Computational Complexity

Theory, Techniques, and Applications

With 1487 Figures and 234 Tables
Preface

Complex systems are systems that comprise many interacting parts with the ability to generate a new quality of collective behavior through self-organization, e.g. the spontaneous formation of temporal, spatial or functional structures. They are therefore adaptive as they evolve and may contain self-driving feedback loops. Thus, complex systems are much more than a sum of their parts. Complex systems are often characterized as having extreme sensitivity to initial conditions as well as emergent behavior that are not readily predictable or even completely deterministic. The conclusion is that a reductionist (bottom-up) approach is often an incomplete description of a phenomenon. This recognition, that the collective behavior of the whole system cannot be simply inferred from the understanding of the behavior of the individual components, has led to many new concepts and sophisticated mathematical and modeling tools for application to many scientific, engineering, and societal issues that can be adequately described only in terms of complexity and complex systems.

The inherent difficulty, or hardness, of computational problems in complex systems is a fundamental concept in computational complexity theory. This compendium, *Computational Complexity*, presents a detailed integrated view of the theoretical basis, computational methods and newest applicable approaches to solving inherently difficult problems whose solution requires extensive resources approaching the practical limits of present day computer systems. Key components of computational complexity are detailed, integrated and utilized, varying from Parameterized Complexity Theory (e.g. see articles entitled ♦ Quantum Computing, and ♦ Analog Computation), the Exponential Time Hypothesis (e.g. see articles on ♦ Cellular Automata and Language Theory) and Complexity Class P (e.g. see ♦ Quantum Computational Complexity and ♦ Cellular Automata, Universality of), to Heuristics (e.g. ♦ Social Network Visualization, Methods of and ♦ Repeated Games with Incomplete Information) and Parallel Algorithms (e.g. ♦ Cellular Automata as Models of Parallel Computation and ♦ Optical Computing).

There are 209 articles which have been organized into 14 sections each headed by a recognized expert in the field and supported by peer reviewers in addition to the section editor. The sections are:

- Agent Based Modeling and Simulation
- Cellular Automata, Mathematical Basis of
- Complex Networks and Graph Theory
- Data Mining and Knowledge Discovery
- Game Theory
- Granular Computing
- Intelligent Systems
- Probability and Statistics in Complex Systems
- Quantum Information Science
- Social Network Analysis
- Social Science, Physics and Mathematics, Applications in
- Soft Computing
- Unconventional Computing
- Wavelets

The complete listing of articles and section editors is presented on pages VII to XII.
The articles are written for an audience of advanced university undergraduate and graduate students, professors, and professionals in a wide range of fields who must manage complexity on scales ranging from the atomic and molecular to the societal and global. Each article was selected and peer reviewed by one of our 13 Section Editors with advice and consultation provided by Board Members: Lotfi Zadeh, Stephen Wolfram and Richard Stearns, and the Editor-in-Chief. This level of coordination assures that the reader can have a level of confidence in the relevance and accuracy of the information far exceeding that generally found on the World Wide Web. Accessibility is also a priority and for this reason each article includes a glossary of important terms and a concise definition of the subject.

Robert A. Meyers  
Editor-in-Chief  
Larkspur, California  
July 2011
Sections

Agent Based Modeling and Simulation,
Section Editor: Filippo Castiglione
Agent Based Computational Economics
Agent Based Modeling and Artificial Life
Agent Based Modeling and Computer Languages
Agent Based Modeling and Simulation, Introduction to
Agent Based Modeling, Large Scale Simulations
Agent Based Modeling, Mathematical Formalism for
Agent-Based Modeling and Simulation
Cellular Automaton Modeling of Tumor Invasion
Computer Graphics and Games, Agent Based Modeling in
Embodied and Situated Agents, Adaptive Behavior in
Interaction Based Computing in Physics
Logic and Geometry of Agents in Agent-Based Modeling
Social Phenomena Simulation
Swarm Intelligence

Cellular Automata, Mathematical Basis of,
Section Editor: Andrew Adamatzky
Additive Cellular Automata
Algorithmic Complexity and Cellular Automata
Cellular Automata and Groups
Cellular Automata and Language Theory
Cellular Automata as Models of Parallel Computation
Cellular Automata in Hyperbolic Spaces
Cellular Automata Modeling of Physical Systems
Cellular Automata on Triangular, Pentagonal and Hexagonal Tessellations
Cellular Automata with Memory
Cellular Automata, Classification of
Cellular Automata, Emergent Phenomena in
Cellular Automata, Universality of
Chaotic Behavior of Cellular Automata
Dynamics of Cellular Automata in Non-compact Spaces
Ergodic Theory of Cellular Automata
Evolving Cellular Automata
Firing Squad Synchronization Problem in Cellular Automata
Gliders in Cellular Automata
Growth Phenomena in Cellular Automata
Identification of Cellular Automata
Mathematical Basis of Cellular Automata, Introduction to
Phase Transitions in Cellular Automata
Quantum Cellular Automata
Reversible Cellular Automata
Self-organised Criticality and Cellular Automata
Self-Replication and Cellular Automata
Structurally Dynamic Cellular Automata
Tiling Problem and Undecidability in Cellular Automata
Topological Dynamics of Cellular Automata

Complex Networks and Graph Theory,
Section Editor: Geoffrey Canright
Community Structure in Graphs
Complex Gene Regulatory Networks – From Structure to Biological Observables: Cell Fate Determination
Complex Networks and Graph Theory
Complex Networks, Visualization of
Food Webs
Growth Models for Networks
Human Sexual Networks
Internet Topology
Link Analysis and Web Search
Motifs in Graphs
Non-negative Matrices and Digraphs
Random Graphs, a Whirlwind Tour of
Synchronization Phenomena on Networks
World Wide Web, Graph Structure

Data Mining and Knowledge Discovery,
Section Editor: Peter Kokol
Data and Dimensionality Reduction in Data Analysis and System Modeling
Data-Mining and Knowledge Discovery, Introduction to
Data-Mining and Knowledge Discovery, Neural Networks in
Data-Mining and Knowledge Discovery: Case Based Reasoning, Nearest Neighbor and Rough Sets
Decision Trees
Discovery Systems
Genetic and Evolutionary Algorithms and Programming: General Introduction and Application to Game Playing
Knowledge Discovery: Clustering
Machine Learning, Ensemble Methods in
Manipulating Data and Dimension Reduction Methods: Feature Selection

Game Theory,
Section Editor: Marilda Sotomayor
Bayesian Games: Games with Incomplete Information
Cooperative Games
Cooperative Games (Von Neumann–Morgenstern Stable Sets)
Correlated Equilibria and Communication in Games
Cost Sharing
Differential Games
Dynamic Games with an Application to Climate Change Models
Evolutionary Game Theory
Fair Division
Game Theory and Strategic Complexity
Game Theory, Introduction to
Implementation Theory
Inspection Games
Learning in Games
Market Games and Clubs
Mechanism Design
Networks and Stability
Principal-Agent Models
Repeated Games with Complete Information
Repeated Games with Incomplete Information
Reputation Effects
Signaling Games
Static Games
Stochastic Games
Two-Sided Matching Models
Voting
Voting Procedures, Complexity of
Zero-sum Two Person Games

Granular Computing,
Section Editor: Tsau Y. Lin

Cooperative Multi-Hierarchical Query Answering Systems
Dependency and Granularity in Data Mining
Fuzzy Logic
Fuzzy Probability Theory
Fuzzy System Models Evolution from Fuzzy Rulebases to Fuzzy Functions
Genetic-Fuzzy Data Mining Techniques
Granular Model for Data Mining
Granular Computing and Data Mining for Ordered Data: The Dominance-Based Rough Set Approach
Granular Computing and Modeling of the Uncertainty in Quantum Mechanics
Granular Computing System Vulnerabilities: Exploring the Dark Side of Social Networking Communities
Granular Computing, Information Models for
Granular Computing, Introduction to
Granular Computing, Philosophical Foundation for
Granular Computing, Principles and Perspectives of
Granular Computing: Practices, Theories and Future Directions
Granular Neural Network
Granulation of Knowledge: Similarity Based Approach in Information and Decision Systems
Multi-Granular Computing and Quotient Structure
Non-standard Analysis, an Invitation to
Rough and Rough-Fuzzy Sets in Design of Information Systems
Rough Set Data Analysis
Rule Induction, Missing Attribute Values and Discretization
Social Networks and Granular Computing

Intelligent Systems,
Section Editor: James A. Hendler

Artificial Intelligence in Modeling and Simulation
Intelligent Control
Intelligent Systems, Introduction to
Learning and Planning (Intelligent Systems)
Mobile Agents
Semantic Web

Probability and Statistics in Complex Systems,
Section Editor: Henrik Jeldtoft Jensen
Bayesian Statistics
Branching Processes
Complexity in Systems Level Biology and Genetics: Statistical Perspectives
Correlations in Complex Systems
Entropy
Extreme Value Statistics
Field Theoretic Methods
Fluctuations, Importance of: Complexity in the View of Stochastic Processes
Hierarchical Dynamics
Levy Statistics and Anomalous Transport: Levy Flights and Subdiffusion
Probability and Statistics in Complex Systems, Introduction to
Probability Densities in Complex Systems, Measuring
Probability Distributions in Complex Systems
Random Matrix Theory
Random Walks in Random Environment
Record Statistics and Dynamics
Stochastic Loewner Evolution: Linking Universality, Criticality and Conformal Invariance in Complex Systems
Stochastic Processes

Quantum Information Science,
Section Editor: Joseph F. Traub
Quantum Algorithms
Quantum Algorithms and Complexity for Continuous Problems
Quantum Computational Complexity
Quantum Computing Using Optics
Quantum Computing with Trapped Ions
Quantum Cryptography
Quantum Error Correction and Fault Tolerant Quantum Computing
Quantum Information Processing
Quantum Information Science, Introduction to

Social Network Analysis,
Section Editor: John Scott
Network Analysis, Longitudinal Methods of
Positional Analysis and Blockmodelling
Social Network Analysis, Estimation and Sampling in
Social Network Analysis, Graph Theoretical Approaches to
Social Network Analysis, Large-Scale
Social Network Analysis, Overview of
Social Network Analysis, Two-Mode Concepts in
Social Network Visualization, Methods of
Social Networks, Algebraic Models for
Social Networks, Diffusion Processes in
Social Networks, Exponential Random Graph (p*) Models for
Social Science, Physics and Mathematics Applications in,
Section Editor: Andrzej Nowak

Minority Games
Rational, Goal-Oriented Agents
Social Processes, Simulation Models of

Soft Computing,
Section Editor: Janusz Kacprzyk

Aggregation Operators and Soft Computing
Evolving Fuzzy Systems
Fuzzy Logic, Type-2 and Uncertainty
Fuzzy Optimization
Fuzzy Sets Theory, Foundations of
Hybrid Soft Computing Models for Systems Modeling and Control
Neuro-fuzzy Systems
Possibility Theory
Rough Sets in Decision Making
Rough Sets: Foundations and Perspectives
Soft Computing, Introduction to
Statistics with Imprecise Data

Unconventional Computing,
Section Editor: Andrew Adamatzky

Amorphous Computing
Analog Computation
Artificial Chemistry
Bacterial Computing
Cellular Computing
Computing in Geometrical Constrained Excitable Chemical Systems
Computing with Solitons
DNA Computing
Evolution in Materio
Immunocomputing
Mechanical Computing: The Computational Complexity of Physical Devices
Membrane Computing
Molecular Automata
Nanocomputers
Optical Computing
Quantum Computing
Reaction-Diffusion Computing
Reversible Computing
Thermodynamics of Computation
Unconventional Computing, Introduction to
Unconventional Computing, Novel Hardware for

Wavelets,
Section Editor: Edward Aboufadel

Bivariate (Two-dimensional) Wavelets
Comparison of Discrete and Continuous Wavelet Transforms
Curvelets and Ridgelets
Multivariate Splines and Their Applications
Multiwavelets
Numerical Issues When Using Wavelets
Popular Wavelet Families and Filters and Their Use
Statistical Applications of Wavelets
Wavelets and PDE Techniques in Image Processing, a Quick Tour of
Wavelets and the Lifting Scheme
Wavelets, Introduction to
About the Editor-in-Chief

Robert A. Meyers

President: RAMTECH Limited
Manager, Chemical Process Technology, TRW Inc.
Post-doctoral Fellow: California Institute of Technology
Ph. D. Chemistry, University of California at Los Angeles
B. A., Chemistry, California State University, San Diego

Biography

Dr. Meyers has worked with more than 25 Nobel laureates during his career.

Research

Dr. Meyers was Manager of Chemical Technology at TRW (now Northrop Grumman) in Redondo Beach, CA and is now President of RAMTECH Limited. He is co-inventor of the Gravimelt process for desulfurization and demineralization of coal for air pollution and water pollution control. Dr. Meyers is the inventor of and was project manager for the DOE-sponsored Magnetohydrodynamics Seed Regeneration Project which has resulted in the construction and successful operation of a pilot plant for production of potassium formate, a chemical utilized for plasma electricity generation and air pollution control. Dr. Meyers managed the pilot-scale DoE project for determining the hydrodynamics of synthetic fuels. He is a co-inventor of several thermo-oxidative stable polymers which have achieved commercial success as the GE PEI, Upjohn Polyimides and Rhone-Polenc bismaleimide resins. He has also managed projects for photochemistry, chemical lasers, flue gas scrubbing, oil shale analysis and refining, petroleum analysis and refining, global change measurement from space satellites, analysis and mitigation (carbon dioxide and ozone), hydrometallurgical refining, soil and hazardous waste remediation, novel polymers synthesis, modeling of the economics of space transportation systems, space rigidizable structures and chemiluminescence-based devices.

He is a senior member of the American Institute of Chemical Engineers, member of the American Physical Society, member of the American Chemical Society and serves on the UCLA Chemistry Department Advisory Board. He was a member of the joint USA-Russia working group on air pollution control and the EPA-sponsored Waste Reduction Institute for Scientists and Engineers.
XIV About the Editor-in-Chief

Dr. Meyers has more than 20 patents and 50 technical papers. He has published in primary literature journals including Science and the Journal of the American Chemical Society, and is listed in Who’s Who in America and Who’s Who in the World. Dr. Meyers’ scientific achievements have been reviewed in feature articles in the popular press in publications such as The New York Times Science Supplement and The Wall Street Journal as well as more specialized publications such as Chemical Engineering and Coal Age. A public service film was produced by the Environmental Protection Agency of Dr. Meyers’ chemical desulfurization invention for air pollution control.

Scientific Books

Dr. Meyers is the author or Editor-in-Chief of 12 technical books one of which won the Association of American Publishers Award as the best book in technology and engineering.

Encyclopedias

Dr. Meyers conceived and has served as Editor-in-Chief of the Academic Press (now Elsevier) Encyclopedia of Physical Science and Technology. This is an 18-volume publication of 780 twenty-page articles written to an audience of university students and practicing professionals. This encyclopedia, first published in 1987, was very successful, and because of this, was revised and reissued in 1992 as a second edition. The Third Edition was published in 2001 and is now online. Dr. Meyers has completed two editions of the Encyclopedia of Molecular Cell Biology and Molecular Medicine for Wiley VCH publishers (1995 and 2004). These cover molecular and cellular level genetics, biochemistry, pharmacology, diseases and structure determination as well as cell biology. His eight-volume Encyclopedia of Environmental Analysis and Remediation was published in 1998 by John Wiley & Sons and his 15-volume Encyclopedia of Analytical Chemistry was published in 2000, also by John Wiley & Sons, all of which are available online.
Editorial Board Members

Lotfi A. Zadeh
Professor in the Graduate School,
Computer Science Division
Department of Electrical Engineering
and Computer Sciences
University of California, Berkeley

Stephen Wolfram
Founder and CEO, Wolfram Research
Creator, Mathematica®
Author, A New Kind of Science

Richard E. Stearns
1993 Turing Award for foundations
of computational complexity
Current interests include: computational complexity,
automata theory, analysis of algorithms, and game theory.
Section Editors

Agent Based Modeling and Simulation

FILIPPO CASTIGLIONE
Research Scientist
Institute for Computing Applications (IAC) “M. Picone”
National Research Council (CNR), Italy

Complex Networks and Graph Theory

GEOFFREY CANRIGHT
Senior Research Scientist
Telenor Research and Innovation
Fornebu, Norway

Cellular Automata, Mathematical Basis of

ANDREW ADAMATZKY
Professor
Faculty of Computing, Engineering and Mathematical Science
University of the West of England

Data Mining and Knowledge Discovery

PETER KOKOL
Professor
Department of Computer Science
University of Maribor, Slovenia
Game Theory

MARILDA SOTOMAYOR
Professor
Department of Economics
University of São Paulo, Brazil
Department of Economics
Brown University, Providence

Granular Computing

TSAU Y. LIN
Professor
Computer Science Department
San Jose State University

Probability and Statistics in Complex Systems

HENRIK JELDTOFT JENSEN
Professor of Mathematical Physics
Department of Mathematics and Institute for Mathematical Sciences
Imperial College London

Quantum Information Science

JOSEPH F. TRAUB
Edwin Howard Armstrong Professor of Computer Science
Computer Science Department
Columbia University

Intelligent Systems

JAMES A. HENDLER
Senior Constellation Professor of the Tetherless World Research Constellation
Rensselaer Polytechnic Institute

Social Network Analysis

JOHN SCOTT
Professor of Sociology
School of Social Science and Law
University of Plymouth
Social Science, Physics and Mathematics Applications in

**ANDRZEJ NOWAK**
Director of the Center for Complex Systems
University of Warsaw
Assistant Professor, Psychology Department
Florida Atlantic University

**JANUSZ KACPRZYK**
Deputy Director for Scientific Affairs, Professor
Systems Research Institute
Polish Academy of Sciences

Unconventional Computing

**ANDREW ADAMATZKY**
Professor
Faculty of Computing, Engineering and Mathematical Science
University of the West of England

**WAVELETS**

**EDWARD ABOUFADEL**
Professor of Mathematics
Grand Valley State University
Table of Contents

Additive Cellular Automata
   Burton Voorhees ................................................. 1
Agent Based Computational Economics
   Moshe Levy .................................................... 18
Agent Based Modeling and Artificial Life
   Charles M. Macal ................................................. 39
Agent Based Modeling and Computer Languages
   Michael J. North, Charles M. Macal ....................................... 58
Agent Based Modeling, Large Scale Simulations
   Hazel R. Parry .................................................. 76
Agent Based Modeling, Mathematical Formalism for
   Reinhard Laubenbacher, Abdul S. Jarrah, Henning S. Mortveit, S.S. Ravi ................... 88
Agent Based Modeling and Simulation
   Stefania Bandini, Sara Manzoni, Giuseppe Vizzari ................................. 105
Agent Based Modeling and Simulation, Introduction to
   Filippo Castiglione ................................................ 118
Aggregation Operators and Soft Computing
   Vicenç Torra ...................................................... 122
Algorithmic Complexity and Cellular Automata
   Julien Cervelle, Enrico Formenti ................................................. 132
Amorphous Computing
   Hal Abelson, Jacob Beal, Gerald Jay Sussman ....................................... 147
Analog Computation
   Bruce J. MacLennan ............................................... 161
Artificial Chemistry
   Peter Dittrich .................................................. 185
Artificial Intelligence in Modeling and Simulation
   Bernard Zeigler, Alexandre Mazu, Levent Yilmaz ............................................. 204
Bacterial Computing
   Martyn Amos ..................................................... 228
Bayesian Games: Games with Incomplete Information
   Shmuel Zamir .................................................... 238
Bayesian Statistics
   David Draper .................................................. 254
Bivariate (Two-dimensional) Wavelets
   Bin Han .......................................................... 275
**Branching Processes**  
*Mikko J. Alava, Kent Bækgaard Lauritsen*  

---  

**Cellular Automata as Models of Parallel Computation**  
*Thomas Worsch*  

---  

**Cellular Automata, Classification of**  
*Klaus Sutner*  

---  

**Cellular Automata, Emergent Phenomena in**  
*James E. Hanson*  

---  

**Cellular Automata and Groups**  
*Tullio Ceccherini-Silberstein, Michel Coornaert*  

---  

**Cellular Automata in Hyperbolic Spaces**  
*Maurice Margenstern*  

---  

**Cellular Automata and Language Theory**  
*Martin Kutrib*  

---  

**Cellular Automata with Memory**  
*Ramón Alonso-Sanz*  

---  

**Cellular Automata Modeling of Physical Systems**  
*Bastien Chopard*  

---  

**Cellular Automata in Triangular, Pentagonal and Hexagonal Tessellations**  
*Carter Bays*  

---  

**Cellular Automata, Universality of**  
*Jérôme Durand-Lose*  

---  

**Cellular Automaton Modeling of Tumor Invasion**  
*Haralambos Hatzikirou, Georg Breier, Andreas Deutsch*  

---  

**Cellular Computing**  
*Christof Teuscher*  

---  

**Chaotic Behavior of Cellular Automata**  
*Julien Cervelle, Alberto Dennunzio, Enrico Formenti*  

---  

**Community Structure in Graphs**  
*Santo Fortunato, Claudio Castellano*  

---  

**Comparison of Discrete and Continuous Wavelet Transforms**  
*Palle E. T. Jorgensen, Myung-Sin Song*  

---  

**Complex Gene Regulatory Networks – from Structure to Biological Observables: Cell Fate Determination**  
*Sui Huang, Stuart A. Kauffman*  

---  

**Complexity in Systems Level Biology and Genetics: Statistical Perspectives**  
*David A. Stephens*  

---  

**Complex Networks and Graph Theory**  
*Geoffrey Canright*  

---  

**Complex Networks, Visualization of**  
*Vladimir Batagelj*  

---  

**Computer Graphics and Games, Agent Based Modeling in**  
*Brian Mac Namee*  

---  

**Computing in Geometrical Constrained Excitable Chemical Systems**  
*Jerzy Gorecki, Joanna Natalia Gorecka*  

---  

**Computing with Solitons**  
*Darren Rand, Ken Steiglitz*
<table>
<thead>
<tr>
<th>Title</th>
<th>Author(s)</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperative Games</td>
<td>Roberto Serrano</td>
<td>666</td>
</tr>
<tr>
<td>Cooperative Games (Von Neumann–Morgenstern Stable Sets)</td>
<td>Jun Wako, Shigeo Muto</td>
<td>675</td>
</tr>
<tr>
<td>Cooperative Multi-hierarchical Query Answering Systems</td>
<td>Zbigniew W. Ras, Agnieszka Dardzinska</td>
<td>690</td>
</tr>
<tr>
<td>Correlated Equilibria and Communication in Games</td>
<td>Françoise Forges</td>
<td>695</td>
</tr>
<tr>
<td>Correlations in Complex Systems</td>
<td>Renat M. Yulmetyev, Peter Hänggi</td>
<td>705</td>
</tr>
<tr>
<td>Cost Sharing</td>
<td>Maurice Koster</td>
<td>724</td>
</tr>
<tr>
<td>Curvelets and Ridgelets</td>
<td>Jalal Fadili, Jean-Luc Starck</td>
<td>754</td>
</tr>
<tr>
<td>Data and Dimensionality Reduction in Data Analysis and System Modeling</td>
<td>Witold Pedrycz</td>
<td>774</td>
</tr>
<tr>
<td>Data-Mining and Knowledge Discovery: Case-Based Reasoning, Nearest Neighbor and Rough Sets</td>
<td>Lech Polkowski</td>
<td>789</td>
</tr>
<tr>
<td>Data-Mining and Knowledge Discovery, Introduction to</td>
<td>Peter Kokol</td>
<td>810</td>
</tr>
<tr>
<td>Data-Mining and Knowledge Discovery, Neural Networks in</td>
<td>Markus Brameier</td>
<td>813</td>
</tr>
<tr>
<td>Decision Trees</td>
<td>Vili Podgorelec, Milan Zorman</td>
<td>827</td>
</tr>
<tr>
<td>Dependency and Granularity in Data-Mining</td>
<td>Shusaku Tsumoto, Shoji Hirano</td>
<td>846</td>
</tr>
<tr>
<td>Differential Games</td>
<td>Marc Quincampoix</td>
<td>854</td>
</tr>
<tr>
<td>Discovery Systems</td>
<td>Petra Povalej, Mateja Verlic, Gregor Stiglic</td>
<td>862</td>
</tr>
<tr>
<td>DNA Computing</td>
<td>Martyn Amos</td>
<td>882</td>
</tr>
<tr>
<td>Dynamic Games with an Application to Climate Change Models</td>
<td>Prajit K. Dutta</td>
<td>897</td>
</tr>
<tr>
<td>Dynamics of Cellular Automata in Non-compact Spaces</td>
<td>Enrico Formenti, Petr Kůrka</td>
<td>914</td>
</tr>
<tr>
<td>Embodied and Situated Agents, Adaptive Behavior in</td>
<td>Stefano Nolfi</td>
<td>925</td>
</tr>
<tr>
<td>Entropy</td>
<td>Constantino Tsallis</td>
<td>940</td>
</tr>
<tr>
<td>Ergodic Theory of Cellular Automata</td>
<td>Marcus Pivato</td>
<td>965</td>
</tr>
<tr>
<td>Evolutionary Game Theory</td>
<td>William H. Sandholm</td>
<td>1000</td>
</tr>
<tr>
<td>Evolution in Materio</td>
<td>Simon Harding, Julian F. Miller</td>
<td>1030</td>
</tr>
</tbody>
</table>
Evolving Cellular Automata
Martin Cenek, Melanie Mitchell .................................................. 1043

Evolving Fuzzy Systems
Plamen Angelov ............................................................................ 1053

Extreme Value Statistics
Mario Nicodemi ........................................................................... 1066

Fair Division
Steven J. Brams ................................................................................ 1073

Field Theoretic Methods
Uwe Claus Täuber ........................................................................... 1080

Firing Squad Synchronization Problem in Cellular Automata
Hiroshi Umeo .................................................................................. 1094

Fluctuations, Importance of: Complexity in the View of Stochastic Processes
Rudolf Friedrich, Joachim Peinke, M. Reza Rahimi Tabar ................ 1131

Food Webs
Jennifer A. Dunne ........................................................................... 1155

Fuzzy Logic
Lotfi A. Zadeh .................................................................................. 1177

Fuzzy Logic, Type-2 and Uncertainty
Robert I. John, Jerry M. Mendel ...................................................... 1201

Fuzzy Optimization
Weldon A. Lodwick, Elizabeth A. Untiedt ........................................ 1211

Fuzzy Probability Theory
Michael Beer .................................................................................... 1240

Fuzzy Sets Theory, Foundations of
Janusz Kacprzyk ............................................................................ 1253

Fuzzy System Models Evolution from Fuzzy Rulebases to Fuzzy Functions
I. Burhan Türkşen ............................................................................. 1274

Game Theory, Introduction to
Marilda Sotomayor .......................................................................... 1289

Game Theory and Strategic Complexity
Kalyan Chatterjee, Hamid Sabourian ................................................. 1292

Genetic and Evolutionary Algorithms and Programming: General Introduction and Appl. to Game Playing
Michael Orlov, Moshe Sipper, Ami Hauptman ................................ 1309

Genetic-Fuzzy Data Mining Techniques
Tzung-Pei Hong, Chun-Hao Chen, Vincent S. Tseng ....................... 1321

Gliders in Cellular Automata
Carter Bays ....................................................................................... 1337

Granular Computing and Data Mining for Ordered Data: The Dominance-Based Rough Set Approach
Salvatore Greco, Benedetto Matarazzo, Roman Słowiński .................. 1347

Granular Computing, Information Models for
Steven A. Demurjian ........................................................................ 1369

Granular Computing, Introduction to
Tsau Young Lin ............................................................................... 1377

Granular Computing and Modeling of the Uncertainty in Quantum Mechanics
Kow-Lung Chang ............................................................................... 1381
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granular Computing, Philosophical Foundation for</td>
<td>1389</td>
</tr>
<tr>
<td>Zhengxin Chen</td>
<td></td>
</tr>
<tr>
<td>Granular Computing: Practices, Theories, and Future Directions</td>
<td>1404</td>
</tr>
<tr>
<td>Tsau Young Lin</td>
<td></td>
</tr>
<tr>
<td>Granular Computing, Principles and Perspectives of</td>
<td>1421</td>
</tr>
<tr>
<td>Jianchao Han, Nick Cercone</td>
<td></td>
</tr>
<tr>
<td>Granular Computing System Vulnerabilities: Exploring the Dark Side of Social Networking Communities</td>
<td>1433</td>
</tr>
<tr>
<td>Steve Webb, James Caverlee, Calton Pu</td>
<td></td>
</tr>
<tr>
<td>Granular Model for Data Mining</td>
<td>1444</td>
</tr>
<tr>
<td>Anita Wasilewska, Ernestina Menalasav</td>
<td></td>
</tr>
<tr>
<td>Granular Neural Network</td>
<td>1455</td>
</tr>
<tr>
<td>Yan-Qing Zhang</td>
<td></td>
</tr>
<tr>
<td>Granulation of Knowledge: Similarity Based Approach in Information and Decision Systems</td>
<td>1464</td>
</tr>
<tr>
<td>Lech Polkowski</td>
<td></td>
</tr>
<tr>
<td>Growth Models for Networks</td>
<td>1488</td>
</tr>
<tr>
<td>Sergey N. Dorogovtsev</td>
<td></td>
</tr>
<tr>
<td>Growth Phenomena in Cellular Automata</td>
<td>1499</td>
</tr>
<tr>
<td>Janko Gravner</td>
<td></td>
</tr>
<tr>
<td>Hierarchical Dynamics</td>
<td>1514</td>
</tr>
<tr>
<td>Martin Nilson Jacobi</td>
<td></td>
</tr>
<tr>
<td>Human Sexual Networks</td>
<td>1535</td>
</tr>
<tr>
<td>Fredrik Liljeros</td>
<td></td>
</tr>
<tr>
<td>Hybrid Soft Computing Models for Systems Modeling and Control</td>
<td>1547</td>
</tr>
<tr>
<td>Oscar Castillo, Patricia Melin</td>
<td></td>
</tr>
<tr>
<td>Identification of Cellular Automata</td>
<td>1564</td>
</tr>
<tr>
<td>Andrew Adamatzky</td>
<td></td>
</tr>
<tr>
<td>Immunecomputing</td>
<td>1576</td>
</tr>
<tr>
<td>Jon Timmis</td>
<td></td>
</tr>
<tr>
<td>Implementation Theory</td>
<td>1588</td>
</tr>
<tr>
<td>Luis C. Corchón</td>
<td></td>
</tr>
<tr>
<td>Inspection Games</td>
<td>1605</td>
</tr>
<tr>
<td>Rudolf Avenhaus, Morton J. Canty</td>
<td></td>
</tr>
<tr>
<td>Intelligent Control</td>
<td>1619</td>
</tr>
<tr>
<td>Clarence W. de Silva</td>
<td></td>
</tr>
<tr>
<td>Intelligent Systems, Introduction to</td>
<td>1642</td>
</tr>
<tr>
<td>James Hendler</td>
<td></td>
</tr>
<tr>
<td>Interaction Based Computing in Physics</td>
<td>1644</td>
</tr>
<tr>
<td>Franco Bagnoli</td>
<td></td>
</tr>
<tr>
<td>Internet Topology</td>
<td>1663</td>
</tr>
<tr>
<td>Yihua He, Georgos Siganos, Michalis Faloutsos</td>
<td></td>
</tr>
<tr>
<td>Knowledge Discovery: Clustering</td>
<td>1681</td>
</tr>
<tr>
<td>Pavel Berkhin, Inderjit S. Dhillon</td>
<td></td>
</tr>
<tr>
<td>Learning in Games</td>
<td>1695</td>
</tr>
<tr>
<td>John Nachbar</td>
<td></td>
</tr>
<tr>
<td>Learning and Planning (Intelligent Systems)</td>
<td>1706</td>
</tr>
<tr>
<td>Ugur Kuter</td>
<td></td>
</tr>
<tr>
<td>Title</td>
<td>Authors</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Levy Statistics and Anomalous Transport: Levy Flights and Subdiffusion</td>
<td>Ralf Metzler, Aleksei V. Chechkin, Joseph Klafter</td>
</tr>
<tr>
<td>Link Analysis and Web Search</td>
<td>Johannes Bjelland, Geoffrey Canright, Kenth Enga-Monsen</td>
</tr>
<tr>
<td>Logic and Geometry of Agents in Agent-Based Modeling</td>
<td>Samson Abramsky</td>
</tr>
<tr>
<td>Machine Learning, Ensemble Methods in</td>
<td>Sašo Džeroski, Panče Panov, Bernard Ženko</td>
</tr>
<tr>
<td>Manipulating Data and Dimension Reduction Methods: Feature Selection</td>
<td>Huan Liu, Zheng Zhao</td>
</tr>
<tr>
<td>Market Games and Clubs</td>
<td>Myrna Wooders</td>
</tr>
<tr>
<td>Mathematical Basis of Cellular Automata, Introduction to</td>
<td>Andrew Adamatzky</td>
</tr>
<tr>
<td>Mechanical Computing: The Computational Complexity of Physical Devices</td>
<td>John H. Reif</td>
</tr>
<tr>
<td>Mechanism Design</td>
<td>Ron Lavi</td>
</tr>
<tr>
<td>Membrane Computing</td>
<td>Gheorghe Paun</td>
</tr>
<tr>
<td>Minority Games</td>
<td>Chi Ho Yeung, Yi-Cheng Zhang</td>
</tr>
<tr>
<td>Mobile Agents</td>
<td>Niranjan Suri, Jan Vitek</td>
</tr>
<tr>
<td>Molecular Automata</td>
<td>Joanne Macdonald, Darko Stefanovic, Milan Stojanovic</td>
</tr>
<tr>
<td>Motifs in Graphs</td>
<td>Sergi Valverde, Ricard V. Solé</td>
</tr>
<tr>
<td>Multi-Granular Computing and Quotient Structure</td>
<td>Ling Zhang, Bo Zhang</td>
</tr>
<tr>
<td>Multivariate Splines and Their Applications</td>
<td>Ming-Jun Lai</td>
</tr>
<tr>
<td>Multiwavelets</td>
<td>Fritz Keinert</td>
</tr>
<tr>
<td>Nanocomputers</td>
<td>Ferdinand Peper</td>
</tr>
<tr>
<td>Network Analysis, Longitudinal Methods of</td>
<td>Tom A. B. Snijders</td>
</tr>
<tr>
<td>Networks and Stability</td>
<td>Frank H. Page Jr., Myrna Wooders</td>
</tr>
<tr>
<td>Neuro-fuzzy Systems</td>
<td>Leszek Rutkowski, Krzysztof Cpakła, Robert Nowicki, Agata Pokropińska, Rafał Scherer</td>
</tr>
<tr>
<td>Non-negative Matrices and Digraphs</td>
<td>Abraham Berman, Naomi Shaked-Monderer</td>
</tr>
<tr>
<td>Non-standard Analysis, an Invitation to</td>
<td>Wei-Zhe Yang</td>
</tr>
</tbody>
</table>
Numerical Issues When Using Wavelets
Jean-Luc Starck, Jalal Fadili .................................................. 2121

Optical Computing
Thomas J. Naughton, Damien Woods ........................................ 2138

Phase Transitions in Cellular Automata
Nino Boccara ........................................................................ 2157

Popular Wavelet Families and Filters and Their Use
Ming-Jun Lai ...................................................................... 2168

Positional Analysis and Blockmodeling
Patrick Doreian .................................................................... 2226

Possibility Theory
Didier Dubois, Henri Prade ...................................................... 2240

Principal-Agent Models
Inés Macho-Stadler, David Pérez-Castrillo .............................. 2253

Probability Densities in Complex Systems, Measuring
Gunnar Pruessner .................................................................. 2267

Probability Distributions in Complex Systems
Didier Sornette .................................................................... 2286

Probability and Statistics in Complex Systems, Introduction to
Henrik Jeldtoft Jensen ............................................................. 2301

Quantum Algorithms
Michele Mosca ...................................................................... 2303

Quantum Algorithms and Complexity for Continuous Problems
Anargyros Papageorgiou, Joseph F. Traub ............................... 2334

Quantum Cellular Automata
Karoline Wiesner ................................................................ 2351

Quantum Computational Complexity
John Watrous ...................................................................... 2361

Quantum Computing
Viv Kendon ......................................................................... 2388

Quantum Computing with Trapped Ions
Wolfgang Lange .................................................................. 2406

Quantum Computing Using Optics
Gerard J. Milburn, Andrew G. White ..................................... 2437

Quantum Cryptography
Hoi-Kwong Lo, Yi Zhao .......................................................... 2453

Quantum Error Correction and Fault Tolerant Quantum Computing
Markus Grassl, Martin Rötteler .............................................. 2478

Quantum Information Processing
Seth Lloyd ............................................................................ 2496

Quantum Information Science, Introduction to
Joseph F. Traub .................................................................... 2534

Random Graphs, a Whirlwind Tour of
Fan Chung ........................................................................ 2536

Random Matrix Theory
Güler Ergün ........................................................................ 2549
Random Walks in Random Environment
Ofer Zeitouni ................................................................. 2564

Rational, Goal-Oriented Agents
Rosaria Conte ................................................................. 2578

Reaction-Diffusion Computing
Andrew Adamatzky ......................................................... 2594

Record Statistics and Dynamics
Paolo Sibani, Henrik, Jeldtoft Jensen .................................. 2611

Repeated Games with Complete Information
Olivier Gossner, Tristan Tomala ......................................... 2620

Repeated Games with Incomplete Information
Jérôme Renault ............................................................... 2635

Reputation Effects
George J. Mailath ............................................................ 2656

Reversible Cellular Automata
Kenichi Morita ............................................................... 2668

Reversible Computing
Kenichi Morita ............................................................... 2685

Rough and Rough-Fuzzy Sets in Design of Information Systems
Theresa Beaubouef, Frederick Petry .................................... 2702

Rough Set Data Analysis
Shusaku Tsumoto ........................................................... 2716

Rough Sets in Decision Making
Roman Slowiński, Salvatore Greco, Benedetto Matarazzo .......... 2727

Rough Sets: Foundations and Perspectives
James F. Peters, Andrzej Skowron, Jaroslaw Stepaniuk ............... 2761

Rule Induction, Missing Attribute Values and Discretization
Jerzy W. Grzymala-Busse .................................................. 2772

Self-organized Criticality and Cellular Automata
Michael Creutz ............................................................... 2780

Self-Replication and Cellular Automata
Gianluca Tempesti, Daniel Mange, André Stauffer ..................... 2792

Semantic Web
Wendy Hall, Kieron O’Hara ................................................. 2810

Signaling Games
Joel Sobel ................................................................. 2830

Social Network Analysis, Estimation and Sampling in
Ove Frank ................................................................. 2845

Social Network Analysis, Graph Theoretical Approaches to
Wouter de Nooy ........................................................... 2864

Social Network Analysis, Large-Scale
Vladimir Batagelj ............................................................ 2878

Social Network Analysis, Overview of
John Scott ................................................................. 2898

Social Network Analysis, Two-Mode Concepts in
Stephen P. Borgatti .......................................................... 2912
<table>
<thead>
<tr>
<th>Topic</th>
<th>Author(s)</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Networks, Algebraic Models for</td>
<td>Philippa Pattison</td>
<td>2925</td>
</tr>
<tr>
<td>Social Networks, Diffusion Processes in</td>
<td>Thomas W. Valente</td>
<td>2940</td>
</tr>
<tr>
<td>Social Networks, Exponential Random Graph ( p^* ) Models for</td>
<td>Garry Robins</td>
<td>2953</td>
</tr>
<tr>
<td>Social Networks and Granular Computing</td>
<td>Churn-Jung Liau</td>
<td>2968</td>
</tr>
<tr>
<td>Social Network Visualization, Methods of</td>
<td>Linton C. Freeman</td>
<td>2981</td>
</tr>
<tr>
<td>Social Phenomena Simulation</td>
<td>Paul Davidsson, Harko Verhagen</td>
<td>2999</td>
</tr>
<tr>
<td>Social Processes, Simulation Models of</td>
<td>Klaus G. Troitzsch</td>
<td>3004</td>
</tr>
<tr>
<td>Soft Computing, Introduction to</td>
<td>Janusz Kacprzyk</td>
<td>3020</td>
</tr>
<tr>
<td>Static Games</td>
<td>Oscar Volij</td>
<td>3023</td>
</tr>
<tr>
<td>Statistical Applications of Wavelets</td>
<td>Sofia Olhede</td>
<td>3043</td>
</tr>
<tr>
<td>Statistics with Imprecise Data</td>
<td>Maria Ángeles Gil, Olgierd Hryniewicz</td>
<td>3052</td>
</tr>
<tr>
<td>Stochastic Games</td>
<td>Eilon Solan</td>
<td>3064</td>
</tr>
<tr>
<td>Stochastic Loewner Evolution: Linking Universality, Criticality and Conformal Invariance in Complex Systems</td>
<td>Hans C. Fogedby</td>
<td>3075</td>
</tr>
<tr>
<td>Stochastic Processes</td>
<td>Alan J. McKane</td>
<td>3097</td>
</tr>
<tr>
<td>Structurally Dynamic Cellular Automata</td>
<td>Andrew Ilachinski</td>
<td>3114</td>
</tr>
<tr>
<td>Swarm Intelligence</td>
<td>Gerardo Beni</td>
<td>3150</td>
</tr>
<tr>
<td>Synchronization Phenomena on Networks</td>
<td>Guanrong Chen, Ming Zhao, Tao Zhou, Bing-Hong Wang</td>
<td>3170</td>
</tr>
<tr>
<td>Thermodynamics of Computation</td>
<td>H. John Caulfield, Lei Qian</td>
<td>3187</td>
</tr>
<tr>
<td>Tiling Problem and Undecidability in Cellular Automata</td>
<td>Jarkko Kari</td>
<td>3198</td>
</tr>
<tr>
<td>Topological Dynamics of Cellular Automata</td>
<td>Petr Kůrka</td>
<td>3212</td>
</tr>
<tr>
<td>Two-Sided Matching Models</td>
<td>Marilda Sotomayor, Ömer Özak</td>
<td>3234</td>
</tr>
<tr>
<td>Unconventional Computing, Introduction to</td>
<td>Andrew Adamatzky</td>
<td>3258</td>
</tr>
<tr>
<td>Topic</td>
<td>Author/Authors</td>
<td>Page</td>
</tr>
<tr>
<td>------------------------------------------------------------</td>
<td>--------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Unconventional Computing, Novel Hardware for</td>
<td>Tetsuya Asai</td>
<td>3260</td>
</tr>
<tr>
<td>Voting</td>
<td>Alvaro Sandroni, Jonathan Pogach, Michela Tincani, Antonio Penta, Deniz Selman</td>
<td>3280</td>
</tr>
<tr>
<td>Voting Procedures, Complexity of</td>
<td>Olivier Hudry</td>
<td>3291</td>
</tr>
<tr>
<td>Wavelets, Introduction to</td>
<td>Edward Aboufadel</td>
<td>3314</td>
</tr>
<tr>
<td>Wavelets and the Lifting Scheme</td>
<td>Anders La Cour–Harbo, Arne Jensen</td>
<td>3316</td>
</tr>
<tr>
<td>Wavelets and PDE Techniques in Image Processing, a Quick Tour of</td>
<td>Hao-Min Zhou, Tony F. Chan, Jianhong Shen</td>
<td>3341</td>
</tr>
<tr>
<td>World Wide Web, Graph Structure</td>
<td>Lada A. Adamic</td>
<td>3358</td>
</tr>
<tr>
<td>Zero-Sum Two Person Games</td>
<td>T.E.S. Raghavan</td>
<td>3372</td>
</tr>
<tr>
<td>List of Glossary Terms</td>
<td></td>
<td>3397</td>
</tr>
<tr>
<td>Index</td>
<td></td>
<td>3417</td>
</tr>
</tbody>
</table>
Contributors

ABELSON, HAL
Massachusetts Institute of Technology
Cambridge
USA

ABOUFADEL, EDWARD
Grand Valley State University
Allendale
USA

ABRAMSKY, SAMSON
Oxford University Computing Laboratory
Oxford
UK

ADAMATZKY, ANDREW
University of the West of England
Bristol
UK

ADAMIC, LADA A.
University of Michigan
Ann Arbor
USA

ALAVA, MIKKO J.
Espoo University of Technology
Espoo
Finland

ALONSO-SANZ, RAMÓN
Universidad Politécnica de Madrid
Madrid
Spain

AMOS, MARTYN
Manchester Metropolitan University
Manchester
UK

ÁNGELES GIL, MARÍA
University of Oviedo
Oviedo
Spain

ANGELOV, PLAMEN
Lancaster University
Lancaster
UK

ASAI, TETSUYA
Hokkaido University
Sapporo
Japan

AVENHAUS, RUDOLF
Armed Forces University Munich
Neubiberg
Germany

BAGNOLI, FRANCO
University of Florence
Florence
Italy

BANDINI, STEFANIA
University of Milan-Bicocca
Milan
Italy

BATAGELJ, VLADIMIR
University of Ljubljana
Ljubljana
Slovenia

BAYS, CARTER
University of South Carolina
Columbia
USA

BEAL, JACOB
Massachusetts Institute of Technology
Cambridge
USA

BEAUBOEF, THERESA
Southeastern Louisiana University
Hammond
USA
BEER, MICHAEL
National University of Singapore
Kent Ridge
Singapore

BENI, GERARDO
University of California Riverside
Riverside
USA

BERKHIN, PAVEL
eBay Inc.
San Jose
USA

BERMAN, ABRAHAM
Technion – Israel Institute of Technology
Haifa
Israel

BJELLAND, JOHANNES
Telenor R&I
Fornebu
Norway

BOCCARA, NINO
University of Illinois
Chicago
USA

CASTELLANO, CLAUDIO
“Sapienza” Università di Roma
Roma
Italy

CASTIGLIONE, FILIPPO
Institute for Computing Applications (IAC) – National Research Council (CNR)
Rome
Italy

CASTILLO, OSCAR
Tijuana Institute of Technology
Tijuana
Mexico

CAULFIELD, H. JOHN
Fisk University
Nashville
USA

CAVERLEE, JAMES
Texas A&M University
College Station
USA

CECCHERINI-SILBERSTEIN, TULLIO
Università del Sannio
Benevento
Italy

CENEK, MARTIN
Portland State University
Portland
USA

CERCONE, NICK
York University
Toronto
Canada

CERVELLE, JULIEN
Université Paris-Est
Marne la Vallée
France

CHANG, KOW-LUNG
National Taiwan University
Taipei
Taiwan
CHAN, TONY F.
University of California
Los Angeles
USA

CHATTERJEE, KALYAN
The Pennsylvania State University
University Park
USA

CHECHKIN, ALEKSEI V.
Institute for Theoretical Physics NSC KIPT
Kharkov
Ukraine

CHEN, CHUN-HAO
National Cheng–Kung University
Tainan
Taiwan

CHEN, GUANRONG
City University of Hong Kong
Hong Kong
China

CHEN, ZHENGXIN
University of Nebraska at Omaha
Omaha
USA

CHOPARD, BASTIEN
University of Geneva
Geneva
Switzerland

CHUNG, FAN
University of California
San Diego
USA

CONTE, ROSARIA
CNR
Rome
Italy

COORNAERT, MICHEL
Université Louis Pasteur et CNRS
Strasbourg
France

CORCHÓN, LUIS C.
Universidad Carlos III
Madrid
Spain

CPALKA, KRZYSZTOF
Częstochowa University of Technology
Częstochowa
Poland

DE NOOY, WOUTER
University of Amsterdam
Amsterdam
The Netherlands

DE SILVA, CLARENCE W.
University of British Columbia
Vancouver
Canada

DEUTSCH, ANDREAS
Technische Universität Dresden
Dresden
Germany

DHILLON, INDERJIT S.
University of Texas
Austin
USA

DITTRICH, PETER
Friedrich Schiller University Jena
Jena
Germany
Doreian, Patrick
University of Pittsburgh
Pittsburgh
USA

Dorogovtsev, Sergey N.
Universidade de Aveiro
Aveiro
Portugal
A. F. Ioffe Physico-Technical Institute
St. Petersburg
Russia

Draper, David
University of California
Santa Cruz
USA

Dubois, Didier
Université Paul Sabatier
Toulouse Cedex
France

Dunne, Jennifer A.
Santa Fe Institute
Santa Fe
USA
Pacific Ecoinformatics and Computational Ecology Lab
Berkeley
USA

Durand-Lose, Jérôme
Université d’Orléans
Orléans
France

Dutta, Prajit K.
Columbia University
New York
USA

Dzeroski, Sašo
Jožef Stefan Institute
Ljubljana
Slovenia

Engø-Monsen, Kenth
Telenor R&I
Fornebu
Norway

Ergün, Güler
University of Bath
Bath
UK

Fadili, Jalal
Ecole Nationale Supérieure d’Ingénieurs de Caen
Caen Cedex
France

Faloutsos, Michalis
University of California
Riverside
USA

Fogedby, Hans C.
University of Aarhus
Aarhus
Denmark
Niels Bohr Institute
Copenhagen
Denmark

Forges, Françoise
Université Paris-Dauphine
Paris
France

Formenti, Enrico
Université de Nice Sophia Antipolis
Sophia Antipolis
France

Fortunato, Santo
ISI Foundation
Torino
Italy

Frank, Ove
Stockholm University
Stockholm
Sweden

Freeman, Linton C.
University of California
Irvine
USA

Friedrich, Rudolf
University of Münster
Münster
Germany

Gorecka, Joanna Natalia
Polish Academy of Science
Warsaw
Poland
GORECKI, JERZY
Polish Academy of Science
Warsaw
Poland
Cardinal Stefan Wyszynski University
Warsaw
Poland

GOSSNER, OLIVIER
Northwestern University
Paris
France

GRASSL, MARKUS
Austrian Academy of Sciences
Innsbruck
Austria

GRAVNER, JANCO
University of California
Davis
USA

GRECO, SALVATORE
University of Catania
Catania
Italy

GRZYMALA-BUSSE, JERZY W.
University of Kansas
Lawrence
USA
Polish Academy of Sciences
Warsaw
Poland

HALL, WENDY
University of Southampton
Southampton
United Kingdom

HAN, BIN
University of Alberta
Edmonton
Canada

HÅNNGI, PETER
University of Augsburg
Augsburg
Germany

HAN, JIANCHAO
California State University
Domínguez Hills, Carson
USA

HANSON, JAMES E.
IBM T.J. Watson Research Center
Yorktown Heights
USA

HARDING, SIMON
Memorial University
St. John’s
Canada

HATZIKIROU, HARALAMBS
Technische Universität Dresden
Dresden
Germany

HAUPTMAN, AMI
Ben-Gurion University
Beer-Sheva
Israel

HENDLER, JAMES
Rensselaer Polytechnic Institute
Troy
USA

HE, YIHUA
University of California
Riverside
USA

HIRANO, SHOJI
Shimane University, School of Medicine
Enya-cho Izumo City, Shimane
Japan

HONG, TZUNG-PEI
National University of Kaohsiung
Kaohsiung
Taiwan

HRYNIEWICZ, OLGIERD
Systems Research Institute
Warsaw
Poland

HUANG, SUI
Department of Biological Sciences, University of Calgary
Calgary
Canada

HUDRY, OLIVIER
École Nationale Supérieure des Télécommunications
Paris
France
ILACHINSKI, ANDREW
Center for Naval Analyses
Alexandria
USA

JARRAH, ABDUL S.
Virginia Polytechnic Institute and State University
Virginia
USA

JENSEN, ARNE
Aalborg University
Aalborg East
Denmark

JENSEN, HENRIK JELDTOFT
Institute for Mathematical Sciences
London
UK

JENSEN, HENRIK JELDTOFT
Imperial College London
London
UK

JOHN, ROBERT I.
De Montfort University
Leicester
United Kingdom

JORGENSEN, PALLE E. T.
The University of Iowa
Iowa City
USA

KACPRZYZK, JANUSZ
Polish Academy of Sciences
Warsaw
Poland

KARI, JARKKO
University of Turku
Turku
Finland

KAUFFMAN, STUART A.
Department of Biological Sciences, University of Calgary
Calgary
Canada

KEINERT, FRITZ
Iowa State University
Ames
USA

KENDON, VIV
University of Leeds
Leeds
UK

KLAFTER, JOSEPH
Tel Aviv University
Tel Aviv
Israel
University of Freiburg
Freiburg
Germany

KOKOL, PETER
University of Maribor
Maribor
Slovenia

KOSTER, MAURICE
University of Amsterdam
Amsterdam
Netherlands

KŮRKA, PETR
Université de Nice Sophia Antipolis
Nice
France
Academy of Sciences and Charles University
Prague
Czechia

KUTER, UGUR
University of Maryland
College Park
USA

KUTRIB, MARTIN
Universität Giessen
Giessen
Germany

LA COUR–HARBO, ANDERS
Aalborg University
Aalborg East
Denmark

LAI, MING-JUN
The University of Georgia
Athens
USA

LANGE, WOLFGANG
University of Sussex
Brighton
UK
LAUBENBACHER, REINHARD  
Virginia Polytechnic Institute and State University  
Virginia  
USA

LAURITSEN, KENT BÆKGAARD  
Danish Meteorological Institute  
Copenhagen  
Denmark

LAVI, RON  
The Technion – Israel Institute of Technology  
Haifa  
Israel

LEYV, MOSHE  
The Hebrew University  
Jerusalem  
Israel

LIAU, CHURN-JUNG  
Academia Sinica  
Taipei  
Taiwan

LILJEROS, FREDRIK  
Stockholm University  
Stockholm  
Sweden

LIN, TSAU YOUNG  
San Jose State University  
San Jose  
USA

LIU, HUAN  
Arizona State University  
Tempe  
USA

LLOYD, SETH  
MIT  
Cambridge  
USA

LODWICK, WELDON A.  
University of Colorado Denver  
Denver  
USA

LO, HOI-KWONG  
University of Toronto  
Toronto  
Canada

MACAL, CHARLES M.  
Center for Complex Adaptive Agent Systems Simulation (CAS²)  
Argonne  
USA

MACDONALD, JOANNE  
Columbia University  
New York  
USA

MACHO-STADLER, INÉS  
Universitat Autònoma de Barcelona  
Barcelona  
Spain

MACLENNAN, BRUCE J.  
University of Tennessee  
Knoxville  
USA

MACNAMEE, BRIAN  
Dublin Institute of Technology  
Dublin  
Ireland

MAILATH, GEORGE J.  
University of Pennsylvania  
Philadelphia  
USA

MANGE, DANIEL  
Ecole Polytechnique Fédérale de Lausanne (EPFL)  
Lausanne  
Switzerland

MANZONI, SARA  
University of Milan-Bicocca  
Milan  
Italy

MARGENSTERN, MAURICE  
Université Paul Verlaine Metz  
Metz  
France

MATARAZZO, BENEDETTO  
University of Catania  
Catania  
Italy

MCKANE, ALAN J.  
University of Manchester  
Manchester  
UK
MELIN, PATRICIA  
Tijuana Institute of Technology  
Tijuana  
Mexico

MENASALVAS, ERNESTINA  
Facultad de Informatica  
Madrid  
Spain

MENDEL, JERRY M.  
University of Southern California  
Los Angeles  
USA

METZLER, RALF  
Technical University of Munich  
Garching  
Germany

MILBURN, GERARD J.  
The University of Queensland  
Brisbane  
Australia

MILLER, JULIAN F.  
University of York  
Heslington  
UK

MITCHELL, MELANIE  
Portland State University  
Portland  
USA

MORITA, KENICHI  
Hiroshima University  
Higashi-Hiroshima  
Japan

MORTVEIT, HENNING S.  
Virginia Polytechnic Institute and State University  
Virginia  
USA

MOSCA, MICHELE  
University of Waterloo  
Waterloo  
Canada

MUOTO, SHIGEO  
Institute of Technology  
Tokyo  
Japan

MUZY, ALEXANDRE  
Università di Corsica  
Corte  
France

NACHBAR, JOHN  
Washington University  
St. Louis  
USA

NAUGHTON, THOMAS J.  
National University of Ireland  
Maynooth County Kildare  
Ireland

University of Oulu, RFMedia Laboratory  
Ylivieska  
Finland

NICODEMI, MARIO  
University of Warwick  
Coventry  
UK

NILSSON JACOBI, MARTIN  
Chalmers University of Technology  
Gothenburg  
Sweden

NOLFI, STEFANO  
National Research Council (CNR)  
Rome  
Italy

NORTH, MICHAEL J.  
Center for Complex Adaptive Agent Systems Simulation (CAS²)  
Argonne  
USA

NOWICKI, ROBERT  
Częstochowa University of Technology  
Częstochowa  
Poland

O’HARA, KIERON  
University of Southampton  
Southampton  
United Kingdom
Olheide, Sofia
University College London
London
UK

Orlov, Michael
Ben-Gurion University
Beer-Sheva
Israel

Özak, Ömer
Brown University
Providence
USA

Page Jr., Frank H.
Indiana University
Bloomington
USA

University Paris 1
Pantheon–Sorbonne
France

Panov, Panče
Jožef Stefan Institute
Ljubljana
Slovenia

Papageorgiou, Anargyros
Columbia University
New York
USA

Parry, Hazel R.
Central Science Laboratory
York
UK

Pattison, Philippa
University of Melbourne
Parkville
Australia

Păun, Gheorghe
Institute of Mathematics of the Romanian Academy
Bucharest
Romania

Pedrycz, Witold
University of Alberta
Edmonton
Canada

Polish Academy of Sciences
Warsaw
Poland

Peinke, Joachim
Carl-von-Ossietzky University Oldenburg
Oldenburg
Germany

Penta, Antonio
University of Pennsylvania
Philadelphia
USA

Peper, Ferdinand
National Institute of Information and Communications Technology
Kobe
Japan

Pérez-Castrillo, David
Universitat Autònoma de Barcelona
Barcelona
Spain

Peters, James F.
University of Manitoba
Winnipeg
Canada

Petry, Frederick
Stennis Space Center
Mississippi
USA

Pivato, Marcus
Trent University
Peterborough
Canada

Podgorelec, Vili
University of Maribor
Maribor
Slovenia

Pogach, Jonathan
University of Pennsylvania
Philadelphia
USA

Pokropińska, Agata
Jan Długosz University
Częstochowa
Poland

Polkowski, Lech
Polish-Japanese Institute of Information Technology
Warsaw
Poland
POVALEJ, PETRA
University of Maribor
Maribor
Slovenia

PRADE, HENRI
Université Paul Sabatier
Toulouse Cedex
France

PRUSSNER, GUNNAR
Imperial College London
London
UK

PU, CALTON
Georgia Institute of Technology
Atlanta
USA

QIAN, LEI
Fisk University
Nashville
USA

QUINCAMPOIX, MARC
Université de Bretagne Occidentale
Brest
France

RAGHAVAN, T.E.S.
University of Illinois
Chicago
USA

RAND, DARREN
Massachusetts Institute of Technology
Lexington
USA

RAS, ZBIGNIEW W.
University of North Carolina
Charlotte
USA

Polish Academy of Sciences
Warsaw
Poland

RAVI, S.S.
University at Albany – State University of New York
New York
USA

REIF, JOHN H.
Duke University
Durham
USA

RENAULT, JÉRÔME
Université Paris Dauphine
Paris
France

REZA RAHIMI TABAR, M.
Sharif University of Technology
Theran
Iran

ROBINS, GARRY
University of Melbourne
Melbourne
Australia

RÖTTELER, MARTIN
NEC Laboratories America, Inc.
Princeton
USA

RUTKOWSKI, LESZEK
Częstochowa University of Technology
Częstochowa
Poland

SABOURIAN, HAMID
University of Cambridge
Cambridge
UK

SANDHOLM, WILLIAM H.
University of Wisconsin
Madison
USA

SANDRONI, ALVARO
University of Pennsylvania
Philadelphia
USA

SCHERER, RAFAL
Częstochowa University of Technology
Częstochowa
Poland

SCOTT, JOHN
University of Plymouth
Plymouth
UK

SELMAN, DENIZ
University of Pennsylvania
Philadelphia
USA
SERRANO, ROBERTO
Brown University
Providence
USA
IMDEA-Social Sciences
Madrid
Spain

SHAKED-MONDERER, NAOMI
Emek Yezreel College
Emek Yezreel
Israel

SHEN, JIANHONG
Barclays Capital
New York
USA

SIBANI, PAOLO
SDU
Odense
Denmark

SIGANOS, GEORGOS
University of California
Riverside
USA

SIPPER, MOSHE
Ben-Gurion University
Beer-Sheva
Israel

SKOWRON, ANDRZEJ
Warsaw University
Warsaw
Poland

SŁOWIŃSKI, ROMAN
Poznan University of Technology
Poznan
Poland
Polish Academy of Sciences
Warsaw
Poland

SNIJDERS, TOM A. B.
University of Oxford
Oxford
United Kingdom

SOBEL, JOEL
University of California
San Diego
USA

SOLAN, EILON
Tel Aviv University
Tel Aviv
Israel

SOLE, RICARD V.
Santa Fe Institute
Santa Fe
USA

SONG, MYUNG-SIN
Southern Illinois University
Edwardsville
USA

SORNETTE, DIDIER
ETH Zurich
Zurich
Switzerland

SOTOMAYOR, MARILDA
University of São Paulo/SP
São Paulo
Brazil
Brown University
Providence
USA

STARCK, JEAN-LUC
CEA/Saclay
Gif sur Yvette
France

STAUFFER, ANDRÉ
Ecole Polytechnique Fédérale de Lausanne (EPFL)
Lausanne
Switzerland

STEFANOVIC, DARKO
University of New Mexico
Albuquerque
USA

STEIGLITZ, KEN
Princeton University
Princeton
USA

STEPANIUK, JAROSŁAW
Białystok University of Technology
Białystok
Poland

STEPHENS, DAVID A.
McGill University
Montreal
Canada
STIGLIC, GREGOR
University of Maribor
Maribor
Slovenia

STOJANOVIC, MILAN
Columbia University
New York
USA

SURI, NIRANJAN
Institute for Human and Machine Cognition
Pensacola
USA

SUSSMAN, GERALD JAY
Massachusetts Institute of Technology
Cambridge
USA

SUTNER, KLAUS
Carnegie Mellon University
Pittsburgh
USA

TAUBER, UWE CLAUS
Virginia Polytechnic Institute and State University
Blacksburg
USA

TEMPESTI, GIANLUCA
University of York
York
UK

TEUSCHER, CHRISTOF
Los Alamos National Laboratory
Los Alamos
USA

TIMMIS, JON
University of York
York
UK

TINCANI, MICHELA
University of Pennsylvania
Philadelphia
USA

TOMALA, TRISTAN
HEC Paris
Paris
France

TORRA, VICENÇ
Institut d’Investigació en Intel·ligència Artificial – CSIC
Bellaterra
Spain

TRAUB, JOSEPH F.
Columbia University
New York
USA

TROITZSCH, KLAUS G.
Universität Koblenz-Landau
Koblenz
Germany

TSALLIS, CONSTANTINO
Centro Brasileiro de Pesquisas Físicas
Rio de Janeiro
Brazil
Santa Fe Institute
Santa Fe
USA

TSENG, VINCENT S.
National Cheng–Kung University
Tainan
Taiwan

TSUMOTO, SHUSAKU
Faculty of Medicine, Shimane University
Shimane
Japan

TÜRKŞEN, I. BURHAN
TOBB-ETÜ, (Economics and Technology University of the Union of Turkish Chambers and Commodity Exchanges)
Ankara
Republic of Turkey

UMEO, HIROSHI
University of Osaka
Osaka
Japan

UNTIEDT, ELIZABETH A.
University of Colorado Denver
Denver
USA

VALENTE, THOMAS W.
University of Southern California
Alhambra
USA
Valverde, Sergi
Parc de Recerca Biomedica de Barcelona
Barcelona
Spain

Verhagen, Harko
Stockholm University and Royal Institute of Technology
Stockholm
Sweden

Verlic, Mateja
University of Maribor
Maribor
Slovenia

Vitek, Jan
Purdue University
West Lafayette
USA

Vizzari, Giuseppe
University of Milan-Bicocca
Milan
Italy

Volić, Oscar
Ben-Gurion University
Beer-Sheva
Israel

Voorhees, Burton
Athabasca University
Athabasca
Canada

Wako, Jun
Gakushuin University
Tokyo
Japan

Wang, Bing-Hong
University of Science and Technology of China
Hefei Anhui
China
Shanghai Academy of System Science
Shanghai
China

Wasilewska, Anita
Stony Brook University
Stony Brook
USA

Watrous, John
University of Waterloo
Waterloo
Canada

Webb, Steve
Georgia Institute of Technology
Atlanta
USA

White, Andrew G.
The University of Queensland
Brisbane
Australia

Wiesner, Karoline
University of Bristol
Bristol
UK

Wodders, Myrna
University College Cork
Cork
Ireland
University of Seville
Seville
Spain

Worsch, Thomas
Universität Karlsruhe
Karlsruhe
Germany

Yang, Wei-Zhe
National Taiwan University
Taipei
Taiwan

Yeung, Chi Ho
The Hong Kong University of Science and Technology
Hong Kong
China

Université de Fribourg
Pérolles, Fribourg
Switzerland

University of Electronic Science and Technology of China
(UESTC)
Chengdu
China
YILMAZ, LEVENT
Auburn University
Alabama
USA

YULMETYEV, RENAT M.
Kazan State University
Kazan
Russia
Tatar State University of Pedagogical and Humanities Sciences
Kazan
Russia

ZADEH, LOTFI A.
University of California
Berkeley
USA

ZAMIR, SHMUEL
Hebrew University
Jerusalem
Israel

ZEIGLER, BERNARD
University of Arizona
Tucson
USA

ZEITOUNI, OFER
University of Minnesota
Minneapolis
USA

ŽENKO, BERNARD
Jožef Stefan Institute
Ljubljana
Slovenia

ZHANG, BO
Tsinghua University
Beijing
China

ZHANG, YAN-QING
Georgia State University
Atlanta
USA

ZHANG, YI-CHENG
The Hong Kong University of Science and Technology
Hong Kong
China
Université de Fribourg
Pérolles, Fribourg
Switzerland
University of Electronic Science and Technology of China (UESTC)
Chengdu
China

ZHANG, YI-QING
Georgia State University
Atlanta
USA

ZHANG, YI-ChENG
The Hong Kong University of Science and Technology
Hong Kong
China
Université de Fribourg
Pérolles, Fribourg
Switzerland
University of Electronic Science and Technology of China (UESTC)
Chengdu
China

ZHANG, YI
University of Toronto
Toronto
Canada

ZHAI, ZHENG
Arizona State University
Tempe
USA

ZHOU, HAO-MIN
Georgia Institute of Technology
Atlanta
USA

ZHOU, TAO
University of Science and Technology of China
Hefei Anhui
China

ZHOU, TAO
University of Science and Technology of China
Hefei Anhui
China

ZORMAN, MILAN
University of Maribor
Maribor
Slovenia