

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

Alfred Kobsa

University of California, Irvine, CA, 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

Gerhard Weikum

Max-Planck Institute of Computer Science, Saarbruecken, Germany

Marina L. Gavrilova C.J. Kenneth Tan
Yingxu Wang Yiyu Yao Guoyin Wang (Eds.)

Transactions on Computational Science II

Editors-in-Chief

Marina L. Gavrilova
University of Calgary, Department of Computer Science
2500 University Drive N.W., Calgary, AB, T2N 1N4, Canada
E-mail: marina@cpsc.ucalgary.ca

C.J. Kenneth Tan
OptimaNumerics Ltd.
Cathedral House, 23-31 Waring Street, Belfast BT1 2DX, UK
E-mail: cjtan@optimanumerics.com

Guest Editors

Yingxu Wang
University of Calgary, Schulich School of Engineering
Department of Electrical and Computer Engineering
2500 University Drive N.W., Calgary, AB, T2N 1N4, Canada
E-mail: yingxu@ucalgary.ca

Yiyu Yao
University of Regina, Department of Computer Science
Regina, SK, S4S 0A2, Canada
E-mail: yyao@cs.uregina.ca

Guoyin Wang
Chongqing University of Posts and Telecommunications
Institute of Computer Science and Technology, Chongqing 400065, China
E-mail: wanggy@cqupt.edu.cn

Library of Congress Control Number: 2008935543

CR Subject Classification (1998): F, D, C.2-3, G, E.1-2

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

ISSN	0302-9743 (Lecture Notes in Computer Science)
ISSN	1866-4733 (Transactions on Computational Science)
ISBN-10	3-540-87562-X Springer Berlin Heidelberg New York
ISBN-13	978-3-540-87562-8 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

© Springer-Verlag Berlin Heidelberg 2008
Printed in Germany

Typesetting: Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India
Printed on acid-free paper SPIN: 12446056 06/3180 5 4 3 2 1 0

LNCS Transactions on Computational Science

Computational science, an emerging and increasingly vital field, is now widely recognized as an integral part of scientific and technical investigations, affecting researchers and practitioners in areas ranging from aerospace and automotive research to biochemistry, electronics, geosciences, mathematics, and physics. Computer systems research and the exploitation of applied research naturally complement each other. The increased complexity of many challenges in computational science demands the use of supercomputing, parallel processing, sophisticated algorithms, and advanced system software and architecture. It is therefore invaluable to have input by systems research experts in applied computational science research.

Transactions on Computational Science focuses on original high-quality research in the realm of computational science in parallel and distributed environments, also encompassing the underlying theoretical foundations and the applications of large-scale computation. The journal offers practitioners and researchers the possibility to share computational techniques and solutions in this area, to identify new issues, and to shape future directions for research, and it enables industrial users to apply leading-edge, large-scale, high-performance computational methods.

In addition to addressing various research and application issues, the journal aims to present material that is validated – crucial to the application and advancement of the research conducted in academic and industrial settings. In this spirit, the journal focuses on publications that present results and computational techniques that are verifiable.

Scope

The scope of the journal includes, but is not limited to, the following computational methods and applications:

- Aeronautics and Aerospace
- Astrophysics
- Bioinformatics
- Climate and Weather Modeling
- Communication and Data Networks
- Compilers and Operating Systems
- Computer Graphics
- Computational Biology
- Computational Chemistry
- Computational Finance and Econometrics
- Computational Fluid Dynamics
- Computational Geometry

- Computational Number Theory
- Computational Physics
- Data Storage and Information Retrieval
- Data Mining and Data Warehousing
- Grid Computing
- Hardware/Software Co-design
- High-Energy Physics
- High-Performance Computing
- Numerical and Scientific Computing
- Parallel and Distributed Computing
- Reconfigurable Hardware
- Scientific Visualization
- Supercomputing
- System-on-Chip Design and Engineering

Preface

The denotational and expressive needs in cognitive informatics, computational intelligence, software engineering, and knowledge engineering have led to the development of new forms of mathematics collectively known as denotational mathematics. *Denotational mathematics* is a category of mathematical structures that formalize rigorous expressions and long-chain inferences of system compositions and behaviors with abstract concepts, complex relations, and dynamic processes. Typical paradigms of denotational mathematics are concept algebra, system algebra, Real-Time Process Algebra (RTPA), Visual Semantic Algebra (VSA), fuzzy logic, and rough sets. A wide range of applications of denotational mathematics have been identified in many modern science and engineering disciplines that deal with complex and intricate mathematical entities and structures beyond numbers, Boolean variables, and traditional sets.

This issue of Springer's Transactions on Computational Science on *Denotational Mathematics for Computational Intelligence* presents a snapshot of current research on denotational mathematics and its engineering applications. The volume includes selected and extended papers from two international conferences, namely IEEE ICCI 2006 (on *Cognitive Informatics*) and RSKT 2006 (on *Rough Sets and Knowledge Technology*), as well as new contributions. The following four important areas in denotational mathematics and its applications are covered:

- *Foundations and applications of denotational mathematics*, focusing on: a) contemporary denotational mathematics for computational intelligence; b) denotational mathematical laws of software; c) a comparative study of STOPA and RTPA; and d) a denotational mathematical model of abstract games.
- *Rough and fuzzy set theories*, focusing on: a) transformation of vague sets to fuzzy sets; b) reduct construction algorithms; and c) attribute set dependence in reduct computation.
- *Granular computing*, focusing on: a) mereological theories of concepts; and b) rough logic and reasoning.
- *Knowledge and information modeling*, focusing on: a) semantic consistency of knowledge bases; b) contingency matrix theory; and c) analysis of information tables containing stochastic values.

The editors believe that the readers of the *Transactions on Computational Science* (TCS) series will benefit from the papers presented in this special issue on the latest advances in denotational mathematics and applications in cognitive informatics, natural intelligence, computational intelligence, and AI.

Acknowledgments

The guest editors of this *Special Issue on Denotational Mathematics for Computational Intelligence* in Springer's Transactions on Computational Science series, would

like to thank all authors for submitting their latest interesting work. We are grateful to the program committee members of the IEEE ICCI 2006 and RSKT 2006 conferences, as well as the reviewers, for their great contributions to this special issue. We would like to thank the Editors-in-Chief of TCS, Dr. Marina L. Gavrilova and Dr. Chih Jeng Kenneth Tan, for their advice, vision, and support. We also thank the editorial staff at Springer for their professional help during the publication of this special issue.

June 2008

Yingxu Wang

Yiyu Yao

Guoyin Wang

LNCS Transactions on Computational Science – Editorial Board

Marina L. Gavrilova, Editor-in-chief	University of Calgary, Canada
Chih Jeng Kenneth Tan, Editor-in-chief	OptimaNumerics, UK
Tetsuo Asano	JAIST, Japan
Brian A. Barsky	University of California at Berkeley, USA
Alexander V. Bogdanov	Institute for High Performance Computing and Data Bases, Russia
Martin Buecker	Aachen University, Germany
Rajkumar Buyya	University of Melbourne, Australia
Hyungseong Choo	Sungkyunkwan University, Korea
Danny Crookes	Queen's University Belfast, UK
Tamal Dey	Ohio State University, USA
Ivan Dimov	Bulgarian Academy of Sciences, Bulgaria
Magdy El-Tawil	Cairo University, Egypt
Oswaldo Gervasi	Università degli Studi di Perugia, Italy
Christopher Gold	University of Glamorgan, UK
Rodolfo Haber	Council for Scientific Research, Spain
Andres Iglesias	University of Cantabria, Spain
Deok-Soo Kim	Hanyang University, Korea
Ivana Kolingerova	University of West Bohemia, Czech Republic
Vipin Kumar	Army High Performance Computing Research Center, USA
Antonio Lagana	Università degli Studi di Perugia, Italy
D.T. Lee	Institute of Information Science, Academia Sinica, Taiwan
Laurence Liew	Platform Computing, Singapore
Nikolai Medvedev	Novosibirsk Russian Academy of Sciences, Russia
Graham M Megson	University of Reading, UK
Edward D. Moreno	UEA – University of Amazonas state, Brazil
Youngsong Mun	Soongsil University, Korea
Dimitri Plemenos	Université de Limoges, France
Viktor K. Prasanna	University of Southern California, USA
Muhammad Sarfraz	KFUPM, Saudi Arabia
Dale Shires	Army Research Lab, USA
Masha Sosonkina	Ames Laboratory, USA
Alexei Sourin	Nanyang Technological University, Singapore
David Taniar	Monash University, Australia
Athanasios Vasilakos	University of Western Macedonia, Greece
Chee Yap	New York University, USA
Igor Zacharov	SGI Europe, Switzerland
Zahari Zlatev	National Environmental Research Institute, Denmark

Table of Contents

Regular Papers

Perspectives on Denotational Mathematics: New Means of Thought	1
<i>Yingxu Wang, Yiyu Yao, and Guoyin Wang</i>	
On Contemporary Denotational Mathematics for Computational Intelligence	6
<i>Yingxu Wang</i>	
Mereological Theories of Concepts in Granular Computing	30
<i>Lech Polkowski</i>	
On Mathematical Laws of Software	46
<i>Yingxu Wang</i>	
Rough Logic and Its Reasoning	84
<i>Qing Liu and Lan Liu</i>	
On Reduct Construction Algorithms	100
<i>Yiyu Yao, Yan Zhao, and Jue Wang</i>	
Attribute Set Dependence in Reduct Computation	118
<i>Pawel Terlecki and Krzysztof Walczak</i>	
A General Model for Transforming Vague Sets into Fuzzy Sets	133
<i>Yong Liu, Guoyin Wang, and Lin Feng</i>	
Quantifying Knowledge Base Inconsistency Via Fixpoint Semantics	145
<i>Du Zhang</i>	
Contingency Matrix Theory I: Rank and Statistical Independence in a Contingency Table	161
<i>Shusaku Tsumoto and Shoji Hirano</i>	
Applying Rough Sets to Information Tables Containing Possibilistic Values	180
<i>Michinori Nakata and Hiroshi Sakai</i>	
Toward a Generic Mathematical Model of Abstract Game Theories	205
<i>Yingxu Wang</i>	
A Comparative Study of STOPA and RTPA	224
<i>Natalia Lopez, Manuel Núñez, and Fernando L. Pelayo</i>	
Author Index	247