

Computational Complexity

Theory, Techniques, and Applications

This book consists of selections from the
Encyclopedia of Complexity and Systems Science
edited by Robert A. Meyers,
published by Springer New York in 2009.

Robert A. Meyers (Ed.)

Computational Complexity

Theory, Techniques, and Applications

With 1487 Figures and 234 Tables



ROBERT A. MEYERS, Ph. D.
Editor-in-Chief
RAMTECH LIMITED
122 Escalle Lane
Larkspur, CA 94939
USA
robert.meyers@ramtechlimited.org

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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

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Section Editor: Filippo Castiglione

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Granular Computing System Vulnerabilities: Exploring the Dark Side of Social Networking Communities
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Section Editor: Edward Aboufadel**

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Multiwavelets

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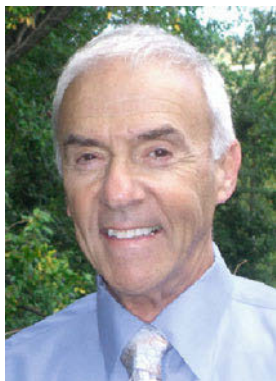
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About the Editor-in-Chief



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.

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.

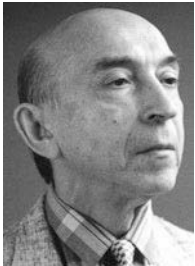
Scientific Books

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 on-line. 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 on-line.

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Professor in the Graduate School,
Computer Science Division
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University of California, Berkeley



RICHARD E. STEARNS
1993 Turing Award for foundations
of computational complexity
Current interests include: computational complexity,
automata theory, analysis of algorithms, and game theory.



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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

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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

BEAUBOUEF, 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
CE Saclay
Gif-sur-Yvette
France

BORGATTI, STEPHEN P.
University of Kentucky
Lexington
USA

BRAMEIER, MARKUS
University of Aarhus
Århus
Denmark

BRAMS, STEVEN J.
New York University
New York
USA

BREIER, GEORG
Technische Universität Dresden
Dresden
Germany

CANRIGHT, GEOFFREY
Telenor R&I
Fornebu
Norway

CANTY, MORTON J.
Forschungszentrum Jülich
Jülich
Germany

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
Taipeh
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

CPAŁKA, KRZYSZTOF
Częstochowa University of Technology
Częstochowa
Poland
Academy of Humanities and Economics
Lodz
Poland

CREUTZ, MICHAEL
Brookhaven National Laboratory
Upton
USA

DARDZINSKA, AGNIESZKA
Białystok Technical University
Białystok
Poland

DAVIDSSON, PAUL
Blekinge Institute of Technology
Ronneby
Sweden

DEMURJIAN, STEVEN A.
The University of Connecticut
Storrs
USA

DENNUNZIO, ALBERTO
Università degli Studi di Milano-Bicocca
Milan
Italy

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

DOROGVTSEV, 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
Universite 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

DŽEROSKI, 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 Wyszyński University
Warsaw
Poland

GOSSNER, OLIVIER
Northwestern University
Paris
France

GRASSL, MARKUS
Austrian Academy of Sciences
Innsbruck
Austria

GRAVNER, JANKO
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

HÄNGGI, PETER
University of Augsburg
Augsburg
Germany

HAN, JIANCHAO
California State University
Dominguez Hills, Carson
USA

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

HARDING, SIMON
Memorial University
St. John's
Canada

HATZIKIROU, HARALAMBOS
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
Imperial College London
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

KACPRZYK, 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

LEVY, 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

MAC NAMEE, 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
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
St. Jerome's University
Waterloo
Canada
Perimeter Institute for Theoretical Physics
Waterloo
Canada

MUTO, 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

OLHEDE, 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
Universite 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
București
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
Universite Paul Sabatier
Toulouse Cedex
France

PRUESSNER, 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, RAFAŁ
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

SOLÉ, 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

TÄUBER, 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
 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

UMEI, 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

VOLIJ, 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
University of Bristol
Bristol
UK

WOODERS, MYRNA
Vanderbilt University
Nashville
USA
University of Warwick
Coventry
UK

WOODS, DAMIEN
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, LING
Anhui University, Hefei
Anhui
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

ZHAO, MING
University of Science and Technology of China
Hefei Anhui
China

ZHAO, YI
University of Toronto
Toronto
Canada

ZHAO, 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

ZORMAN, MILAN
University of Maribor
Maribor
Slovenia