Natural Computing Series

Joshua Knowles · David Corne ·
Kalyanmoy Deb (Eds.)

Multiobjective Problem Solving from Nature

From Concepts to Applications

With 178 Figures and 53 Tables

Springer

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To Julia and Luca
(JK)

To Mervyn Joseph Corne
(DC)

To Debjani
(KD)

Preface

To those unfamiliar with the field of evolutionary computation (EC), its problem-solving achievements must seem as magical, nearly, as the products of natural evolution itself. Air traffic control in four dimensions and robot teams that perform co-operative navigation; billion-transistor microchips and expert-level poker playing: these are not the future, but just some of the past trophies of the computer scientist's version of descent with modification.

Of course, behind these achievements lurks some human ingenuity, and liberal amounts of human perspiration. Practitioners of EC know that it does not do its magic at the mere twitch of a wand — and there is much work still ahead to understand how the next step-changes in capability will be reached.

But it remains true that EC demands relatively little from the practitioner in order to function with at least moderate success. Three ingredients, only, are needed: a way to express a solution as a data-structure, a way to modify instances of that data-structure, and a way to calculate the relative quality of two solutions. These are often simple things to design and implement, and consequently EC enjoys the labels 'generic' and 'flexible', able to tackle a huge diversity of problems.

In at least one important respect, however, the flexibility of EC was not fully realized until the emergence, in the 1980s, of *evolutionary multiobjective optimization* (EMO), now a burgeoning sub-discipline. Handling problems with multiple (conflicting) objectives *the way EMO does* can be profoundly useful. Consequently, EMO has spread rapidly, with some three- or four-thousand scientific papers on the subject being published since its inception, sprinkled among the literature of many disciplines.

Straightforward explanations of EMO's growth and appeal typically refer to the extra information it provides when it yields a diverse set of solutions. However, it turns out that EMO has *many* more feathers in its cap. We propose, in this book, a characterization of EMO that accounts more for recent innovations, and which shows where we think much of the future growth in EMO and its applications will be.

The view we adopt, and that the contributed chapters here make concrete, stems from the observation that, alongside ‘vanilla’ EMO research there has been a parallel development in terms of the *ways that multiple objectives can be used to help solve problems* in general. With notable and often remarkable effectiveness, we find, for example, that EMO techniques can accelerate the search process (for single objective problems), provide novel methods for machine learning, and reliably address dynamic optimization tasks. Similarly we see that EMO techniques can uncover novel design principles, help us to better understand natural complex systems, lead to better solutions even for problems that are unashamedly single-objective, and more.

Some of the ideas presented in this book have become apparent to one or other of the editors, in gradual degrees over the past half-dozen years or so. For JK, the idea of objective function decomposition, explored with Richard A. Watson and DC, in 2000–2001, is one of his earlier memories of thinking more flexibly about how EMO would be used in the future. JK has also been inspired by the recent work he did with Julia Handl on multiobjective clustering, particularly her innovative ideas about objectives as proxies for fundamentally unmeasurable criteria. For DC, an ever-present interest in the link between landscape topology and search dynamics (partially seeding the aforementioned ‘multiobjectivization’ — objective function decomposition — work) underpins his view that *every* realistic problem is a many-objective one, and he has come to see EMO as a way to help in understanding the ‘true’ structure of a problem while, or before, solving it. For KD, the concept of using EMO principles for other kinds of problem-solving tasks came to him in 1999, while working on another book. His earlier experiences with single-objective optimization algorithms had taught him that the dogged pursuit of a single specified goal often leads to a rapid loss of solution diversity, with many potentially powerful solutions being discarded; the possibility of using helper objectives to prevent this effect was thus intriguing. KD is also excited with the possibility of using EMO-found trade-off solutions for knowledge discovery in real-world problem-solving tasks.

Our combined interest in this area was piqued again, most recently, by the contributions to the MPSN workshop we co-chaired at PPSN in Reykjavik in 2006, where many of the ideas in this book finally came together and ‘brushed shoulders’ for the first time.

It has been a lot of work; if only science could disseminate itself. Since it can’t, we are most grateful to Ronan Nugent, the Springer editor, for his general support as well as his careful checkign of some of the txet. But, all in all, we have had great pleasure in compiling this book, and we do hope readers will find in it some exciting challenges for their future work. We hope so, or the various sacrifices and injustices imposed by us on our families during the book’s production will be wasted. So, enjoy it or else!

Manchester, Edinburgh, Helsinki
August 2007

Joshua Knowles
David Corne
Kalyanmoy Deb

Contents

Introduction: Problem Solving, EC and EMO
Joshua Knowles, David Corne, Kalyanmoy Deb 1

Part I Exploiting Multiple Objectives: From Problems to Solutions

Multiobjective Optimization and Coevolution
Sevan Gregory Ficici 31

Constrained Optimization via Multiobjective Evolutionary Algorithms
Efrén Mezura-Montes, Carlos A. Coello Coello 53

Tackling Dynamic Problems with Multiobjective Evolutionary Algorithms
Lam T. Bui, Minh-Ha Nguyen, Jürgen Branke, Hussein A. Abbass 77

Computational Studies of Peptide and Protein Structure Prediction Problems via Multiobjective Evolutionary Algorithms
Vincenzo Cutello, Giuseppe Narzisi, Giuseppe Nicosia 93

Can Single-Objective Optimization Profit from Multiobjective Optimization?
Frank Neumann, Ingo Wegener 115

Modes of Problem Solving with Multiple Objectives: Implications for Interpreting the Pareto Set and for Decision Making
Julia Handl, Joshua Knowles 131

Part II Machine Learning with Multiple Objectives

Multiobjective Supervised Learning
Jonathan E. Fieldsend, Richard M. Everson 155

Reducing Bloat in GP with Multiple Objectives
Stefan Bleuler, Johannes Bader, Eckart Zitzler 177

Multiobjective GP for Human-Understandable Models: A Practical Application
Katya Rodríguez-Vázquez, Peter J. Fleming 201

Multiobjective Classification Rule Mining
Hisao Ishibuchi, Isao Kuwajima, Yusuke Nojima 219

Part III Multiple Objectives in Design and Engineering

INNOVIZATION**: Discovery of Innovative Design Principles Through Multiobjective Evolutionary Optimization**
Kalyanmoy Deb and Aravind Srinivasan 243

User-Centric Evolutionary Computing: Melding Human and Machine Capability to Satisfy Multiple Criteria
Ian C. Parmee, Johnson A. R. Abraham, Azahar Machwe 263

Multi-competence Cybernetics: The Study of Multiobjective Artificial Systems and Multi-fitness Natural Systems
Amiram Moshaiov 285

Part IV Scaling up Multiobjective Optimization

Fitness Assignment Methods for Many-Objective Problems
Evan J. Hughes 307

Modeling Regularity to Improve Scalability of Model-Based Multiobjective Optimization Algorithms
Yaochu Jin, Aimin Zhou, Qingfu Zhang, Bernhard Sendhoff, Edward Tsang 331

Objective Set Compression
Edwin D. de Jong, Anthony Bucci 357

On Handling a Large Number of Objectives A Posteriori and During Optimization
Dimo Brockhoff, Dhish Kumar Saxena, Kalyanmoy Deb, Eckart Zitzler . 377

Index 405

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