

---

# NEW OPTIMIZATION TECHNIQUES IN ENGINEERING

---

**Godfrey C. Onwubolu, Professor of Engineering, The University of the South Pacific, Fiji**

**B. V. Babu, Professor of Chemical Engineering, Birla Institute of Technology and Science, Pilani (India)**

---

## CONTENTS

---

Preface  
Contributors  
Acknowledgements

Chapter 1: Introduction

### **Part I: New Optimization Techniques**

Chapter 2: An Introduction to Genetic Algorithms for Engineering Applications  
Chapter 3: Memetic Algorithms  
Chapter 4: Scatter Search and Path Relinking: Foundations and Advanced Designs  
Chapter 5: Ant Colony Optimization  
Chapter 6: Differential Evolution  
Chapter 7: SOMA-Self-Organizing Migrating Algorithm  
Chapter 8: Discrete Particle Swarm Optimization: Illustrated by the Traveling Salesman Problem

### **Part II: Applications of New Optimization Techniques in Engineering**

#### **Part II.1: Chemical/Metallurgical Engineering**

Chapter 9: Applications in Heat Transfer  
Chapter 10: Mass Transfer  
Chapter 11: Applications in Reaction Engineering  
Chapter 12: Fluid Mechanics

#### **Part II.2: Civil/Environmental Engineering/ Interdisciplinary**

Chapter 13: New Ideas and Applications of Scatter Search and Path Relinking  
Chapter 14: Beams/Transportation: GA  
Chapter 15: Transportation: ACO  
Chapter 16: Genetic Algorithms in Irrigation Planning: A Case Study of Sri Ram Sagar Project, India

#### **Part II.3: Electrical/Electronics Engineering**

Chapter 17: Optimization of Helical Antenna Electromagnetic Pattern Field  
Chapter 18: Memetic Algorithms for VLSI design: the Gate Matrix Layout Problem

- Chapter 19: Parametric Optimization of a Fuzzy Logic Controller for Non-linear Dynamical Systems using Evolutionary Computation  
Chapter 20: DNA Coded GA: Rule Base Optimization of FLC for Mobile Robot

**Part II.4: Manufacturing/Industrial Engineering**

- Chapter 21: TRIBES application to the flow shop scheduling problem  
Chapter 22: Optimizing CNC Drilling Machine Operations: Traveling Salesman Problem-Differential Evolution Approach  
Chapter 23: Particle swarm optimization for the assignment of facilities to locations  
Chapter 24: Differential Evolution for the Flow Shop Scheduling Problem

**Part II.5: Mechanical/Aeronautical Engineering**

- Chapter 25: Evaluation of Form Errors to Large Measurement Data Sets Using Scatter Search  
Chapter 26: Mechanical engineering problem optimization by SOMA  
Chapter 27: Memetic Algorithms for Scheduling and Production & Control  
Chapter 28: Determination of Optimal Machining Conditions Using Scatter Search

**Part III: Extended Frontiers**

- Chapter 29: Extended Frontiers in optimization techniques

References

Index

---

## PREFACE

---

Presently, general-purpose optimization techniques such as Simulated Annealing, and Genetic Algorithms, have become standard optimization techniques. These optimization techniques commence with a single solution and then find the best from several moves made, and generally, past history is not carried forward into the present. Many researchers agree that firstly, having a population of initial solutions increases the possibility of converging to an optimum solution, and secondly, updating the current information of the search strategy from previous history is a natural tendency. Accordingly, attempts have been made by researchers to restructure these standard optimization techniques in order to achieve the two goals mentioned.

To achieve these two goals, researchers have made concerted efforts in the last one-decade in order to invent novel optimization techniques for solving real life problems, which have the attributes of memory update and population-based search solutions. This book describes these novel optimization techniques, which in most cases outperform their counterpart standard optimization techniques in many application areas. Despite these already promising results, these novel optimization techniques are still in their infancy and can most probably be improved. To date, researchers are still carrying out studies on sound theoretical basis and analysis to determine why some of these novel optimization techniques converge so well compared to their counterpart standard optimization techniques.

Interestingly, most books that have reported the applications and results of these novel optimization techniques have done so without sufficiently considering practical problems in the different engineering disciplines. This book, *New Optimization Techniques in Engineering* has three main objectives: (i) to discuss in the clearest way possible, these novel optimization techniques, (ii) to apply these novel optimization techniques in the conventional engineering disciplines, and (iii) to suggest and incorporate the improvements in these novel optimization techniques that are feasible as and when it is possible in the application areas chosen.

To achieve the first objective, Part I containing seven chapters have been written by the inventors of these novel optimization techniques or experts who have done considerable work in the areas (Memetic Algorithm, Scatter Search, Ant Colony Optimization, Differential Evolution, Self-Organizing Migrating Algorithm, Particle Swarm Optimization). Genetic Algorithm has been included for completeness since it is the progenitor of Memetic Algorithm. The contributor for Genetic Algorithm has been chosen, not as the inventor, but due to his expertise and contributions in Genetic Algorithms. To achieve the second objective, Part II contains several chapters in which researchers have applied these novel optimization techniques to different Engineering disciplines such as Chemical/Metallurgical Engineering, Civil/Environmental Engineering/Interdisciplinary, Electrical/Electronics Engineering, Manufacturing/Industrial Engineering, and Mechanical/Aeronautical Engineering. Firstly, the Engineering background is sufficiently given concerning the problem-domain, and then a novel optimization technique is applied. Consequently, Part II makes it easy for engineers and scientists to understand the link between theory and application of a particular novel optimization technique. To achieve the third objective, the possible improvements in these novel optimization techniques are identified, suggested and applied to some of the engineering problems successfully. Part III discusses newer areas, which are considered as extended frontiers.

The text serves as an instructional material for upper division undergraduates, entry-level graduate student, and a resource material for practicing engineers, research scientists, operations researchers, computer scientists, applied mathematicians, and management scientists. Those to purchase the book include upper division undergraduates or entry-level graduate students, academics, professionals and researchers of disciplines listed above, and libraries.

Godfrey C. Onwubolu and B. V. Babu  
January 2002

---

## CONTRIBUTORS

---

**B. V. Babu**, Professor & Head, Chemical Engineering & Engineering Technology Departments, In-charge of Workshop, E.S.D, Birla Institute of Technology and Science (BITS), Pilani-333 031 (Rajasthan), India. E-mail: [bvbabu@bits-pilani.ac.in](mailto:bvbabu@bits-pilani.ac.in) (CHAP. 1, 9, 10, 11 & 12)

**Laxmidhar Behera**, Assistant Professor, Department of Electrical Engineering, Indian Institute of Technology, Kanpur-208 016, India. E-mail: [lbehera@iitk.ac.in](mailto:lbehera@iitk.ac.in) (CHAP. 19)

**Antonella Carbonaro**, Department of Computer Science, University of Bologna via Sacchi, 3, 47023 Cesena, Italy. Email: [carbonar@csr.unibo.it](mailto:carbonar@csr.unibo.it) (CHAP. 15)

**Kai-Ying Chen**, Assistant Professor, Department of Industrial Engineering, National Taipei University of Technology, E-mail: [kychen@ntut.edu.tw](mailto:kychen@ntut.edu.tw) (CHAP. 25 & 28)

**Mu-Chen Chen**, Professor, Department of Business Management, National Taipei University of Technology, No. 1, Section 3, Chung-Hsiao E. Road, Taipei 106, Taiwan, ROC.  
Email: [bmcchen@ntut.edu.tw](mailto:bmcchen@ntut.edu.tw) / [iemcchen@yahoo.com.tw](mailto:iemcchen@yahoo.com.tw) (CHAP. 25 & 28)

**Maurice Clerc**, France Télécom Recherche & Développement, 90000, Belfort, France  
Email: [Maurice.Clerc@WriteMe.com](mailto:Maurice.Clerc@WriteMe.com) (CHAP. 8)

**Carlos Cotta**, Associate Professor, University of Málaga, Departamento de Lenguajes y Ciencias de la Computación Complejo Tecnológico (Despacho 3.2.49), Campus de Teatinos 29071-Málaga. SPAIN. Email: [ccottap@lcc.uma.es](mailto:ccottap@lcc.uma.es) (CHAP. 3 & 27)

**Kalyanmoy Deb**, Professor of Department of Mechanical Engineering, Indian Institute of Technology, Kanpur, Pin 208 016, INDIA. E-mail: [deb@iitk.ac.in](mailto:deb@iitk.ac.in) (CHAP. 2)

**Luca Maria Gambardella**, Director, IDSIA, Istituto Dalle Molle di Studi sull'Intelligenza Artificiale Galleria 2 6928 Manno-Lugano, Switzerland. Email: [luca@idsia.ch](mailto:luca@idsia.ch) (CHAP. 5)

**Fred Glover**, MediaOne Chaired Professor of Systems Science, University of Colorado; Visiting Hearin Professor, University of Mississippi; Research Director of the Hearin Center for Enterprise Science; School of Business Administration University of Mississippi University, MS 38677. Email: [fglover@bus.olemiss.edu](mailto:fglover@bus.olemiss.edu) (CHAP. 4 & 13)

**Lee Tong Heng**, Department of Electrical & Computer Engineering, National University of Singapore, 4 Engineering Drive 3, Singapore-117 576, E-mail: [eleleeth@nus.edu.sg](mailto:eleleeth@nus.edu.sg) (CHAP. 20)

**Hanno Hildmann**, University of Amsterdam, Department of Sciences, The Netherlands. Email: [hanno@dfki.de](mailto:hanno@dfki.de) (CHAP. 15)

**D. Nagesh Kumar**, Associate Professor, Civil Engineering Department, Indian Institute of Science, Bangalore-560 012, India. E-mail: [nagesh@civil.iisc.ernet.in](mailto:nagesh@civil.iisc.ernet.in) (CHAP. 16)

**Manuel Laguna**, Leeds School of Business, University of Colorado, Boulder, CO 80309-0419, USA. Email: Manuel.Laguna@Colorado.edu (CHAP. 4 & 13)

**Fabio de Luigi**, Dept. Computer Science, University of Ferrara, Italy. Email: f.deluigi@unife.it (CHAP. 5)

**Jouni Lampinen**, Department of Information Technology, Laboratory of Information Processing, Lappeenranta University of Technology, P.O.Box 20, FIN-53851 Lappeenranta, Finland. E-mail: Jouni.Lampinen@lut.fi (CHAP. 6 & 26)

**Alexandre Linhares**, Adjunct Professor, Brazilian School of Business and Public Administration, FGV, Praia de Botafogo 190/426, Rio de Janeiro 22257-970. Email: linhares@fgv.br (CHAP. 18)

**Vittorio Maniezzo**, Professor, Department of Computer Science, University of Bologna via Sacchi, 3, 47023 Cesena, Italy. Email: maniezzo@csr.unibo.it (CHAP. 5 & 15)

**Rafael Marti**, Departamento de Estadística e Investigación Operativa, Facultad de Matemáticas, Universidad de Valencia, C/ Dr. Moliner 50, 46100 Burjassot, Valencia, Spain. E-mail: Rafael.Marti@uv.es (CHAP. 4 & 13)

**Alexandre de Sousa Mendes**, Universidade Estadual de Campinas - UNICAMP Faculdade de Engenharia Elétrica e de Computação – FEEC Departamento de Engenharia de Sistemas - DENSIS C.P. 6101 - CEP 13083-970, Campinas - SP - Brazil E-mail: asmendes@yahool.com (CHAP.3, 18 & 27)

**Pablo Moscato**, Senior Lecturer and Postgraduate Director for Computer Science, School of Electrical Engineering and Computer Science, Faculty of Engineering and Built Environment, The University of Newcastle, Callaghan, 2308 New South Wales, Australia. Email: moscato@cs.newcastle.edu.au (CHAP. 3, 18, & 27)

**Godfrey C. Onwubolu**, Professor and Chair of Engineering, Department of Engineering, The University of the South Pacific, PO Box 1168, Suva, FIJI. Email: onwubolu\_g@usp.ac.fj (CHAP. 1, 21, 22, 23, & 24)

**Panos M. Pardalos**, Professor and Co-Director, Center for Applied Optimization, Industrial and Systems Engineering Department, 303 Weil Hall, University of Florida, PO Box 116595, Gainesville, FL 32611-6595, Email: pardalos@ufl.edu / pardalos@cao.ise.ufl.edu (CHAP. 29)

**Xiao Peng**, Department of Electrical & Computer Engineering, National University of Singapore, 4 Engineering Drive 3, Singapore-117 576, E-mail: engp0525@nus.edu.sg (CHAP. 20)

**K. Srinivasa Raju**, Assistant Professor, Civil Engineering Group, Birla Institute of Technology and Science (BITS), Pilani -333 031 Rajasthan, India. Email: ksraju@bits-pilani.ac.in (CHAP. 16)

**K. S. Reddy**, Associate Professor, Department of Civil Engineering, Indian Institute of Technology, Kharagpur-721 302, India. E-mail: ksreddy@civil.iitkgp.ernet.in (CHAP. 14)

**Anuraganand Sharma**, Computer Section, Colonial, Suva, Fiji. Email: ANDS@Colonial.com.au (CHAP. 23)

**Rainer Storn**, Infineon AG, TR PRM AL, Balanstr. 73, D-81541 Muenchen, Germany / International Computer Science Institute 1947 Center Street, Suite 600, Berkeley, CA 94704-1198. E-mail: rainer.storn@infineon.com / storn@icsi.berkeley.edu (CHAP. 6)

**Prahlad Vadakkepat**, Assistant Professor, Department of Electrical & Computer Engineering, National University of Singapore & General Secretary, Federation of International Robot-soccer Association, Singapore, E-mail: prahlad@nus.edu.sg (CHAP. 20).

**Ivan Zelinka**, Tomas Bata University in Zlin, Faculty of Technology, Institut of Information Technologies, Mostni 5139, Zlin 760 01, Czech Republic. Email: zelinka@ft.utb.cz (CHAP. 7, 17, & 26)