N. Nedjah, E. Alba, L. de Macedo Mourelle (Eds.)

Parallel Evolutionary Computations

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Editor-in-chief
Prof. Janusz Kacprzyk
Systems Research Institute
Polish Academy of Sciences
ul. Newelska 6
01-447 Warsaw
Poland
E-mail: kacprzyk@ibspan.waw.pl

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Dr. Nadia Nedjah
Department of System Engineering
and Computation
Faculty of Engineering
State University of Rio de Janeiro
Rua São Francisco Xavier, 524, 50. andar
Maracanã, CEP 20559-900
Rio de Janeiro, RJ
Brazil
E-mail: nadia@eng.uerj.br

Professor Enrique Alba
Universidad de Málaga
Depto. of Lenguajes y Ciencias de la
Computación
Campus de Teatinos
29071 Málaga, Spain
E-mail: eat@lcc.uma.es

Dr. Luiza de Macedo Mourelle
Department of System Engineering
and Computation
Faculty of Engineering
State University of Rio de Janeiro
Rua São Francisco Xavier, 524, 50. andar
Maracanã, CEP 20559-900
Rio de Janeiro, RJ
Brazil
E-mail: ldmm@eng.uerj.br

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To the memory of my father Ali and my beloved mother Fatiha,

Nadia Nedjah

Thanks to my wife Ana,

Enrique Alba

To the memory of my beloved father Luiz and my mother Neuza,

Luiza Mourelle

Preface

Evolutionary algorithms and their related computations are solver systems which use computational models inspired in Darwinian natural selection processes as a key element in their design and implementation. In general, evolutionary computation (EC) is used to solve *NP*-hard problems which cannot be solved with other tools because of their intrinsic difficulty, high dimensionality or incomplete definition. In practice, EC is composed of a set of different families of algorithms that iteratively improve a set of tentative solutions to obtain an optimal or quasi-optimal solution to the problem. Therefore, evolutionary algorithms require sometimes a massive computational effort to yield efficient and competitive solutions to real-size engineering problems which would otherwise rest unsolved today.

This book focuses on the aspects related to the parallelization of evolutionary computations, such as parallel genetic operators, parallel fitness evaluation, distributed genetic algorithms, and parallel hardware implementations, as well as on the impact of parallel EC on several applications.

The book is divided into four parts. The first part deals with a clear software-like and algorithmic vision on parallel evolutionary optimizations. The second part is about hardware implementations of genetic algorithms, a valuable topic which is hard to find in the present literature. The third part treats the problem of distributed evolutionary computation and presents three interesting applications wherein parallel EC new ideas are featured. Finally, the last part deals with the up-to-date field of parallel particle swarm optimization to illustrate the intrinsic similarities and potential extensions to techniques in this domain.

The goal of this volume has been to offer a wide spectrum of sample works developed in leading research throughout the world about parallel implementations of efficient techniques at the heart of computational intelligence. The book should be useful both for beginners and experienced researchers in the field of computational intelligence.

Part I: Parallel Evolutionary Optimization

In Chapter 1, which is entitled *A Model for Parallel Operators in Genetic Algorithms*, the authors analyze a model for applying crossover and varying mutation separately in parallel. The authors focus on the gains of performance that can be achieved from the concurrent application of variation operators with different and complementary roles. An important aim of this chapter is to show that, for the actual parallelization of operators to be meaningful, appropriate models for the concurrent application of operators should be devised first.

In Chapter 2, which is entitled *Parallel Evolutionary Multiobjective Optimization*, the authors' first goal is to provide the reader with a wide overview of the literature on parallel evolutionary algorithms for multiobjective optimization. Also, the authors include an experimental study wherein *p*PAES, a parallel evolutionary algorithm for multiobjective optimization based on the Pareto Archived Evolution Strategy (PAES) is developed and analyzed. The obtained results show that *p*PAES is a promising option for solving multiobjective optimization problems.

Part II: Parallel Hardware for Genetic Algorithms

In Chapter 3, which is entitled *A Reconfigurable Parallel Hardware for Genetic Algorithms*, the authors propose a massively parallel architecture for hardware implementation of genetic algorithms. The authors claim that this design is quite innovative as it provides a viable solution to the fitness computation problem, which depends heavily on the problem-specific knowledge. The proposed architecture is completely independent of such specifics. It implements the fitness computation using a neural network. The hardware implementation of the neural network is stochastic and thus minimises the required hardware area without much increase in response time. The authors also demonstrate the characteristics of the proposed hardware and compare it to existing ones.

In Chapter 4, which is entitled *Reconfigurable Computing and Parallelism for Implementing and Accelerating Evolutionary Algorithms*, the authors present two instances of hardware implementation of evolutionary algorithms. Both instances provide distinct points of view on how to apply reconfigurable computing technology to increase algorithm efficiency. The cases considered are genetic algorithms and one parallel evolutionary algorithm. In particular, the authors illustrate through an experimental study the performance of the presented hardware implementations using the Travelling Salesman Problem.

Part III: Distributed Evolutionary Computation

In Chapter 5, which is entitled *Performance of Distributed GAs on DNA Fragment Assembly*, the authors present results on analyzing the behaviour of a parallel distributed genetic algorithm over different LAN technologies. Their main goal is to offer a study on the potential impact in the search mechanics when shifting between LANs: a Fast Ethernet network, a Gigabit Ethernet network, and a Myrinet network. They also study the importance of several parameters of the migration policy. The author use the DNA fragment assembly problem to show the actual power and utility of the proposed distributed technique.

In Chapter 6, which is entitled *On Parallel Evolutionary Algorithms on the Computational Grid*, the authors analyze the major traditional parallel models of evolutionary algorithms. The objective consists of adapting the parallel models to to grids taking into account the characteristics of such execution environments in terms of volatility, heterogeneity, large scale and multi-administrative domain. The authors give an overview of such frameworks and present a case study related to ParadisEO-CMW which is a porting of ParadisEO onto Condor and MW allowing a transparent deployment of the parallel EAs on grids.

In Chapter 7, which is entitled *Parallel Evolutionary Algorithms on Consumer-Level Graphics Processing Unit*, the author propose to implement a parallel evolutionary algorithm on consumer-level Graphics Processing Unit. They perform experiments to compare the proposed parallel evolutionary algorithm with an ordinary one and demonstrate that the former is much more effective than the latter. The authors claim that as consumer-level graphics processing units are already widely available and installed on personal computers and they are easy to use and manage, more people will be able to use our parallel algorithm to solve their problems encountered in real-world applications.

Part IV: Parallel Particle Swarm Optimization

In Chapter 8, which is entitled *Intelligent Parallel Particle Swarm Optimization Algorithms*, the authors present a parallel version of the particle swarm optimization (PPSO) algorithm together with three communication strategies which can be used according to the independence of the data. They discuss some communication strategies for PPSO, which can be used according to the strength of the correlation of parameters. Experimental results confirm the superiority of the PPSO algorithms.

In Chapter 9, which is entitled *Parallel Ant Colony Optimization for 3D Protein Structure Prediction using the HP Lattice Model*, the authors introduce a novel method of solving the Hydrophobic-Hydrophilic (HP) protein folding problem in both two and three dimensions using Ant Colony Optimizations and a distributed programming paradigm. They claim that tests across a small number of processors indicate that the multiple colony distributed ACO (MACO) approach outperforms single colony implementations and that experimental results also demonstrate that the proposed algorithms perform well in terms of network scalability.

We are very much grateful to the authors of this volume and to the reviewers for their tremendous service by critically reviewing the chapters. The editors would also like to thank Prof. Janusz Kacprzyk, the editor-in-chief of the Studies in Computational Intelligence Book Series and Dr. Thomas Ditzinger from Springer-Verlag, Germany for their editorial assistance and excellent collaboration to produce this scientific work. We hope that the reader will share our excitement on this **Parallel Evolutionary Computations** volume and will find it useful.

Nadia Nedjah
Enrique Alba
Luiza M. Mourelle

Brazil, Spain
January 2006

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