

*Commenced Publication in 1973*

Founding and Former Series Editors:

Gerhard Goos, Juris Hartmanis, and Jan van Leeuwen

## Editorial Board

David Hutchison

*Lancaster University, UK*

Takeo Kanade

*Carnegie Mellon University, Pittsburgh, PA, USA*

Josef Kittler

*University of Surrey, Guildford, UK*

Jon M. Kleinberg

*Cornell University, Ithaca, NY, USA*

Friedemann Mattern

*ETH Zurich, Switzerland*

John C. Mitchell

*Stanford University, CA, USA*

Moni Naor

*Weizmann Institute of Science, Rehovot, Israel*

Oscar Nierstrasz

*University of Bern, Switzerland*

C. Pandu Rangan

*Indian Institute of Technology, Madras, India*

Bernhard Steffen

*University of Dortmund, Germany*

Madhu Sudan

*Massachusetts Institute of Technology, MA, USA*

Demetri Terzopoulos

*University of California, Los Angeles, CA, USA*

Doug Tygar

*University of California, Berkeley, CA, USA*

Moshe Y. Vardi

*Rice University, Houston, TX, USA*

Gerhard Weikum

*Max-Planck Institute of Computer Science, Saarbruecken, Germany*

Thomas Stützle Mauro Birattari  
Holger H. Hoos (Eds.)

# Engineering Stochastic Local Search Algorithms

Designing, Implementing and Analyzing  
Effective Heuristics

International Workshop, SLS 2007  
Brussels, Belgium, September 6-8, 2007  
Proceedings



Springer

## Volume Editors

Thomas Stützle  
Mauro Birattari  
Université Libre de Bruxelles (ULB)  
CoDE, IRIDIA  
Av. F. Roosevelt 50, CP 194/6, 1050 Bruxelles, Belgium  
E-mail: {stuetzle,mbiro}@ulb.ac.be

Holger H. Hoos  
University of British Columbia  
Computer Science Department  
2366 Main Mall, Vancouver, BC, V6T 1Z4, Canada  
E-mail: hoos@cs.ubc.ca

Library of Congress Control Number: 2007933306

CR Subject Classification (1998): E.2, E.5, D.2, F.2, H.2, I.1.2, I.2.8, I.7

LNCS Sublibrary: SL 1 – Theoretical Computer Science and General Issues

ISSN	0302-9743
ISBN-10	3-540-74445-2 Springer Berlin Heidelberg New York
ISBN-13	978-3-540-74445-0 Springer Berlin Heidelberg New York

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, re-use of illustrations, recitation, broadcasting, reproduction on microfilms or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer. Violations are liable to prosecution under the German Copyright Law.

Springer is a part of Springer Science+Business Media

[springer.com](http://springer.com)

© Springer-Verlag Berlin Heidelberg 2007  
Printed in Germany

Typesetting: Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India  
Printed on acid-free paper      SPIN: 12111459      06/3180      5 4 3 2 1 0

# Preface

Stochastic local search (SLS) algorithms enjoy great popularity as powerful and versatile tools for tackling computationally hard decision and optimization problems from many areas of computer science, operations research, and engineering. To a large degree, this popularity is based on the conceptual simplicity of many SLS methods and on their excellent performance on a wide gamut of problems, ranging from rather abstract problems of high academic interest to the very specific problems encountered in many real-world applications. SLS methods range from quite simple construction procedures and iterative improvement algorithms to more complex general-purpose schemes, also widely known as metaheuristics, such as ant colony optimization, evolutionary computation, iterated local search, memetic algorithms, simulated annealing, tabu search and variable neighborhood search.

Historically, the development of effective SLS algorithms has been guided to a large extent by experience and intuition, and overall resembled more an art than a science. However, in recent years it has become evident that at the core of this development task there is a highly complex engineering process, which combines various aspects of algorithm design with empirical analysis techniques and problem-specific background, and which relies heavily on knowledge from a number of disciplines and areas, including computer science, operations research, artificial intelligence, and statistics. This development process needs to be assisted by a sound methodology that addresses the issues arising in the various phases of algorithm design, implementation, tuning, and experimental evaluation. A similarly principled approach is key to understanding better which SLS techniques are best suited for particular problem types and to gaining further insights into the relationship between algorithm components, parameter settings, problem characteristics, and performance.

The aim of *SLS 2007, Engineering Stochastic Local Search Algorithms — Designing, Implementing and Analyzing Effective Heuristics* was to stress the importance of an integration of relevant aspects of SLS research into a more coherent engineering methodology and to provide a forum for research in this direction. The workshop brought together researchers working on various aspects of SLS algorithms, ranging from fundamental SLS methods and techniques to more applied work on specific problems or real-life applications. We hope that this event will lead to an increased awareness of the importance of the engineering aspects in the design and implementation of SLS algorithms, and that it will help to tie together existing activities and to seed new efforts in this promising research area.

The importance and the timeliness of the topic of SLS engineering is witnessed by the more than 50 submissions we received for this workshop. From these submissions, the 12 full and 9 short papers contained in this volume and

presented at the workshop were chosen based on a highly selective and rigorous peer-reviewing process; each of them reports results of very promising, ongoing research efforts from, or highly related to, the budding area of SLS engineering. The workshop program was complemented by the Doctoral Symposium on Engineering Stochastic Local Search Algorithms, which was organized by Enda Ridge and Edward Curry, and five tutorials on important topics in SLS engineering given by well-known researchers in the field.

We gratefully acknowledge the contributions of everyone at IRIDIA who helped in organizing SLS 2007. Special thanks go to Enda Ridge and Edward Curry for their enthusiasm in organizing the doctoral symposium. We thank all researchers who submitted their work and thus provided the basis for the workshop program; the members of the Program Committee and the additional referees for their help with the paper selection process; the Université Libre de Bruxelles for providing the rooms and logistic support; and, more generally, all those who contributed to the organization of the workshop. Finally, we would like to thank COMP2SYS,<sup>1</sup> the Belgian National Fund for Scientific Research, and the French Community of Belgium for supporting the workshop.

June 2007

Thomas Stützle  
Mauro Birattari  
Holger H. Hoos

---

<sup>1</sup> A Marie Curie Early Stage Training Site funded by the European Commission; more information is available at <http://iridia.ulb.ac.be/comp2sys>.

# Organization

SLS 2007 was organized by IRIDIA, CoDE, Université Libre de Bruxelles, Belgium.

## Workshop Chairs

Thomas Stützle	Université Libre de Bruxelles, Belgium
Mauro Birattari	Université Libre de Bruxelles, Belgium
Holger H. Hoos	University of British Columbia, Canada

## Program Committee

Thomas Bartz-Beielstein	Cologne University of Applied Sciences, Germany
Roberto Battiti	Università di Trento, Italy
Christian Blum	Universitat Politècnica de Catalunya, Spain
Marco Chiarandini	University of Southern Denmark, Denmark
Carlos Cotta	University of Málaga, Spain
Camil Demetrescu	Università La Sapienza, Italy
Luca Di Gaspero	Università degli Studi di Udine, Italy
Karl F. Doerner	Universität Wien, Austria
Marco Dorigo	Université Libre de Bruxelles, Belgium
Carlos M. Fonseca	University of Algarve, Portugal
Michel Gendreau	Université de Montréal, Canada
Jens Gottlieb	SAP AG, Germany
Walter J. Gutjahr	Universität Wien, Austria
Pierre Hansen	GERAD and HEC Montreal, Canada
Jin-Kao Hao	University of Angers, France
Richard F. Hartl	Universität Wien, Austria
Geir Hasle	SINTEF Applied Mathematics, Norway
David Johnson	AT&T Labs Research, USA
Joshua Knowles	University of Manchester, UK
Arne Løkketangen	Molde University College, Norway
Vittorio Maniezzo	Università di Bologna, Italy
Catherine C. McGeoch	Amherst College, USA
Daniel Merkle	Universität Leipzig, Germany
Peter Merz	Universität Kaiserslautern, Germany
Martin Middendorf	Universität Leipzig, Germany
Pablo Moscato	University of Newcastle, Australia
Luis Paquete	University of Algarve, Portugal
Steven Prestwich	University College Cork, Ireland

## VIII Organization

Günther Raidl	Vienna University of Technology, Austria
Celso Ribeiro	Pontificia Univ. Católica do Rio de Janeiro, Brazil
Andrea Roli	Università degli Studi G. D'Annunzio, Italy
Jonathan Rowe	University of Birmingham, UK
Ruben Ruiz	Valencia University of Technology, Spain
Michael Sampels	Université Libre de Bruxelles, Belgium
Andrea Schaerf	Università degli Studi di Udine, Italy
El-Ghazali Talbi	University of Lille, France
Pascal Van Hentenryck	Brown University, USA
Stefan Voss	University of Hamburg, Germany
Jean-Paul Watson	Sandia National Labs, USA
Ingo Wegener	Universität Dortmund, Germany
David Woodruff	University of California, Davis, USA
Mutsunori Yagiura	Nagoya University, Japan

## Local Arrangements

Prasanna Balaprakash	Université Libre de Bruxelles, Belgium
Carlotta Pisco	Université Libre de Bruxelles, Belgium

## Additional Referees

Prasanna Balaprakash  
Frank Hutter  
Marco A. Montes de Oca

## Sponsoring Institutions

COMP2SYS, Marie Curie Early Stage Training Site  
<http://iridia.ulb.ac.be/comp2sys>

National Fund for Scientific Research, Belgium  
<http://www.fnrs.be>

French Community of Belgium (through the research project ANTS)  
<http://www.cfwb.be>

# Table of Contents

The Importance of Being Careful . . . . .	1
<i>Arne Løkke Tangen</i>	
Designing and Tuning SLS Through Animation and Graphics: An Extended Walk-Through . . . . .	16
<i>Steven Halim and Roland H.C. Yap</i>	
Implementation Effort and Performance . . . . .	31
<i>Paola Pellegrini and Mauro Birattari</i>	
Tuning the Performance of the MMAS Heuristic . . . . .	46
<i>Enda Ridge and Daniel Kudenko</i>	
Comparing Variants of MMAS ACO Algorithms on Pseudo-Boolean Functions . . . . .	61
<i>Frank Neumann, Dirk Sudholt, and Carsten Witt</i>	
EasyAnalyzer: An Object-Oriented Framework for the Experimental Analysis of Stochastic Local Search Algorithms . . . . .	76
<i>Luca Di Gaspero, Andrea Roli, and Andrea Schaerf</i>	
Mixed Models for the Analysis of Local Search Components . . . . .	91
<i>Jørgen Bang-Jensen, Marco Chiarandini, Yuri Goegebeur, and Bent Jørgensen</i>	
An Algorithm Portfolio for the Sub-graph Isomorphism Problem . . . . .	106
<i>Roberto Battiti and Franco Mascia</i>	
A Path Relinking Approach for the Multi-Resource Generalized Quadratic Assignment Problem . . . . .	121
<i>Mutsunori Yagiura, Akira Komiya, Kenya Kojima, Koji Nonobe, Hiroshi Nagamochi, Toshihide Ibaraki, and Fred Glover</i>	
A Practical Solution Using Simulated Annealing for General Routing Problems with Nodes, Edges, and Arcs . . . . .	136
<i>Hisafumi Kokubugata, Ayako Moriyama, and Hironao Kawashima</i>	
Probabilistic Beam Search for the Longest Common Subsequence Problem . . . . .	150
<i>Christian Blum and Maria J. Blesa</i>	
A Bidirectional Greedy Heuristic for the Subspace Selection Problem . . .	162
<i>Dag Haugland</i>	



## Short Papers

EasySyn++: A Tool for Automatic Synthesis of Stochastic Local Search Algorithms .....	177
<i>Luca Di Gaspero and Andrea Schaerf</i>	
Human-Guided Enhancement of a Stochastic Local Search: Visualization and Adjustment of 3D Pheromone .....	182
<i>Jaya Sreevalsan-Nair, Meike Verhoeven, David L. Woodruff, Ingrid Hotz, and Bernd Hamann</i>	
Solving a Bi-objective Vehicle Routing Problem by Pareto-Ant Colony Optimization .....	187
<i>Joseph M. Pasia, Karl F. Doerner, Richard F. Hartl, and Marc Reimann</i>	
A Set Covering Approach for the Pickup and Delivery Problem with General Constraints on Each Route .....	192
<i>Hideki Hashimoto, Youichi Ezaki, Mutsunori Yagiura, Koji Nonobe, Toshihide Ibaraki, and Arne Løkketangen</i>	
A Study of Neighborhood Structures for the Multiple Depot Vehicle Scheduling Problem .....	197
<i>Benoît Laurent and Jin-Kao Hao</i>	
Local Search in Complex Scheduling Problems .....	202
<i>Thijs Urlings and Rubén Ruiz</i>	
A Multi-sphere Scheme for 2D and 3D Packing Problems .....	207
<i>Takashi Imamichi and Hiroshi Nagamochi</i>	
Formulation Space Search for Circle Packing Problems .....	212
<i>Nenad Mladenović, Frank Plastria, and Dragan Urošević</i>	
Simple Metaheuristics Using the Simplex Algorithm for Non-linear Programming .....	217
<i>João Pedro Pedroso</i>	
<b>Author Index</b> .....	223