

Evolutionary Computation

Techniques and Applications

Editors | Ashish M. Gujarathi and B. V. Babu

AAP | APPLE
ACADEMIC
PRESS

CRC CRC Press
Taylor & Francis Group

EVOLUTIONARY COMPUTATION

Techniques and Applications



Taylor & Francis

Taylor & Francis Group

<http://taylorandfrancis.com>

EVOLUTIONARY COMPUTATION

Techniques and Applications

Edited by

Ashish M. Gujarathi, PhD

B. V. Babu, PhD

AAP | APPLE
ACADEMIC
PRESS

Apple Academic Press Inc. | Apple Academic Press Inc.
3333 Mistwell Crescent | 9 Spinnaker Way
Oakville, ON L6L 0A2 | Waretown, NJ 08758
Canada | USA

©2017 by Apple Academic Press, Inc.

Exclusive worldwide distribution by CRC Press, a member of Taylor & Francis Group

No claim to original U.S. Government works

Printed in the United States of America on acid-free paper

International Standard Book Number-13: 978-1-77188-336-8 (Hardcover)

International Standard Book Number-13: 978-1-315-36638-8 (CRC/Taylor & Francis eBook)

International Standard Book Number-13: 978-1-77188-337-5 (AAP eBook)

All rights reserved. No part of this work may be reprinted or reproduced or utilized in any form or by any electric, mechanical or other means, now known or hereafter invented, including photocopying and recording, or in any information storage or retrieval system, without permission in writing from the publisher or its distributor, except in the case of brief excerpts or quotations for use in reviews or critical articles.

This book contains information obtained from authentic and highly regarded sources. Reprinted material is quoted with permission and sources are indicated. Copyright for individual articles remains with the authors as indicated. A wide variety of references are listed. Reasonable efforts have been made to publish reliable data and information, but the authors, editors, and the publisher cannot assume responsibility for the validity of all materials or the consequences of their use. The authors, editors, and the publisher have attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission to publish in this form has not been obtained. If any copyright material has not been acknowledged, please write and let us know so we may rectify in any future reprint.

Trademark Notice: Registered trademark of products or corporate names are used only for explanation and identification without intent to infringe.

Library and Archives Canada Cataloguing in Publication

Evolutionary computation : techniques and applications / edited by Ashish M. Gujarathi, PhD, B.V. Babu, PhD.

Includes bibliographical references and index.

Issued in print and electronic formats.

ISBN 978-1-77188-336-8 (hardcover).--ISBN 978-1-77188-337-5 (pdf)

1. Evolutionary computation. 2. Genetic algorithms. 3. Software engineering. I. Gujarathi, Ashish M., author, editor II. Babu, B. V., author, editor

TA347.E96E96 2016

006.3'823

C2016-905450-0

C2016-905451-9

Library of Congress Cataloging-in-Publication Data

Names: Gujarathi, Ashish M., editor. | Babu, B. V., editor.

Title: Evolutionary computation : techniques and applications / editors, Ashish M. Gujarathi, PhD, B.V. Babu, PhD.

Other titles: Evolutionary computation (Gujarathi)

Description: Toronto ; Waretown, New Jersey : Apple Academic Press, [2017] |

Includes bibliographical references and index.

Identifiers: LCCN 2016035469 (print) | LCCN 2016037827 (ebook) | ISBN 9781771883368 (hardcover : acid-free paper) | ISBN 9781771883375 (ebook) | ISBN 9781771883375 (ebook)

Subjects: LCSH: Evolutionary computation. | System engineering. | Mathematical optimization.

Classification: LCC TA347.E96 E96 2017 (print) | LCC TA347.E96 (ebook) | DDC 006.3/823--dc23

LC record available at <https://lccn.loc.gov/2016035469>

Apple Academic Press also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic format. For information about Apple Academic Press products, visit our website at www.appleacademicpress.com and the CRC Press website at www.crcpress.com

CONTENTS

<i>List of Contributors</i>	<i>ix</i>
<i>List of Abbreviations</i>	<i>xiii</i>
<i>Preface</i>	<i>xix</i>
<i>About the Editors</i>	<i>xxiii</i>

PART 1. THEORY AND APPLICATIONS

IN ENGINEERING SYSTEMS..... 1

- 1. Introduction..... 3**
Ashish M. Gujarathi and B. V. Babu
- 2. Bio-Mimetic Adaptations of Genetic Algorithm and Their Applications to Chemical Engineering..... 21**
Vibhu Trivedi and Manojkumar Ramteke
- 3. Surrogate-Assisted Evolutionary Computing Methods..... 55**
Saket Kansara, Sumeet Parashar, and Abdus Samad
- 4. Evolutionary Algorithms in Ironmaking Applications 81**
Tamoghna Mitra, Henrik Saxén, and Nirupam Chakraborti
- 5. Harmony Search Optimization for Multilevel Thresholding in Digital Images.....113**
Diego Oliva, Erik Cuevas, Gonzalo Pajares, Daniel Zaldivar, Marco Pérez-Cisneros, and Valentín Osuna-Enciso
- 6. Swarm Intelligence in Software Engineering Design Problems..... 163**
Tarun Kumar Sharma and Millie Pant
- 7. Gene Expression Programming in Nanotechnology Applications..... 195**
Pravin M. Singru, Vishal Jain, Nikilesh Krishnakumar, A. Garg, K. Tai, and V. Vijayaraghavan

PART 2. THEORY AND APPLICATIONS OF SINGLE OBJECTIVE

OPTIMIZATION STUDIES211

- 8. An Alternate Hybrid Evolutionary Method for Solving MINLP Problems 213**
Munawar A. Shaik and Ravindra D. Gudi

9. Differential Evolution for Optimal Design of Shell-and-Tube Heat Exchangers.....	239
Munawar A. Shaik and B. V. Babu	
10. Evolutionary Computation Based QoS-Aware Multicast Routing.....	269
Manas Ranjan Kabat, Satya Prakash Sahoo, and Manoj Kumar Patel	
11. Performance Assessment of the Canonical Genetic Algorithm: A Study on Parallel Processing Via GPU Architecture.....	301
Paulo Fazendeiro and Paula Prata	
12. An Efficient Approach for Populating Deep Web Repositories Using SFLA.....	321
Shikha Mehta and Hema Banati	
13. Closed Loop Simulation of Quadruple Tank Process Using Adaptive Multi-Loop Fractional Order PID Controller Optimized Using Bat Algorithm	349
U. Sabura Banu	
PART 3. THEORY AND APPLICATIONS OF SINGLE AND MULTIOBJECTIVE OPTIMIZATION STUDIES.....	373
14. A Practical Approach Towards Multiobjective Shape Optimization	375
G. N. Sashi Kumar	
15. Nature-Inspired Computing Techniques for Integer Factorization	401
Mohit Mishra, S. K. Pal, and R. V. Yampolskiy	
16. Genetic Algorithm Based Real-Time Parameter Identifier for an Adaptive Power System Stabilizer.....	421
Wael Mohamed Fayek and O. P. Malik	
17. Applied Evolutionary Computation in Fire Safety Upgrading.....	461
Jordanis A. Naziris, Nikos D. Lagaros, and Kyriakos Papaioannou	
18. Elitist Multiobjective Evolutionary Algorithms for Voltage and Reactive Power Optimization in Power Systems	483
S. B. D. V. P. S. Anauth and Robert T. F. Ah King	
19. Evaluation of Simulated Annealing, Differential Evolution and Particle Swarm Optimization for Solving Pooling Problems	513
Ying Chuan Ong, Shivom Sharma, and G. P. Rangaiah	

20. Performance Improvement of NSGA-II Algorithm by Modifying Crossover Probability Distribution	545
K .V. R. B. Prasad and P. M. Singru	
21. Evolutionary Algorithms for Malware Detection and Classification	569
Kamran Morovati and Sanjay S. Kadam	
<i>Index</i>	<i>611</i>



Taylor & Francis

Taylor & Francis Group

<http://taylorandfrancis.com>

LIST OF CONTRIBUTORS

Robert T. F. Ah King

Department of Electrical and Electronic Engineering, University of Mauritius, Reduit 80837, Mauritius

S. B. D. V. P. S. Anauth

Department of Electrical and Electronic Engineering, University of Mauritius, Reduit 80837, Mauritius

B. V. Babu

Vice Chancellor, Galgotias University, Greater Noida, Uttar Pradesh, India, E-mail: profbvbabu@gmail.com, Tel: +91-12-04806849

Hema Banati

Dyal Singh College, Department of Computer Science, University of Delhi, Delhi, E-mail: banatihema@hotmail.com

U. Sabura Banu

Professor Department of Electronics and Instrumentation Engineering, BS Abdur Rahman University, Vandalur, Chennai – 600048, Tamilnadu, India

Nirupam Chakraborti

Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Kharagpur, 712 302, West Bengal, India

Erik Cuevas

Departamento de Ciencias Computacionales, Universidad de Guadalajara, CUCEI, CU-TONALA, Av. Revolución 1500, Guadalajara, Jal, México

Wael Mohamed Fayek

Assistant Professor, Department of Electrical Engineering, Helwan University, Cairo, Egypt

Paulo Fazendeiro

University of Beira Interior, Department of Informatics, Portugal
Instituto de Telecomunicações (IT), Portugal, E-mail: fazendeiro@ubi.pt

A. Garg

School of Mechanical and Aerospace Engineering, Nanyang Technological University, 50 Nanyang Avenue, 639798, Singapore

Ravindra D. Gudi

Professor, Department of Chemical Engineering, Indian Institute of Technology Bombay, Powai, Mumbai, India, E-mail: ravigudi@iitb.ac.in, Tel: +91-22-25767231

Ashish M. Gujarathi

Department of Petroleum and Chemical Engineering, College of Engineering, Sultan Qaboos University, P.O. Box 33, Al-Khod, Muscat-123, Sultanate of Oman, Phone: +968 2414 1320, E-mail: ashishgujarathi@gmail.com, ashishg@squ.edu.om

Vishal Jain

Department of Mechanical Engineering, Birla Institute of Technology and Science, BITS Pilani, K.K. Birla Goa Campus, Zuarinagar, Goa 403726, India

Manas Ranjan Kabat

Department of Computer Science and Engineering, Veer Surendra Sai University of Technology, Burla, India, E-mail: kabatmanas@gmail.com

Sanjay S. Kadam

Evolutionary Computing and Image Processing Group (ECIP), Center for Development of Advanced Computing (C-DAC), Savitribai Phule Pune University Campus, Ganeshkhind, Pune-411007, India

Saket Kansara

ESTECO Software India Pvt. Ltd., Pune, Maharashtra, India

Nikilesh Krishnakumar

Department of Mechanical Engineering, Birla Institute of Technology and Science, BITS Pilani, K.K. Birla Goa Campus, Zuarinagar, Goa 403726, India

G. N. Sashi Kumar

Scientific Officer, Computational Studies Section, Machine Dynamics Division, Bhabha Atomic Research Centre, Trombay, Mumbai, India-400 085, Tel.: +91-22-2559-3611; E-mail: gnsk@barc.gov.in

Nikos D. Lagaros

Assistant Professor, Institute of Structural Analysis and Antiseismic Research, School of Civil Engineering, National Technical University of Athens, 15780, Greece

O. P. Malik

Professor Emeritus, Department of Electrical and Computer Engineering, University of Calgary, Alberta, Canada

Shikha Mehta

Dyal Singh College, Department of Computer Science, University of Delhi, Delhi, E-mail: mehtshikha@gmail.com

Mohit Mishra

Department of Computer Science and Engineering, Indian Institute of Technology (Banaras Hindu University), Varanasi, India

Tamoghna Mitra

Thermal and Flow Engineering Laboratory, Åbo Akademi University, Biskopsgatan 8, FI-20500 Åbo, Finland

Kamran Morovati

Information Security Center of Excellence (ISCX), Faculty of Computer Science, University of New Brunswick, 550 Windsor St., Head Hall E128, Fredericton, NB, E3B 5A3, Canada

Iordanis A. Naziris

PhD Candidate, Laboratory of Building Construction and Building Physics, Department of Civil Engineering, Aristotle University of Thessaloniki, 54124, Greece

Diego Oliva

Dpto. Ingeniería del Software e Inteligencia Artificial, Facultad Informática, Universidad Complutense de Madrid, 28040 Madrid, Spain, E-mail: doliva@ucm.es; pajares@ucm.es

Ying Chuan Ong

Department of Chemical and Biomolecular Engineering, National University of Singapore, Engineering Drive 4, Singapore 117585, Republic of Singapore

Valentín Osuna-Enciso

Departamento de Ingenierías, CUTONALA, Universidad de Guadalajara, Sede Provisional Casa de la Cultura – Administración, Morelos #180, Tonalá, Jalisco 45400, México, E-mail: valentin.osuna@cutonala.udg.mx

Gonzalo Pajares

Dpto. Ingeniería del Software e Inteligencia Artificial, Facultad Informática, Universidad Complutense de Madrid, 28040 Madrid, Spain, E-mail: doliva@ucm.es; pajares@ucm.es

S. K. Pal

Senior Research Scientist, Scientific Analysis Group, Defence Research and Development Organization, Ministry of Defence, Govt. of India, New Delhi, India

Millie Pant

Department of Applied Science and Engineering, Saharanpur Campus, IIT Roorkee, India

Kyriakos Papaioannou

Professor Emeritus, Laboratory of Building Construction and Building Physics, Department of Civil Engineering, Aristotle University of Thessaloniki, 54124, Greece

Sumeet Parashar

ESTECO North America, Novi, MI 48375, USA

Manoj Kumar Patel

Department of Computer Science and Engineering, Veer Surendra Sai University of Technology, Burla, India, E-mail: patel.mkp@gmail.com

Marco Pérez-Cisneros

Departamento de Ciencias Computacionales, Universidad de Guadalajara, CUCEI, CU-TONALA, Av. Revolución 1500, Guadalajara, Jal, México

K. V. R. B. Prasad

Professor, Department of E.E.E., MITS, P.B. No: 14, Kadiri Road, Angallu (V), Madanapalle – 517325, Chittoor District, Andhra Pradesh, India, E-mail: prasad_brahma@rediffmail.com

Paula Prata

University of Beira Interior, Department of Informatics, Portugal
Instituto de Telecomunicações (IT), Portugal, E-mail: pprata@di.ubi.pt

Manojkumar Ramteke

Department of Chemical Engineering, Indian Institute of Technology Delhi, Hauz Khas, New Delhi-110 016, India, E-mail: ramtekemanoj@gmail.com, mcramteke@chemical.iitd.ac.in

G. P. Rangaiah

Department of Chemical and Biomolecular Engineering, National University of Singapore, Engineering Drive 4, Singapore 117585, Republic of Singapore

Satya Prakash Sahoo

Department of Computer Science and Engineering, Veer Surendra Sai University of Technology, Burla, India, E-mail: sahoosatyaprakash@gmail.com

Abdus Samad

Department of Ocean Engineering, Indian Institute of Technology Madras, Chennai-600036, India

Henrik Saxén

Thermal and Flow Engineering Laboratory, Åbo Akademi University, Biskopsgatan 8, FI-20500 Åbo, Finland

Munawar A. Shaik

Associate Professor, Department of Chemical Engineering, Indian Institute of Technology Delhi, Hauz Khas, New Delhi, India, E-mail: munawar@iitd.ac.in, Tel: +91-11-26591038

Shivom Sharma

Department of Chemical and Biomolecular Engineering, National University of Singapore, Engineering Drive 4, Singapore 117585, Republic of Singapore

Tarun Kumar Sharma

Amity School of Engineering & Technology, Amity University Rajasthan, Jaipur, India

Pravin M. Singru

Department of Mechanical Engineering, Birla Institute of Technology and Science, BITS Pilani, K.K. Birla Goa Campus, Zuarinagar, Goa 403726, India

K. Tai

School of Mechanical and Aerospace Engineering, Nanyang Technological University, 50 Nanyang Avenue, 639798, Singapore

Vibhu Trivedi

Department of Chemical Engineering, Indian Institute of Technology Delhi, Hauz Khas, New Delhi-110 016, India

V. Vijayaraghavan

School of Mechanical and Aerospace Engineering, Nanyang Technological University, 50 Nanyang Avenue, 639798, Singapore

R. V. Yampolskiy

Associate Professor, Department of Computer Engineering and Computer Science, University of Louisville, KY, USA

Daniel Zaldívar

Departamento de Ciencias Computacionales, Universidad de Guadalajara, CUCEI, CU-TONALA, Av. Revolución 1500, Guadalajara, Jal, México

LIST OF ABBREVIATIONS

ABC	Artificial bee colony
ACO	Ant colony optimization
AGA	Adaptive genetic algorithm
AGSAA	Adaptive genetic simulated annealing algorithm
AHP	Analytic hierarchy process
AI	Artificial intelligence
ANN	Artificial neural networks
APSS	Adaptive power system stabilizer
AR	Aspect ratio
ARNA-GA	Adaptive RNA-GA
ARX	Auto regressive model with eXogenous signal
ASF	Achievement scalarization function
ASP	Active server pages
AVR	Automatic voltage regulator
BF	Bacterial foraging
BFA	Bacterial foraging algorithm
BFOA	Bacterial foraging optimization algorithm
BioGP	Bi-objective genetic programming
BITS	Birla Institute of Technology and Science
BNNT	Boron nitride nanotubes
BT	Bi-level thresholding
BW	Bandwidth factor
CAD	Computer aided design
CEC	Congress on Evolutionary Computation
CFD	Computational fluid dynamics
CGA	Cockroach GA
CNT	Carbon nanotubes
COCOMO	Constructive cost model
CPSS	Conventional power system stabilizer
CTT	Constrained tree traversal
CV	Constraint violations
DE	Differential evolution
DFS	Depth first search

DLOC	Developed line of code
DM	Decision maker
DNA-HGA	DNA based hybrid genetic algorithm
DNM	Deep net meta-crawler
DRI	Directly reduced iron
DSSM	Delayed S-shaped model
EAs	Evolutionary algorithms
EC	Evolutionary computation
EMO	Electromagnetism-like optimization
EP	Evolutionary programming
ES	Evolutionary strategies
EXMP	Exponential model
FCCU	Fluid catalytic cracking unit
FEM	Finite element methods
FLC	Fuzzy logic control
FN	False negative
FP	False positive
FSI	Fire safety index
FTA	Fault tree analysis
GA	Genetic algorithm
GMV	Generalized minimum variance
GNFS	General number sieve algorithm
GP	Genetic programming
GPUs	Graphic processing units
H DNA-GA	Hybrid DNA-GA
HLGA	Hajela and Lin's genetic algorithm
HM	Harmony memory
HMCR	Harmony-memory consideration rate
HS	Harmony search
HSA	Harmony search algorithm
HSMA	Harmony search multi-thresholding algorithm
IA	Inverse-anticodon
IACC	International Advance Computing Conference
ICA	Imperialist competitive algorithm
ICIT	International Conference on Industrial Technology
ICMST	International Conference on Mining Science and Technology
IDE	Integrated DE

IET	Institute of Engineering and Technology
IJCNN	International Joint Conference on Neural Networks
IL	Intermediate locations
IT	Information technology
ITAE	Integral time absolute error
JG	Jumping genes
JPSO	Jumping PSO
JSP	Java server pages
KLOC	Kilo line of code
LCI	Lower confidence interval
LO	Local optimum
LOC	Lines of code
LPPE	Low density polyethylene
M DNA-GA	Modified DNA-GA
MACK	Multivariate adaptive cross-validating Kriging
MACO	Multiobjective ACO
MAPE	Mean absolute percentage error
MAXGEN	Maximum number of generations
MCDM	Multi-criteria decision making
MCN	Maximum cycle number
MD	Molecular dynamics
MDE	Modified differential evolution
ME	Methodology
MFR	Mixed flow reactor
MGGP	Multi-gene genetic programming
MGO	Molecular geometry optimization
MIMO	Multi input multi output
MINLP	Mixed-integer nonlinear programming
MM	Maximum-minimum
MNFE	Mean number of function evaluations
MODE	Multiobjective differential evolution
MOEAs	Multiobjective evolutionary algorithms
MOO	Multiobjective optimization
MOPs	Multiobjective optimization problems
MRP	Multiple routing paths
MSE	Mean square error
MSIGA	Modified self-adaptive immune GA
MT	Multilevel thresholding

MU	Monetary units
NACO	Niched ant colony optimization
NEMS	Nano electro mechanical systems
NFE	Number of function evaluations
NI	National Instrument
NLP	Nonlinear programming
NM	Normal-mutation
NMP	Non-minimum-phase
NNs	Neural networks
NP	Nondeterministic polynomial time
NP	Number of population size
NPGA	Niched-Pareto genetic algorithm
NPI	Node parent index
NSGA	Nondominated sorting genetic algorithm
NSGA-II	Elitist nondominated sorting genetic algorithm
NWeSP	Next generation web services practices
OBL	Opposition based learning
OF	Objective functions
PA	Phthalic anhydride
PA	Pole assignment
PAES	Pareto archived evolution strategy
PAR	Pitch adjusting rate
PESA	Pareto envelope based selection algorithm
PET	Polyethylene terephthalate
PIRGA	Protein inspired RNA-GA
PLCs	Programmable logic controllers
PM	Polynomial mutation
PM10	Particulate matter
POS	Pareto-optimal solutions
POWM	Power model
PS	Pole shift
PSNR	Peak signal-to-noise ratio
PSO	Particle swarm optimization
PSSs	Power system stabilizers
QS	Quadratic sieve
RBF	Radial basis functions
RGA	Relative gain array
RJGGA	Real jumping gene genetic algorithm

RMSE	Root mean square error
RN	Random number
RSM	Response surface models
RSS	Random search space
SA	Sensitivity analysis
SA	Simulated annealing
SBX	Simulated binary crossover
SE mean	Standard error of mean
SEDP	Software engineering design problems
SFLA	Shuffled Frog Leaping Algorithm
SGA	Simple genetic algorithm
SI	Swarm intelligence
SIMD	Single instruction multiple data
SOP	Single objective optimization problem
SOR	Steam over reactant
SPEA	Strength-Pareto evolutionary algorithm
SPMD	Single program multiple data
SPP	Scout production period
SR	Success rate
SRP	Single routing path
STD	Standard deviation
SWCNT	Single-walled carbon nanotube
TBP	True boiling point
TCR	Time constant regulator
TEM	Transmission electron microscopy
TN	True negative
TP	True positive
TSP	Traveling salesman problem
UBBPSO	Unified bare-bones particle swarm optimization
UCI	Upper confidence interval
VFSA	Very fast-simulated annealing
WNYIPW	Western New York Image Processing Workshop



Taylor & Francis

Taylor & Francis Group

<http://taylorandfrancis.com>

PREFACE

Evolutionary computation has gained popularity in the recent past due to its several advantages over deterministic methods. Unlike deterministic methods, the evolutionary computation methods start with multiple solutions (both for single and multiobjective optimization (MOO) studies) so as to obtain wide range of initial population members. Evolutionary computation methods are also highly preferred to solve multiobjective optimization problems where conflicting objective functions are involved. The individual evolutionary computation method is expected to converge—to a single optimum solution (global solution) for single objective optimization and—to the Pareto optimal front for multiobjective optimization studies. As multiobjective optimization algorithm results in a set of solutions, the two goals are associated with each multiobjective optimization algorithm. The algorithm should converge to the true Pareto front and the algorithm should maintain a diverse set of solutions on the Pareto front. While achieving these two goals of MOO and dealing with two search spaces, the search for the true Pareto front in case of MOO study depends upon the following key issues, such as, number and type of decision variables (continuous, discontinuous) and nature of decision variable space; type of objective functions (minimization, maximization) and nature of objective space; nonlinearity and stiffness of model equations; type of constraints (equality and inequality); an ability of algorithm to handle the search spaces of objectives and decision variables. This book talks about recent advancement of evolutionary computation on both theory and applications.

This book is broadly organized in three sections. Part 1 contains 7 chapters on ‘Theory and applications in engineering systems.’ Part 2 has 6 chapters on ‘Theory and applications of single objective optimization studies.’ Part 3 has 8 chapters and is titled as ‘Theory and applications of single and multiobjective optimization studies’

Chapter 1 gives introduction on theory of evolutionary algorithms, single and multiobjective optimization. This chapter also includes paragraph on organization of book. In chapter 2 the Bio-Mimetic adaptations of genetic algorithm and their applications to chemical engineering is discussed. An overview of use of surrogate-assisted evolutionary algorithms in various