Experimental Methods for the Analysis of Optimization Algorithms

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Editors

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Foreword

This book belongs on the shelf of anyone interested in carrying out experimental research on algorithms and heuristics for optimization problems.

The editors have brought together expertise from diverse sources to address methodological issues arising in this field. The presentation is wide-ranging, containing “big picture” discussions as well as more focused treatment of specific statistical techniques and their application. The emphasis throughout is on careful process and scientific rigor; the discussion is illuminated with many case studies, small tutorials, and references to the literature on optimization.

Don’t keep this book on the shelf: read it, and apply the techniques and tools contained herein to your own algorithmic research project. Your experiments will become more efficient and more trustworthy, and your experimental data will lead to clearer and deeper insights about performance.

Amherst, Massachusetts, February 2010 *Catherine C. McGeoch*

Foreword

Once upon a time, more exactly nearly half a century ago, when the first cybernetic machines, henceforth called computers, became available to academic institutions, a few people seemed to have waited for their iterative power to perform otherwise boring procedures like solving sets of linear equations, etc. Among other ideas to make use of their tireless working through loops of instructions was the simulation of organic evolution, the main subroutines of which are mutation, recombination, and natural selection. It was only a small step to imagine that by means of the same principles the design of technical devices, managerial tasks and other systems could be stepwise improved, if not even optimized. Competing methods from numerical mathematics were known, of course, but also their limitations to linear and quadratic dependencies between decision variables and objectives. In so-called black box situations where much more complex dependencies prevail and nonlinear constraints, stochastic disturbances, and the like hamper the search for optima, using evolutionary variation and evaluation processes showed up their capacities. Evolutionary algorithms thus were born during the 1960s, and they have matured ever since to a powerful and broadly accepted tool within many disciplines. Together with two other modern streams, artificial *neural networks* (NN) and *fuzzy systems* (FS), they have been subsumed into the so-called *computational intelligence* (CI) field, at least since 1994, when the first world congress on CI took place with its three subbranches NN, FS, and EC (evolutionary computation).

In the beginning of EC one had to be happy if one could rerun a numerical experiment a few times, for example with different seeds of the pseudo random generator or different start positions in the search space. Gathering a whole set of statistical data was unimaginable then, so that many open questions remained about the performance of the algorithms. What are those questions? It's not only an average value and its variance and skewness, or the best result out of a few runs that are interesting. One wants to know whether the ultimate result, i.e. using the algorithm specific stopping criterion, is always the same, whether and how it depends on the random numbers and starting points used. Further it may happen or not that fatal execution errors occur, like division by zero or extracting the square root of a negative number, or that the stopping criterion does not work properly – even if the optimum was found exactly. And what exactly does it mean to talk of four or eight precise digits or even more (which may depend on the hardware and on the system software handling real numbers, their mantissae and exponents)? Introducing common stopping criteria to compare different methods can easily deliver controversial results depending on the slopes of best (or average) intermediate results over the number of objective function values. Such slopes can not only have one crossing, but even two or more. Then the result depends heavily upon the number of admitted iterations, one method being quicker at the beginning while finally delivering mediocre final results, or the other way round, or even more complicated.

If you are interested in such questions, THIS is the book to look into. Here you will find even more aspects that are treated scientifically by the experts in that exciting domain offering their up-to-date know-how and even leading into philosophical domains.

Dortmund, February 2010 *Hans-Paul Schwefel*

Preface

Optimization algorithms are used to solve problems that arise in relevant research and application areas such as operations research, computer science, and engineering. During recent decades the experimental approach has been recognized and accepted in the analysis of these algorithms and a considerable body of research has been devoted to the development and establishment of an adequate scientific methodology for pursuing this kind of analysis. Statistical tools have become more and more popular. This book is written for researchers and practitioners of operations research and computer science who wish to improve the experimental assessment of their optimization algorithms with the final goal of improving their design. It collects prominent methodological works on different scenarios of experimental analysis.

The book consists of an introduction and 4 chapters written by the editors plus 11 chapters (including an appendix) written by *invited* contributors. All together the project involved 30 authors of 16 world-wide academic institutions.

The first part of the book lays the basis giving an all-round view of the issues involved in the experimental analysis of algorithms. The second part treats the characterization by means of statistical distributions of the algorithm performance in terms of solution quality, run-time, and other measures. The third part collects advanced methods from experimental design for configuring and tuning algorithms on a specific class of instances with the goal of using the least amount of experimentation and attaining sound conclusions. Several chapters are enriched with case studies.

Acknowledgments

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The book is the result of an inspiring and fruitful cooperation among the editors. First contacts were established during the Metaheuristic International Conference in Vienna in 2005 — followed by research visits and meetings during conferences.

We realized that problems that we had been trying to solve are of interest for a broader audience and not restricted to our own research areas (computational intelligence, operations research, mathematical optimization). Certainly, a milestone in the pathway to this book was the Workshop on Empirical Methods for the Analysis of Algorithms held in Reykjavik in 2006. We are thankful to all the participants of that workshop, many of whom became authors in this book and contributed to define its scope. Among them, a special mention goes to Catherine McGeoch whose perspective in the experimental analysis of algorithms highly influenced our views.

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Gummersbach, Odense, Coimbra, Dortmund,
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