Genetic Algorithms and Fuzzy Multiobjective Optimization

OPERATIONS RESEARCH/COMPUTER SCIENCE INTERFACES SERIES

Series Editors

Professor Ramesh Sharda
Oklahoma State University

Prof. Dr. Stefan Voß
Technische Universität Braunschweig

Other published titles in the series:

Brown, Donald/Scherer, William T.
Intelligent Scheduling Systems

Nash, Stephen G./Sofer, Ariela
The Impact of Emerging Technologies on Computer Science & Operations Research

Barth, Peter
Logic-Based 0-1 Constraint Programming

Jones, Christopher V.
Visualization and Optimization

Barr, Richard S./ Helgason, Richard V./ Kennington, Jeffery L.
Interfaces in Computer Science and Operations Research: Advances in Metaheuristics, Optimization, and Stochastic Modeling Technologies

Ellacott, Stephen W./ Mason, John C./ Anderson, Iain J.
Mathematics of Neural Networks: Models, Algorithms & Applications

Woodruff, David L.
Advances in Computational & Stochastic Optimization, Logic Programming, and Heuristic Search

Klein, Robert
Scheduling of Resource-Constrained Projects

Bierwirth, Christian
Adaptive Search and the Management of Logistics Systems

Laguna, Manuel / González-Velarde, José Luis
Computing Tools for Modeling, Optimization and Simulation

Stilman, Boris
Linguistic Geometry: From Search to Construction

GENETIC ALGORITHMS AND FUZZY MULTIOBJECTIVE OPTIMIZATION

MASATOSHI SAKAWA
Department of Artificial Complex Systems Engineering
Graduate School of Engineering
Hiroshima University
Higashi-Hiroshima, 739-8527, Japan

Springer Science+Business Media, LLC

Library of Congress Cataloging-in-Publication Data

Sakawa, Masatoshi, 1947-
Genetic algorithms and fuzzy multiobjective optimization / Masatoshi Sakawa.
p. cm. -- (Operations research/computer science interfaces series ; ORCS 14)
Includes bibliographical references and index.
ISBN 978-1-4613-5594-6 ISBN 978-1-4615-1519-7 (eBook)
DOI 10.1007/978-1-4615-1519-7
1. Genetic algorithms. 2. Mathematical optimization. 3. Fuzzy logic. 4. Fuzzy systems.
5. Fuzzy algorithms. I. Title. II. Series.

QA402.5 S247 2001
519.3--dc21 2001038702

Originally published by Kluwer Academic Publishers in 2002
Softcover reprint of the hardcover 1st edition 2002

Printed on acid-free paper.

To my parents,
Takeshige and Toshiko;
my wife Masako; and
my son Hideaki

Contents

Preface ix

1. INTRODUCTION 1
   - 1.1 Introduction and historical remarks 1
   - 1.2 Organization of the book 7

2. FOUNDATIONS OF GENETIC ALGORITHMS 11
   - 2.1 Outline of genetic algorithms 11
   - 2.2 Coding, fitness, and genetic operators 15

3. GENETIC ALGORITHMS FOR 0-1 PROGRAMMING 29
   - 3.1 Introduction 29
   - 3.2 Multidimensional 0-1 knapsack problems 30
   - 3.3 0-1 programming 39
   - 3.4 Conclusion 52

4. FUZZY MULTIOBJECTIVE 0-1 PROGRAMMING 53
   - 4.1 Introduction 53
   - 4.2 Fuzzy multiobjective 0-1 programming 54
   - 4.3 Fuzzy multiobjective 0-1 programming with fuzzy numbers 70
   - 4.4 Conclusion 81

5. GENETIC ALGORITHMS FOR INTEGER PROGRAMMING 83
   - 5.1 Introduction 83
   - 5.2 Multidimensional integer knapsack problems 84
   - 5.3 Integer programming 98
   - 5.4 Conclusion 104

6. FUZZY MULTIOBJECTIVE INTEGER PROGRAMMING 107
   - 6.1 Introduction 107
   - 6.2 Fuzzy multiobjective integer programming 108
   - 6.3 Fuzzy multiobjective integer programming with fuzzy numbers 118

6.4 Conclusion 131

7. GENETIC ALGORITHMS FOR NONLINEAR PROGRAMMING 133
7.1 Introduction 133
7.2 Floating-point genetic algorithms 134
7.3 GENOCOP III 141
7.4 Revised GENOCOP III 143
7.5 Conclusion 151

8. FUZZY MULTIOBJECTIVE NONLINEAR PROGRAMMING 153
8.1 Introduction 153
8.2 Multiobjective nonlinear programming 154
8.3 Multiobjective nonlinear programming problem with fuzzy numbers 159
8.4 Conclusion 167

9. GENETIC ALGORITHMS FOR JOB-SHOP SCHEDULING 169
9.1 Introduction 169
9.2 Job-shop scheduling 171
9.3 Genetic algorithms for job-shop scheduling 174

10. FUZZY MULTIOBJECTIVE JOB-SHOP SCHEDULING 189
10.1 Introduction 189
10.2 Job-shop scheduling with fuzzy processing time and fuzzy due date 191
10.3 Multiobjective job-shop scheduling under fuzziness 208

11. SOME APPLICATIONS 223
11.1 Flexible scheduling in a machining center 223
11.2 Operation planning of district heating and cooling plants 236
11.3 Coal purchase planning in electric power plants 253

References 273

Index 287

Preface

In the early 1970s, genetic algorithms were initially proposed by Holland, his colleagues, and his students at the University of Michigan as stochastic search techniques based on the mechanism of natural selection and natural genetics. Although genetic algorithms were not well-known at the beginning, since the First International Conference on Genetic Algorithms was held at the Carnegie-Mellon University in 1985, an enormous number of articles together with several significant monographs and books have been published, and nowadays, genetic algorithms make a major contribution to optimization, adaptation, and learning in a wide variety of unexpected fields.

As we look at recent applications of genetic algorithms to optimization problems, especially to various kind of discrete optimization problems, global optimization problems, or other hard optimization problems, we can see continuing advances. However, there seemed to be no genetic algorithm approach to deal with multiobjective programming problems, until Schaffer first proposed the so-called VEGA (Vector Evaluated Genetic Algorithm). Although VEGA was implemented to find Pareto optimal solutions of several multiobjective numerical optimization test problems, the algorithm seems to have bias toward some Pareto optimal solutions. Since then, several articles have been published to overcome the weakness of VEGA.

Unfortunately, however, these papers focused on multiobjective nonlinear programming problems with continuous variables and were mainly weighted toward finding Pareto optimal solutions, not toward deriving a compromise or satisficing (see p. 2) solution for the decision maker.

Although several excellent books in the field of genetic algorithm optimization have already been published in recent years, they focus mainly on single-objective discrete or other hard optimization problems under certainty. In spite of its urgent necessity, there seems to be no book that

is designed to present genetic algorithms for solving not only single-objective but also fuzzy and multiobjective optimization problems in a unified way.

In this book, the author is concerned with introducing the latest advances in the field of genetic algorithm optimization for 0-1 programming, integer programming, nonconvex programming, and job-shop scheduling problems under multiobjectiveness and fuzziness together with a wide range of actual applications on the basis of the author's continuing research works. Special stress is placed on interactive decision-making aspects of fuzzy multiobjective optimization for human-centered systems in most realistic situations when dealing with fuzziness.

The intended readers of this book are senior undergraduate students, graduate students, researchers, and practitioners in the fields of operations research, computer science, industrial engineering, management science, systems engineering, and other engineering disciplines that deal with the subjects of multiobjective programming for discrete or other hard optimization problems under fuzziness. In order to master all the material discussed in this book, the readers would probably be required to have some background in linear algebra and mathematical programming. However, by skipping the mathematical details, much can be learned about fuzzy multiobjective programming through genetic algorithms for human-centered systems in most realistic settings without prior mathematical sophistication.

The author would like to express his sincere appreciation to Professor Yoshikazu Sawaragi, chairman of the Japan Institute of Systems Research and emeritus professor of Kyoto University, Department of Applied Mathematics and Physics, for his invariant stimulus and encouragement ever since the author's student days at Kyoto University. The author is also thankful to Dr. Kosuke Kato of Hiroshima University for his contribution to Chapters 3 through 6 and Dr. Masahiro Inuiguchi of Osaka University and Dr. Isao Shiroumaru of The Chugoku Electric Power Co., Inc. for their contributions to Section 11.3. Further thanks are due to Dr. Kosuke Kato of Hiroshima University for reviewing parts of the manuscript and for his helpful comments and suggestions. The author also wishes to thank all of his undergraduate and graduate students at Hiroshima University. Finally, the author would like to thank Dr. Gary Folven, the Managing Editor of Kluwer Academic Publishers, Boston, for his assistance in the publication of this book.

Hiroshima, April 2001 *Masatoshi Sakawa*