Lecture Notes in Computer Science 3172

Commenced Publication in 1973
Founding and Former Series Editors:
Gerhard Goos, Juris Hartmanis, and Jan van Leeuwen

Marco Dorigo Mauro Birattari
Christian Blum Luca M. Gambardella
Francesco Mondada Thomas Stützle (Eds.)

Ant Colony Optimization and Swarm Intelligence

4th International Workshop, ANTS 2004
Brussels, Belgium, September 5 - 8, 2004
Proceedings

Volume Editors

Marco Dorigo
Mauro Birattari
Christian Blum
Université Libre de Bruxelles, IRIDIA CP 194/6
Avenue Franklin Roosevelt 50, 1050 Bruxelles, Belgium
E-mail: {mdorigo, mbiro, cblum}@ulb.ac.be

Luca M. Gambardella
IDSIA, Instituto Dalle Molle di Studi sull'Intelligenza Artificiale
Galleria 2, 6928 Manno-Lugano, Switzerland
E-mail: luca@idsia.ch

Francesco Mondada
Swiss Federal Institute of Technology of Lausanne (EPFL)
Autonomous Systems Lab - LSA
LSA-I2S-EPFL
CH-1015 Lausanne, Switzerland
E-mail: francesco.mondada@epfl.ch

Thomas Stützle
Darmstadt University of Technology
Computer Science Department, Intellectics Group
Hochschulstr. 10, 64283 Darmstadt, Germany
E-mail: stuetzle@informatik.tu-darmstadt.de

Library of Congress Control Number: 2004109777

CR Subject Classification (1998): F.2.2, F.1.1, G.1, G.2, I.2, C.2.4, J.1

ISSN 0302-9743
ISBN 3-540-22672-9 Springer Berlin Heidelberg New York

Typesetting: Camera-ready by author, data conversion by Olgun Computergrafik
Printed on acid-free paper SPIN: 11307815 06/3142 5 4 3 2 1 0

Preface

With its fourth edition, the *ANTS* series of workshops[1] has changed its name. The original *"ANTS – From Ant Colonies to Artificial Ants: International Workshop on Ant Algorithms"* has become *"ANTS – International Workshop on Ant Colony Optimization and Swarm Intelligence"*. This change is mainly due to the following reasons.

First, the term "*ant algorithms*" was slower in spreading in the research community than the term "*swarm intelligence*", while at the same time research in so-called *swarm robotics* was the subject of increasing activity: it was therefore an obvious choice to substitute the term *ant algorithms* with the more accepted and used term *swarm intelligence*.

Second, although *swarm intelligence* research has undoubtedly produced a number of interesting and promising research directions[2], we think it is fair to say that its most successful strand is the one known as "*ant colony optimization*". *Ant colony optimization*, first introduced in the early 1990s as a novel tool for the approximate solution of discrete optimization problems, has recently seen an explosion in the number of its applications, both to academic and real-world problems, and is currently being extended to the realm of continuous optimization (a few papers on this subject being published in these proceedings). It is therefore a reasonable choice to have the term *ant colony optimization* as part of the workshop name.

As mentioned above, this is the fourth edition of the *ANTS* workshops. The series started in 1998 with the organization of *ANTS'98*. On that occasion more than 50 researchers from around the world joined for the first time in Brussels, Belgium to discuss *swarm intelligence* related research, and a selection of the best papers presented at the workshop was published as a special issue of the *Future Generation Computer Systems* journal (Vol. 16, No. 8, 2000). Two years later the experience was repeated with the organization of *ANTS 2000*, which attracted more than 70 participants. The 41 extended abstracts presented as talks or posters at the workshop were collected in a booklet distributed to participants, and a selection of the best papers was published as a special section of the *IEEE Transactions on Evolutionary Computation* (Vol. 6, No. 4, 2002). After these first two successful editions, it was decided to make of *ANTS* a series of biannual events. Accordingly, the third edition was organized in September 2002, in Brussels, Belgium. The success of the workshop and the quality of the papers presented in the second edition had also made it clear that it was the right time to have an official workshop proceedings: the *ANTS 2002* proceedings was

[1] `http://iridia.ulb.ac.be/~ants/`

[2] Think, for example, in addition to the already mentioned swarm robotics, of algorithms for clustering and data mining inspired by the ants' cemetery building behavior, of dynamic task allocation algorithms inspired by the behavior of wasp colonies, of particle swarm optimization, and so on.

published by Springer as Volume 2463 of LNCS, and contained 36 contributions: 17 full papers, 11 short papers, and 8 extended abstracts, selected out of a total of 52 submissions.

The *Ant Colony Optimization and Swarm Intelligence* field is still growing, as testified, for example, by the success of the *1st IEEE Swarm Intelligence Symposium*, held in 2003 in Indianapolis, Indiana, US; or by the steady increase we are observing in the number of submissions to *ANTS* workshops, which resulted in the 79 papers submitted to *ANTS 2004*. This relatively high number of submissions allowed us to set the acceptance threshold for full and short papers at approximately 50%, which guaranteed a fairly high quality of the proceedings, and, at the same time, a reasonably dense workshop program[3]. We are sure that the readers of these proceedings will enjoy the quality of the papers collected in this volume, quality that somehow reflects the growing maturity of the *swarm intelligence* field.

We wish to conclude by saying that we are very grateful to the authors who submitted their works; to the members of the international program committee and to the additional referees for their detailed reviews; to the IRIDIA people for their enthusiasm in helping with organization matters; to the Université Libre de Bruxelles for providing rooms and logistic support; and, more generally, to all those contributing to the organization of the workshop. Finally, we would like to thank our sponsors, the company *AntOptima*[4] and the *Metaheuristics Network*[5], who financially supported the workshop.

June 2004

Marco Dorigo
Mauro Birattari
Christian Blum
Luca M. Gambardella
Francesco Mondada
Thomas Stützle

[3] In addition to the accepted papers, a small number of posters were selected for presentation: these are works that, although in a rather preliminary phase, show high potential and are therefore worth discussing at the workshop.

[4] More information available at `www.antoptima.com`

[5] A Marie Curie Research Training Network funded by the European Commission. More information available at `www.metaheuristics.org`

Organization

ANTS 2004 was organized by IRIDIA, Université Libre de Bruxelles, Belgium.

Workshop Chair

Marco Dorigo	IRIDIA, ULB, Brussels, Belgium

Technical Program Chairs

Luca M. Gambardella	IDSIA, USI-SUPSI, Manno-Lugano, Switzerland
Francesco Mondada	ASL, EPFL, Lausanne, Switzerland
Thomas Stützle	Intellektik, TUD, Darmstadt, Germany

Publication Chairs

Mauro Birattari	IRIDIA, ULB, Brussels, Belgium
Christian Blum	IRIDIA, ULB, Brussels, Belgium

Program Committee

Tucker Balch	Georgia Tech, Atlanta, GA, USA
Christian Blum	IRIDIA, ULB, Brussels, Belgium
Eric Bonabeau	Icosystem, Boston, MA, USA
Oscar Cordón	Universidad de Granada, Spain
David Corne	University of Reading, UK
Jean-Louis Deneubourg	CENOLI, ULB, Brussels, Belgium
Gianni di Caro	IDSIA, Manno-Lugano, Switzerland
Dario Floreano	ASL, EPFL, Lausanne, Switzerland
Michel Gendreau	Université de Montréal, Canada
Deborah Gordon	Stanford University, CA, USA
Walter Gutjahr	Universität Wien, Austria
Richard Hartl	Universität Wien, Austria
Owen Holland	University of Essex, Colchester, UK
Holger Hoos	University of British Columbia, Vancouver, Canada
Paul B. Kantor	Rutgers University, New Brunswick, NJ, USA
Joshua Knowles	MIB, UMIST, Manchester, UK
Sven Koenig	Georgia Tech, Atlanta, GA, USA

Vittorio Maniezzo	Università di Bologna, Italy
Alcherio Martinoli	EPFL, Lausanne, Switzerland
Chris Melhuish	University of the West of England, Bristol, UK
Ronaldo Menezes	Florida Tech, Melbourne, FL, USA
Daniel Merkle	Universität Karlsruhe, Germany
Peter Merz	Universität Tübingen, Germany
Martin Middendorf	Universität Leipzig, Germany
Stefano Nolfi	CNR, Rome, Italy
Ben Paechter	Napier University, Edinburgh, UK
Van Parunak	Altarum Institute, Ann Arbor, MI, USA
Andrea Roli	Università degli Studi G. D'Annunzio, Chieti, Italy
Erol Şahin	Middle East Technical University, Ankara, Turkey
Michael Sampels	IRIDIA, ULB, Brussels, Belgium
Guy Theraulaz	Université Paul Sabatier, Toulouse, France
Franco Zambonelli	Università di Modena, Italy
Mark Zlochin	Weizmann Institute, Rehovot, Israel

Publicity Chair

Andrea Roli	Università degli Studi G. D'Annunzio, Chieti, Italy

Local Arrangements

Max Manfrin	IRIDIA, ULB, Brussels, Belgium
Carlotta Piscopo	IRIDIA, ULB, Brussels, Belgium

Additional Referees

Ashraf Abdelbar	Julia Handl	Rubén Ruiz García
Christian Almeder	Stephane Magnenat	Jürgen Schmidhuber
Erkin Bahceci	Marco Mamei	Alena Shmygelska
Levent Bayindir	Roberto Montemanni	Kevin Smyth
Leonora Bianchi	Alberto Montresor	Krzysztof Socha
Gilles Caprari	Luís Paquete	Onur Soysal
Karl Doerner	Yves Piguet	Christine Strauss
Alberto V. Donati	Andrea Emilio Rizzoli	Emre Ugur
Frederick Ducatelle	Daniel Roggen	Markus Waibel
Michael Guntsch	Martin Romauch	

Sponsoring Institutions

AntOptima (`www.antoptima.com`), Lugano, Switzerland
Metaheuristics Network (`www.metaheuristics.org`), a Marie Curie Research Training Network of the Improving Human Potential Programme funded by the European Commission

Table of Contents

Short Papers

Posters