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Vol. 379. Ferrante Neri, Carlos Cotta, and Pablo Moscato (Eds.)
Handbook of Memetic Algorithms, 2012
ISBN 978-3-642-23246-6

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Handbook of Memetic Algorithms

Springer

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ISBN 978-3-642-23246-6 e-ISBN 978-3-642-23247-3

DOI 10.1007/978-3-642-23247-3

Studies in Computational Intelligence ISSN 1860-949X

Library of Congress Control Number: 2011938286

Typeset & *Cover Design:* Scientific Publishing Services Pvt. Ltd., Chennai, India.

Printed on acid-free paper

9 8 7 6 5 4 3 2 1

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If the world doesn't adapt itself to you, you have to adapt yourself to it. (Gil Grissom)

Imagination could conceive almost anything in connection with this place. (Howard Phillips Lovecraft)

We must be the change we want to see in the world. (Mahatma Gandhi)

To my friends in Jyväskylä and worldwide, to my parents in Bari, global thanks for patience and support (Ferrante Neri)

To Rocío(s), Carlos and Alicia, the local-optimizers of my life (Carlos Cotta)

To those that in elementary schools teach our children about the power of evolution, and to those that use this power to make the world a better place (Pablo Moscato)

Preface

Memetic Algorithms (MAs) are computational intelligence structures combining multiple and various operators in order to address optimization problems. The diversity in the operator selection is at the basis of MA success and their capability of facing complex problems. Besides the details correlated to specific implementations, the importance and need of MAs is in the fact that they opened a new scenario in front of the scientific community. More specifically, MAs suggested to the computer science community that optimization problems can be more efficiently tackled by hybridizing and combining existing algorithmic structures rather than using existing paradigms. A crucially important contribution of MAs has been to offer a new perspective in algorithmic design. Before MA diffusion, the various paradigms were considered as "separated islands" to be elected as a solver for a given problem. On the contrary, MAs assume that a paradigm should not be necessarily selected. A solver can be generated by combining the strong points of various paradigms and obtaining a solver which is capable to outperform each paradigm, separately. This approach is the basics of the problem oriented algorithmic design which is, on one hand, the natural consequence of the No Free Lunch theorems, on the other hand, the founding concept for the automatic and real time design of problem solvers. The latter will likely be the future of computational intelligence as machines, in the future, will need to analyse and "understand" the problems before automatically proposing a suitable solver.

This book organizes, in a structured way, all the the most important results in the field of MAs since their earliest definition until now. This is one of the few books explicitly addressing MAs, algorithmic aspects, and specific implementations and is the only book which offers a systematic set of "recipes" to tackle, by means of memetic approaches, a broad set of optimization problems. Optimization in the presence of both discrete and continuous representation is analysed as well as constrained and multi-objective problems in both stationary case and in the presence of uncertainties. Each chapter describes the algorithmic solutions for facing one of the above-mentioned problems. A big emphasis is also given to the automatic coordination of algorithmic components by means of self-adaptive, co-evolutionary, and diversity-adaptive schemes. In addition, this book attempts to be self-consistent as

it gives a description of a set of possible modules composing a MA. In addition, a set of successful examples in real-world applications in engineering is also given.

The book is structured in four parts. In the first part, containing Chapters 1–4, the basic concepts and elements composing Memetic Algorithms (MAs) are introduced. Chapter 1 defines basic concepts and definitions about optimization, complexity and metaheuristics. Chapter 2 describes the general structure and issues about Evolutionary Algorithms (EAs). General issues concerning the operation of EAs are discussed and different EA variants presented. Then, the problem of choosing the right EA instance, that is, the problem of designing and tuning evolutionary algorithms is presented. Chapter 3 defines Local Search and gives some examples of Local Search Algorithms by distinguishing the main algorithmic structures in continuous and combinatorial spaces. Chapter 4 gives a definition of MA, analyzes the reason of its success and distinguishes between MAs and Memetic Computing.

In the second part, containing Chapters 5–14, methodological aspects about algorithmic design and how to handle problem difficulties are studied. For each class of problems a review on the subject is given and some study cases are displayed for clarity. Chapter 5 discusses parametrization problems and balance of global and local search within MA frameworks. MAs in discrete and combinatorial optimization problems are analyzed in Chapters 6 and 7, respectively. Chapter 6 focuses on the design of semantic combination operators, development of dedicated local search procedures and management of population diversity. Other important issues, such as design of rich evaluation functions and constraint handling techniques, are also discussed. Two case studies with the purpose of showing how these issues can be effectively implemented in practice are also included in Chapter 6. Combinatorial problems and MA performance is the main focus of Chapter 7 where the concept of fitness landscapes is introduced and advanced fitness landscape analysis techniques are presented. A comparative analysis of the performance is carried out for the Travelling Salesman Problem an the Binary Quadratic Programming Problem. MAs for continuous optimization are presented in Chapter 8 after an overview on popular global optimizers for continuous problems. Particularities of memetic approaches for continuous optimization are highlighted in a novel taxonomy. Constrained optimization problems are addressed in Chapter 9 where a review on MAs for constrained problems is given and and two algorithmic implementations are presented in greater details. In the subsequent two chapters, the automatic coordination of local search components within evolutionary frameworks is discussed. Chapter 10 discusses diversity-based adaptive systems and focuses on fitness diversity techniques for adaptive MAs. A comparative analysis of recently proposed diversity metrics is also given. Chapter 11 presents recent research results about self-adaptive evolution of the memes and co-evolutionary MAs. It is shown how adaptive schemes containing local search information encoded within solutions and evolving in parallel populations connected to the population of solutions can lead to the design of flexible memetic frameworks. The chapter describes a framework for this research and previous findings with self-adaptive methods concerning representation and scalability. It then goes on to consider in more depth issues relevant to co-evolutionary systems such as credit assignment and the ratio of population sizes which can be thought

of as the memetic "load" that an evolving population can support. Chapter 12 discusses another trending topic in MAs, namely the combination of MAs with complete techniques (i.e., techniques capable of provably finding the global optimum, or guaranteeing approximation bounds), and with incomplete variants thereof. The book also focuses on MAs for specific classes of optimization problems. Chapter 13 presents MA implementations for multi-objective optimization problems. Chapter 14 shows recent MA implementations for optimization problems in the presence of uncertainties.

The third part contains Chapter 15 and 16 and gives some examples of domain specific MA implementations and applications in given fields. Chapter 15 presents relevant MA applications in engineering and design while Chapter 16 summarizes the most significative applications of MAs in Bioinformatics.

Finally the fourth part, containing the epilogue of this book, Chapter 17 within the context of biographical notes and anecdotes, present the ideas that guided MAs at their earliest definition stage and how many open problems posed before can guide the future development of the field.

We wish to express our sincere gratitude for all the external contributors of this book who allowed us to produce a solid and high quality work covering a large spectrum in the field of MAs. Last but not least, we thank our families and friends for the constant support during the production of this volume.

Jyväskylä, Finland, June 2011 Ferrante Neri
Málaga, Spain, June 2011 Carlos Cotta
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Acronyms

ACA	Adaptive Checkers Algorithm
ACO	Ant Colony Optimization
ADM	Adaptive Dual Mapping
AES	Average Evaluation of Success
AGLMA	Adaptive Global-Local Memetic Algorithm
AnDE	Annealing Differential Evolution
ANN	Artificial Neural Network
B&B	Branch and Bound
BE	Bucket Elimination
BLX	Blended Crossover
BP	Backpropagation algorithm
BQP	Binary quadratic Programming
BS	Beam Search
CA	Checkers Algorithms
CDMOMA	Cross-Dominance Multi-Objective Memetic Algorithm
CE	Controlled Evaluation
CHC	Cross generational elitist selection, Heterogeneous recombination, and Cataclysmic mutation
CI	Computational Intelligence
CMA-ES	Covariance Matrix Adaptation Evolution Strategy
COMA	Co-evolutionary Memetic Algorithm
COP	Combinatorial Optimization Problem
ConOP	Constrained Optimization Problem
CVRP	Capacitated Vehicle Routing Problem
CCVRP	Cumulative Vehicle Routing Problems
DE	Differential Evolution
DFSS	Design For Six Sigma
DiBIP	Diversity-Based Information Preservation Crossover
DOR	Dynastically Optimal Recombination

DPX	Distance Preserving Crossover
DT	Discrete Tomography
EA	Evolutionary Algorithm
EC	Evolutionary Computation
EDA	Estimation of Distribution Algorithm
EIT	Electrical Impedance Tomography
EMDE	Enhanced Memetic Differential Evolution
EO	Extremal Optimization
EP	Evolutionary Programming
ET	Exact Technique
FAMA	Fast Adaptive Memetic Algorithm
FDA	Fitness Diversity Adaptation
FDC	Fitness Distance Correlation
FET	Full Employment Theorem
FPGA	Field Programmable Gate Array
FPT	Fixed-Parameter Tractable
GA	Genetic Algorithm
GARSS	Genetic Algorithm with Robust Selection Scheme
GCHC	Greedy Crossover Hill Climbing
GP	Genetic Programming
GPX	Greedy Partition Crossover
HC	Hill Climbing
H-IFF	Hierarchical-if-and-only-if
HJA	Hooke-Jeeves Algorithm
HK	Held-Karp bound
IDEA	Infeasibility Driven Evolutionary Algorithm
IEMA	Infeasibility Empowered Memetic Algorithm
ILK	Iterated Lin-Kernighan heuristic
IPE	Inexact Pre-Evaluation
k-COLOR	graph k-Coloring Problem
LKH	Lin-Kernighan Heuristic
LP	Linear Programming
LS	Local Search
LSD	Least Significant Difference
LTFE	Life Time Fitness Evaluation
MA	Memetic Algorithm
MaxCMO	Maximum Contact Map Overlap
MAX-SAT	Maximum Satisfiability
MC	Memetic Computing
MC-VRP	Multi-Compartment Vehicle Routing Problem
MDE	Memetic Differential Evolution
MOEA/D	Multi-Objective Evolutionary Algorithm based on Decomposition
MOGLS	Multi-Objective Genetic Local Search

MOMA	Multi-Objective Memetic Algorithm
MOO	Multi-Objective Optimization
MOP	Multi-objective Optimization Problem
MORA	Multi-Objective Rosenbrock Algorithm
MSE	Mean-Squared Error
MST	Minimum Spanning Tree
NEWUOA	NEW Unconstrained Optimization Algorithm
NFLT	No Free Lunch Theorem
NSGA	Non-dominated Sorting Genetic Algorithm
PALS	Problem-Aware Local Search
PBIL	Population-Based Incremental Learning
PCR	Polymerase Chain Reaction
PD	Proportional Derivative
PDMOSA	Pareto Dominance Multi-Objective Simulated Annealing
PF	Pareto Front
PI	Proportional Integral
PID	Proportional Integral Derivative
PLS	Polynomial Local Search
PMSM	Permanent Magnet Synchronous Motor
PNS	Progressive Neighborhood Search
PTAS	Polynomial Time Approximation Scheme
PSO	Particle Swarm Optimization
QAP	Quadratic Assignment Problem
QB	Queen-Bee algorithm
RBF	Radial Basis Function
REVAC	Relevance Estimation and VAlue Calibration
RM-MEDA	Regularity Model-Based Multi-objective Estimation of Distribution Algorithm
SA	Simulated Annealing
SIA	Swarm Intelligence Algorithm
SLS	Stochastic Local Search
SMHC	Steepest Mutation hill Climbing
SNP	Single Nucleotide Polymorphism
SNR	Signal-to-Noise Ratio
SOM	Self-Organizing Map
SPEA2	modified Strength Pareto Evolutionary Algorithm
SPMDE	Super Fit Memetic Differential Evolution
SPO	Sequential Parameter Optimization
SPOT	Sequential Parameter Optimization Toolbox
SQP	Sequential Quadratic Programming
SR	Success Rate
SS	Scatter Search
TR	Trust Region

TRI	Triggered Random Immigrants
TS	Tabu Search
TSP	Traveling Salesman Problem
UPGMA	Unweighted Pair Group Method with Arithmetic Mean
VEGA	Vector Evaluated Genetic Algorithm
VLS	Variable Local Search
VLSI	Very-Large Scale Integration
VRP	Vehicle Routing Problem
WCSP	Weighted constraint Satisfaction Problem