research efforts.

After a successful special session on constraint-handling techniques used in evolutionary algorithms within the Congress on Evolutionary Computation (CEC) in 2007, and motivated by the kind invitation made by Dr. Janusz Kacprzyk, I decided to edit a book, with the aim of putting together recent studies on constrained numerical optimization using evolutionary algorithms and other bio-inspired approaches.

The intended audience for this book comprises graduate students, practitioners and researchers interested on alternative techniques to solve numerical optimization problems in presence of constraints.

The book covers six main topics: The first two chapters refer to swarm-intelligence-based approaches. Differential evolution, a very competitive evolutionary algorithm for constrained optimization, is studied in the next three chapters. Two different constraint-handling techniques for evolutionary multiobjective optimization are presented in the two subsequent chapters. Two hybrid approaches, one with a combination of two nature-inspired heuristics and the other with the mix of a genetic algorithm and a local search operator, are detailed in the next two chapters. Finally, a constraint-handling technique

designed for a real-world problem and a survey on artificial immune system in constrained optimization are the subjects of the final two chapters.

Angel E. Muñoz-Zavala, Arturo Hernández-Aguirre and Enrique R. Villadiharce, present the adaptation of particle swarm optimization (PSO) to solve constrained optimization problems. The search capabilities improve by means of the following modifications: (1) a novel neighborhood structure to slow-down convergence, (2) two perturbation operators applied to the memory of each particle to favor diversity in the swarm and (3) a dynamic tolerance to handle equality constraints.

Guillermo Leguizamón and Carlos A. Coello Coello show an alternative approach to explore the boundary between the feasible and infeasible regions of the search space by means of two perspectives: (1) the use of *ad hoc* operators and (2) a more general operator. The authors couple their approach to two swarm intelligence search engines and a general evolutionary algorithm. These examples show that significant changes to the original version of each algorithm were not required.

Tetsuyuki Takahama and Setsuko Sakai propose an improved version of their ϵ DE algorithm to solve constrained optimization problems. A faster reduction of the relaxation for equality constraints in the ϵ constrained method coupled with a more frequent use of gradient-based mutation lead ϵ DE to provide even more competitive results in highly constrained problems. Furthermore, the authors present two mechanisms to keep variable values within the valid search space.

Janez Brest presents some modifications to his jDE algorithm to deal with constrained search spaces: (1) The use of the ϵ -constraint method, (2) a population size reduction, (3) the combination of three differential evolution variants, (4) different mechanisms to keep valid variable values and (5) a self-adaptive approach for two DE parameters (F and CR).

Efrén Mezura-Montes and Ana Gabriela Palomeque-Ortiz analyze the behavior of one deterministically-controlled and three self-adapted parameters in differential evolution for constrained optimization. The approach considers two parameters related to the constraint-handling technique. The experimental design analyzes (1) the online-behavior of the algorithm by using two performance measures and (2) the behavior shown by the parameter values.

Gary G. Yen presents a parameterless adaptive penalty function coupled with a distance measure for evolutionary multiobjective constrained optimization. The non-dominated sorting process then uses this modified fitness value. The number of feasible solutions in the population determines the behavior of the process, which may lead the search to either find more feasible solutions or locate the optimal solution.

Tapabrata Ray, Hemant Kumar Singh, Amitay Isaacs and Warren Smith emphasize the importance of maintaining infeasible solutions close to the feasible space in evolutionary multiobjective constrained optimization. The aim is to focus the search precisely on the boundaries of the feasible and infeasible regions.

Heder S. Bernardino, Helio J.C. Barbosa, Afonso C.C. Lemonge and Leonardo G. Fonseca combine the use of an artificial immune system to bias the search to the feasible region and a standard genetic algorithm. A clearing procedure, based on a niching mechanism, helps the search by improving the diversity in the population.

Marcella C. Araujo, Elizabeth F. Wanner, Frederico G. Guimarães and Ricardo H.C. Takahashi, improve a genetic algorithm with a local search operator based on quadratic and linear approximations for the objective function and the constraints of the problem as well. This operator defines a sub-problem with a quadratic objective function and quadratic and/or linear constraints, which is solved with a linear matrix inequality formulation. The aim of the special operator is to improve the satisfaction of constraints.

Akira Oyama presents a constraint-handling technique for aerodynamic and multidisciplinary design optimization. The approach is suitable for problems where the number of evaluations must be kept low due to the cost associated with each one of them. A combination of dominance in the constraints space and a niching mechanism helps the approach to reach the feasible region by requiring a low number of evaluations.

Nareli Cruz-Cortes presents the main proposals for constrained optimization based on an artificial immune system. The suggested taxonomy divides the approaches in “hybrid” (artificial immune systems with genetic algorithms) and “pure” schemes (i.e., those in which only artificial immune system processes and theories are adopted for the search engine).

The themes tackled in this book give evidence of the current research paths regarding constraint-handling in evolutionary optimization, such as the following:

- The generation of special mechanisms to focus the search on the boundaries of the feasible region and the importance of good infeasible solutions in the process.
- Constraint-handling in evolutionary multiobjective optimization.
- Parameter control mechanisms to keep the user from the fine-tuning process.
- Hybrid algorithms, such as global-local search, combination of heuristics-based approaches and the use of mathematical programming methods, in order to improve the search capabilities in constrained search spaces.
- The exploration of novel bio-inspired approaches such as particle swarm optimization, ant colony optimization, artificial immune systems, differential evolution, among others.
- Constraint-handling techniques able to perform well with a low number of objective function evaluations.

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