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Handbook of Optimization

From Classical to Modern Approach

Springer

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Preface

Optimization problems have belonged to the mathematical and technical publications with myriad applications for a considerable period of time. The relatively long optimization problem was solved by the now classical mathematical apparatus, which is based on infinitesimal calculus, methods of variations applied in functional areas or numerical methods. This apparatus enables and allows finding of the optimal solution for the simpler nature of the problems and solving complex problems usually sub-optimally. Computational and algorithmic complexity increases not only the complexity of the problem, but also by whether the subject of arguments optimized functions of one type or not. In the domain of current engineering problems, it is quite frequent to meet optimization problems in which the objective function arguments are defined in different domains (real, integer, logical, linguistic), but also with the fact that an argument may change in certain parts of the interval allowed values not only within its own field, and with various restrictions resulting from physical or economic feasibility. The same is true of the field values of objective function.

The fact that the classical optimization methods are not usually suitable for a certain class of problems, beyond a certain degree of difficulty or complexity, implies the fact that we need more powerful methods to access the wider engineering community, which facilitated the solution of complex optimization tasks. The term "not appropriate" here does not mean that classical methods cannot solve it, but implies that with increasing difficulty and complexity of the problem, it usually require a migration from analytical to numerical methods and also the increasing complexity of the problem does not automatically require only longer time to get a solution, but also participation of a suitable expert.

In the last 30-40 years a new type the so-called evolutionary algorithms have been created. The name of these algorithms comes from the "philosophy" or the basis on which these algorithms have been developed. They have several traits that make them widely applicable and also used, as well as the neglect of some "classic rigorous" mathematics. Their advantage is such that it is able to solve very hard optimization problems. It also requires a very good knowledge of an optimized problem and the ability to define problems correctly using utility functions, whose optimization

should lead to solving of the problem. Another advantage is that these algorithms are of the nature that its principle focus is always on the search for extreme global and not local, as is often the case with classical optimization methods, particularly numerical.

The disadvantage of these algorithms is that their results cannot be accurately predicted in advance, thanks to randomness presence inside such algorithms. Hence the fact that mathematical proof of these kinds of algorithms is quite difficult to formulate. In most cases, therefore, experiences with these algorithms, is what clearly demonstrates their viability and usability.

Simultaneous development of optimization methods and theoretical computer science has shown that with the advance of evolutionary techniques probably fosters new computer technologies based on parallelization. The future of scientific computing undoubtedly lies in parallelization of mathematical operations, especially when complexity of some problems is taken into consideration. Just taking into account the problems which include, in particular the exponential growth of $n!$, Which applies, inter alia, for the business traveller, for instance, then the size $n = 59$ the number of combinations can be obtained (10^{80}), a number which exceeds the estimated number of protons (10^{79}) in the universe. If we could write to each proton one possible combination for later evaluation and for problems with $n > 59$, then there is not enough memory in our universe to accomplish this task. Not to mention the length calculations (number of microseconds since the universe is supposed to exist, has 24 digits). It is therefore clear that unless some new mathematics is discovered, or at least legal mathematical shortcut through this "combinatorial maze", parallelization and the use of heuristic techniques combined with classical ones is the only feasible way. Classical and heuristic optimization techniques, specifically the evolutionary algorithms, are discussed in this book.

Chapter Authors Background: Chapter authors are to the best of our knowledge the originators or experts of the mentioned optimization methods and applications of described techniques. Hence, this book will be one of the books discussing the benefit from intersection of modern and classical methods of optimization.

Organization of the Chapters and Book Structure: The book consists of four parts. The first part is dedicated to classical methods and further to the theory and applications of classical optimization methods. Here are research papers that discuss, for example, dynamic optimization using analytic and evolutionary approaches and compare two different approaches or a chapter discussing bounded dual simplex algorithm. The application part discusses the intersection of bio-inspired optimization and game theory amongst others.

The heuristic part is significantly bigger and also divided into two parts, again being theory and applications. In the theoretical part can be found chapters about genetic programming, differential evolution, automatic design and optimization of fuzzy inference systems or relations between complex networks and dynamics of evolutionary algorithms. Lastly, the application part, contain chapters that discuss the use of evolutionary algorithms in a wide range of applications from evolutionary algorithms based on game theory and cellular automata with coalitions to chaotic

systems control. The book is based on original research and contains all important results.

Audience: The book will be an instructional material for senior undergraduate and entry-level graduate students in computer science, physics, applied mathematics and engineering, who are working in the area of classical optimization and evolutionary algorithms. Researchers from field of optimization will find this book a very useful handbook and starting step-stone. The book will also be a resource and material for practitioners who want to apply these methods to solve real-life problems in their challenging applications.

Motivation: The decision as why to write this book was based on a few facts. The main one is that the research field on optimization algorithms is an interesting area, which is under intensive research from many other branches of science today. Optimization algorithms with its applications can be found in biology, physics, economy, chemical technologies, air industry, job scheduling, space research (i.e. antenna design for space mission), amongst others. Due to the fact that modern optimization algorithms are capable of solving many problems including problems containing imprecise information or uncertainties, it is obvious that it can also be used on problems that suffer by noise or missing information. Together with classical techniques, evolutionary algorithms can be used to solve various tasks.

It is obvious that this book does not encompass all aspects of these two fields of research due to limited space. Only the main ideas and results are reported here. The authors and editors hope that the readers will be inspired to do their own experiments and simulations, based on information reported in this book, thereby moving beyond the scope of the book.

April 2012

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