

# Lecture Notes in Computer Science

8572

*Commenced Publication in 1973*

Founding and Former Series Editors:

Gerhard Goos, Juris Hartmanis, and Jan van Leeuwen

## Editorial Board

David Hutchison, UK

Josef Kittler, UK

Alfred Kobsa, USA

John C. Mitchell, USA

Oscar Nierstrasz, Switzerland

Bernhard Steffen, Germany

Demetri Terzopoulos, USA

Gerhard Weikum, Germany

Takeo Kanade, USA

Jon M. Kleinberg, USA

Friedemann Mattern, Switzerland

Moni Naor, Israel

C. Pandu Rangan, India

Doug Tygar, USA

## Advanced Research in Computing and Software Science

Subline of Lectures Notes in Computer Science

### Subline Series Editors

Giorgio Ausiello, *University of Rome 'La Sapienza', Italy*

Vladimiro Sassone, *University of Southampton, UK*

### Subline Advisory Board

Susanne Albers, *University of Freiburg, Germany*

Benjamin C. Pierce, *University of Pennsylvania, USA*

Bernhard Steffen, *University of Dortmund, Germany*

Deng Xiaotie, *City University of Hong Kong*

Jeannette M. Wing, *Microsoft Research, Redmond, WA, USA*

Javier Esparza Pierre Fraigniaud  
Thore Husfeldt Elias Koutsoupias (Eds.)

# Automata, Languages, and Programming

41st International Colloquium, ICALP 2014  
Copenhagen, Denmark, July 8-11, 2014  
Proceedings, Part I



Springer

## Volume Editors

Javier Esparza  
Technische Universität München, Germany  
E-mail: [esparza@in.tum.de](mailto:esparza@in.tum.de)

Pierre Fraigniaud  
LIAFA, Université Paris Diderot-Paris 7, France  
E-mail: [pierre.fraigniaud@liafa.univ-paris-diderot.fr](mailto:pierre.fraigniaud@liafa.univ-paris-diderot.fr)

Thore Husfeldt  
IT University of Copenhagen, Denmark  
E-mail: [thore@itu.dk](mailto:thore@itu.dk)

Elias Koutsoupias  
University of Oxford, UK  
E-mail: [elias@cs.ox.ac.uk](mailto:elias@cs.ox.ac.uk)

ISSN 0302-9743  
ISBN 978-3-662-43947-0  
DOI 10.1007/978-3-662-43948-7  
Springer Heidelberg New York Dordrecht London

e-ISSN 1611-3349  
e-ISBN 978-3-662-43948-7

Library of Congress Control Number: 2014941765

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

© Springer-Verlag Berlin Heidelberg 2014

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

*Typesetting:* Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India

Printed on acid-free paper

Springer is part of Springer Science+Business Media ([www.springer.com](http://www.springer.com))

# Preface

This volume contains the papers presented at ICALP 2014: the 41st International Colloquium on Automata, Languages and Programming, held during July 8–11, 2014, at IT University of Copenhagen. ICALP is the main conference and annual meeting of the European Association for Theoretical Computer Science (EATCS) and first took place in 1972. This year the ICALP program consisted of three tracks:

- Track A: Algorithms, Complexity, and Games
- Track B: Logic, Semantics, Automata, and Theory of Programming
- Track C: Foundations of Networked Computation

In response to the call for papers, the three Program Committees received 484 submissions, a record number for ICALP. Track A received 319 submissions (another record), track B received 106 submissions, and track C received 59 submissions. Each submission was reviewed by at least three Program Committee members, aided by many subreviewers. The committee decided to accept 136 papers, which are collected in these proceedings. The selection was made by the Program Committees based on originality, quality, and relevance to theoretical computer science. The quality of the submissions was very high indeed, and many deserving papers could not be selected.

The EATCS sponsored awards for both a best paper and a best student paper for each of the three tracks, selected by the Program Committees.

The best paper awards were given to the following papers:

- Track A: Andreas Björklund and Thore Husfeldt, “Shortest Two Disjoint Paths in Polynomial Time”
- Track B: Joel Ouaknine and James Worrell, “Ultimate Positivity Is Decidable for Simple Linear Recurrence Sequences”
- Track C: Oliver Göbel, Martin Hoefer, Thomas Kesselheim, Thomas Schließen, and Berthold Vöcking, “Online Independent Set Beyond the Worst-Case: Secretaries, Prophets, and Periods”

The best student paper awards, for papers that are solely authored by students, were given to the following papers:

- Track A: Sune K. Jakobsen, “Information Theoretical Cryptogenography”
- Track B: Michael Wehar, “Hardness Results for Intersection Non-Emptiness”
- Track C: Mohsen Ghaffari, “Near-Optimal Distributed Approximation of Minimum-Weight Connected Dominating Set”

Apart from the contributed talks, the conference included invited presentations by Sanjeev Arora, Maurice Herlihy, Viktor Kuncak, and Claire Mathieu. Abstracts of their talks are included in these proceedings as well.

The program of ICALP 2014 also included presentation of the Presburger Award 2014 to David Woodruff, the EATCS Award 2014 to Gordon Plotkin, and the Gödel Prize to Ronald Fagin, Amnon Lotem, and Moni Naor.

Two satellite events of ICALP were held on 7 July, 2014:

- Trends in Online Algorithms (TOLA 2014)
- Young Researcher Workshop on Automata, Languages and Programming (YR-ICALP 2014)

We wish to thank all the authors who submitted extended abstracts for consideration, the members of the three Program Committees for their scholarly efforts, and all additional reviewers who assisted the Program Committees in the evaluation process. We thank the sponsors Springer-Verlag, EATCS, CWI Amsterdam, and Statens Kunstfond for their support, and the IT University of Copenhagen for hosting ICALP 2014.

We are also grateful to all members of the Organizing Committee and to their support staff.

The conference-management system EasyChair was used to handle the submissions, to conduct the electronic Program Committee meetings, and to assist with the assembly of the proceedings.

May 2014

Javier Esparza  
Pierre Fraigniaud  
Thore Husfeldt  
Elias Koutsoupias

# Organization

## Program Committee

Dimitris Achlioptas	UC, Santa Cruz, USA
Pankaj Agrawal	Duke University, USA
Paolo Baldan	Università di Padova, Italy
Nikhil Bansal	Eindhoven University of Technology, The Netherlands
Michele Boreale	Università di Firenze, Italy
Tomas Brazdil	Masaryk University, Czech Republic
Gerth Stølting Brodal	Aarhus University, Denmark
Véronique Bruyère	University of Mons, Belgium
Jean Cardinal	Université libre de Bruxelles, Belgium
Ning Chen	Nanyang Technological University, Singapore
Giorgos Christodoulou	University of Liverpool, UK
Andrea Clementi	University of Rome Tor Vergata, Italy
Veronique Cortier	CNRS, Loria, France
Anuj Dawar	University of Cambridge, UK
Xiaotie Deng	Shanghai Jiaotong University, China
Ilias Diakonikolas	University of Edinburgh, UK
Benjamin Doerr	MPI Saarbrücken, Germany
Chaled Elbassioni	Masdar Institute, Abu Dhabi
Javier Esparza	TU München, Germany
Kousha Etessami	University of Edinburgh, UK
Panagiota Fatourou	University of Crete, Greece
Michal Feldman	Hebrew University, Israel
Maribel Fernandez	Kings College London, UK
Antonio Fernández Anta	Universidad Rey Juan Carlos, Spain
Amos Fiat	Tel Aviv University, Israel
Pierre Fraigniaud	CNRS and University of Paris Diderot, France
David Frutos Escrig	Complutense University of Madrid, Spain
Pierre Ganty	IMDEA Software Institute, Spain
Leszek Gasieniec	University of Liverpool, UK
Phillip Gibbons	Intel Labs, USA
Leslie Goldberg	University of Oxford, UK
Vipul Goyal	Microsoft, India
Peter Habermehl	LIAFA, University of Paris 7, France
Magnus Halldorsson	Reykjavik University, Iceland
Giuseppe Italiano	University of Rome Tor Vergata, Italy
Marcin Kaminski	University of Warsaw, Poland

Haim Kaplan	Tel Aviv University, Israel
Anna Karlin	University of Washington, USA
Ioordanis Kerenidis	University of Paris Diderot, France
Anne-Marie Kermarrec	Inria Rennes, France
Robert Kleinberg	Cornell University, USA
Michal Koucky	Czech Academy of Sciences, Czech Republic
Elias Koutsoupias	University of Oxford, UK
Robert Krauthgamer	Weizmann Institute, Israel
Manfred Kufleitner	University of Stuttgart, Germany
Sławomir Lasota	Warsaw University, Poland
James Lee	University of Washington, USA
Oded Maler	CNRS-VERIMAG, France
Sebastian Maneth	NICTA and UNSW, Australia
Madhavan Mukund	Chennai Mathematical Institute, India
Ashwin Nayak	University of Waterloo, Canada
Jens Palsberg	UCLA, USA
Gopal Pandurangan	Nanyang Technological University, Singapore
Boaz Patt-Shamir	Tel Aviv University, Israel
Andrea Pietracaprina	Università di Padova, Italy
Andrea Richa	Arizona State University, USA
Luís Rodrigues	Universidade Técnica de Lisboa, Portugal
Jared Saia	University of New Mexico, USA
Piotr Sankowski	University of Warsaw, Poland
Christian Scheideler	Universität Paderborn, Germany
Thomas Schwentick	TU Dortmund, Germany
Maria Serna	UP Catalunya, Spain
Sonja Smets	University of Amsterdam, The Netherlands
Christian Sohler	TU Dortmund, Germany
Jiri Srba	Aalborg University, Denmark
Jukka Suomela	Aalto University, Finland
Ryan Williams	Stanford University, USA
Philipp Woelfel	University of Calgary, Canada
Steve Zdancewic	University of Pennsylvania, USA

## Additional Reviewers

Aaronson, Scott	Agarwal, Rachit
Abe, Masayuki	Aghazadeh, Zahra
Abraham, Ittai	Agrawal, Shweta
Aceto, Luca	Ajwani, Deepak
Adler, Isolde	Akutsu, Tatsuya
Adsul, Bharat	Al-Humaimedy, Abeer
Afshani, Peyman	Alamdari, Soroush
Agarwal, Alekh	Alglave, Jade

Allender, Eric  
Alon, Noga  
Althaus, Ernst  
Alves, Sandra  
An, Hyung-Chan  
Anagnostopoulos, Aris  
Ananth, Prabhanjan  
Andoni, Alex  
Andoni, Alexandr  
Ardenboim, Alon  
Arkhipov, Alex  
Asarin, Eugene  
Aspnes, James  
Atig, Mohamed Faouzi  
Atserias, Albert  
Augustine, John  
Avron, Haim  
Babichenko, Yakov  
Bacci, Giorgio  
Bacci, Giovanni  
Bach, Eric  
Balabonski, Thibaut  
Banerjee, Abhishek  
Barrington, David  
Bartoletti, Massimo  
Basset, Nicolas  
Bavarian, Mohammad  
Beame, Paul  
Becchetti, Luca  
Bei, Xiaohui  
Belmonte, Rémy  
Ben Avraham, Rinat  
Ben-Amram, Amir  
Berger, Eli  
Berry, Jonathan  
Bertrand, Nathalie  
Berwanger, Dietmar  
Bhaskar, Umang  
Bitansky, Nir  
Blazy, Olivier  
Blesa, Maria J.  
Blömer, Johannes  
Bodirsky, Manuel  
Bodlaender, Hans L.  
Bodlaender, Marijke  
Bogdanov, Andrej  
Bojanczyk, Mikolaj  
Boker, Udi  
Bollig, Beate  
Bollig, Benedikt  
Bonamy, Marthe  
Bonchi, Filippo  
Boneh, Dan  
Bonifaci, Vincenzo  
Bonnet, Edouard  
Bonsangue, Marcello  
Bonsma, Paul  
Borgström, Johannes  
Boutsidis, Christos  
Boyar, Joan  
Boyle, Elette  
Brakerski, Zvika  
Brandstadt, Andreas  
Braverman, Mark  
Bremner, Michael  
Brettell, Nick  
Briet, Jop  
Brihaye, Thomas  
Broadbent, Anne  
Brody, Joshua  
Bruni, Roberto  
Brzuska, Christina  
Buchbinder, Niv  
Buchin, Kevin  
Buhrman, Harry  
Byrka, Jaroslaw  
Böhl, Florian  
Cai, Yang  
Caltais, Georgiana  
Canetti, Ran  
Canonne, Clément  
Cao, Yixin  
Carraro, Alberto  
Cash, David  
Ceccarelo, Matteo  
Chakrabarti, Amit  
Chakraborty, Supratik  
Chalermsook, Parinya  
Chan, Hubert  
Chan, Siu On



Chan, Timothy  
Chandran, Nishanth  
Charatonik, Witold  
Chase, Melissa  
Chatterjee, Krishnendu  
Chechik, Shiri  
Chekuri, Chandra  
Chen, Jing  
Chen, Xujin  
Chen, Zhou  
Cheval, Vincent  
Choudhury, Ashish  
Chow, Sherman S.M.  
Chrobak, Marek  
Chung, Kai-Min  
Ciancia, Vincenzo  
Cicalese, Ferdinando  
Clavier, Christophe  
Clemente, Lorenzo  
Codenotti, Paolo  
Cohen, Edith  
Cohen, Sarel  
Cohn, Henry  
Colcombet, Thomas  
Colini Baldeschi, Riccardo  
Costello, Craig  
Crescenzi, Pierluigi  
Cryan, Mary  
Cygan, Marek  
Czerwiński, Wojciech  
Dalmau, Victor  
Damaschke, Peter  
Damgård, Ivan  
Dang, Thao  
Dani, Varsha  
Dasgupta, Bhaskar  
Datta, Samir  
David, Alexandre  
De Bonis, Annalisa  
de Caro, Angelo  
De Caro, Angelo  
De Liguoro, Ugo  
de Wolf, Ronald  
Decker, Normann  
Degorre, Aldric  
Delahaye, Benoit  
Delling, Daniel  
Delvenne, Jean-Charles  
Delzanno, Giorgio  
Denysyuk, Oksana  
Dereniowski, Dariusz  
Devanur, Nikhil  
Devroye, Luc  
Diaz, Josep  
Dietzfelbinger, Martin  
Diks, Krzysztof  
Dima, Catalin  
Diochnos, Dimitris  
Dobrev, Stefan  
Doerr, Carola  
Doyen, Laurent  
Driemel, Anne  
Dufflot, Marie  
Dumitrescu, Adrian  
Dupuis, Frédéric  
Durand, Arnaud  
Durand-Gasselín, Antoine  
Durnoga, Konrad  
Dvir, Zeev  
Dyer, Martin  
Edmonds, Jeff  
Efremenko, Klim  
Efthymiou, Charilaos  
Ehrgott, Matthias  
Ehsanfar, Ebrahim  
Elbassioni, Khaled  
Elberfeld, Michael  
Elmasry, Amr  
Elsässer, Robert  
Emmi, Michael  
Ene, Alina  
Enea, Constantin  
Enqvist, Sebastian  
Eppstein, David  
Epstein, Leah  
Erlebach, Thomas  
Escoffier, Bruno  
Even, Guy  
Fahrenberg, Uli  
Fanelli, Angelo

Farshim, Pooya  
Fefferman, Bill  
Feige, Uriel  
Fekete, Sándor  
Fernau, Henning  
Fijalkow, Nathanaël  
Filiot, Emmanuel  
Filmus, Yuval  
Fiorini, Samuel  
Firmani, Donatella  
Fisman, Dana  
Flammini, Michele  
Forbes, Michael A.  
Forejt, Vojtech  
Fortnow, Lance  
Fotakis, Dimitris  
Fountoulakis, Nikolaos  
Franciosa, Paolo  
Fрати, Fabrizio  
Frieze, Alan  
Fu, Hu  
Fu, Zhiguo  
Fábregas, Ignacio  
Gaboardi, Marco  
Gadducci, Fabio  
Gaertner, Bernd  
Galanis, Andreas  
Galesi, Nicola  
Gambs, Sebastien  
Garg, Ankit  
Gaspers, Serge  
Gastin, Paul  
Gavinsky, Dmitry  
Gawrychowski, Pawel  
Geck, Gaetano  
Geeraerts, Gilles  
Gelles, Ran  
Genest, Blaise  
Ghaffari, Mohsen  
Giakkoupis, George  
Giannakopoulos, Yiannis  
Giannopoulou, Archontia  
Giaquinta, Emanuele  
Gierasimczuk, Nina  
Gilbert, Seth  
Gille, Marc  
Giunti, Marco  
Gkatzelis, Vasilis  
Glacet, Christian  
Glen, Amy  
Gmyr, Robert  
Gogacz, Tomasz  
Goldberg, Paul  
Gonzalez Vasco, Maria Isabel  
Gopalan, Parikshit  
Gorbunov, Sergey  
Gorecki, Pawel  
Gorgunov, Sergey  
Gorla, Daniele  
Grandoni, Fabrizio  
Greco, Gianluigi  
Green, Oded  
Grenet, Bruno  
Grigorescu, Elena  
Grigoryev, Dmitry  
Grossi, Roberto  
GualÀ, Luciano  
Guo, Heng  
Guo, Jiong  
Guo, Siyao  
Guruswami, Venkatesan  
Gutwenger, Carsten  
Göbel, Andreas  
Haeupler, Bernhard  
Haghpanah, Nima  
Haitner, Iftach  
Hajiaghayi, Mohammadtaghi  
Hansen, Kristoffer Arnsfelt  
Hansen, Thomas Dueholm  
Hardt, Moritz  
Harju, Tero  
Harrow, Aram  
Harsha, Prahladh  
Hatami, Hamed  
Haviv, Ishay  
Hayes, Thomas  
Hazay, Carmit  
He, Meng  
Heam, Pierre-Cyrille  
Heggernes, Pinar

Helmi, Maryam  
Hirschhoff, Daniel  
Hlout, Loc  
Hoefler, Martin  
Hoffmann, Hella-Franziska  
Hofheinz, Dennis  
Hofman, Piotr  
Huang, Chien-Chung  
Huang, Sangxia  
Huang, Xiangru  
Huang, Zhiyi  
Hunter, Paul  
Husfeldt, Thore  
Im, Hyeonseung  
Indyk, Piotr  
Iovino, Vincenzo  
Irani, Sandy  
Isopi, Marco  
Ito, Takehiro  
Jacob, Riko  
Jain, Rahul  
Jansen, Bart M.P.  
Jao, David  
Jerrum, Mark  
Jež, Artur  
Jež, Lukasz  
Jiang, Minghui  
Jiang, Zhansheng  
Joret, Gwenaël  
Joux, Antoine  
Jurdzinski, Tomasz  
Jørgensen, Allan Grønlund  
Kakimura, Naonori  
Kantor, Erez  
Kao, Ming-Yang  
Kapralov, Michael  
Kapur, Deepak  
Kara, Ahmet  
Karakostas, George  
Karhumäki, Juhani  
Kausch, Jonathan  
Kavitha, Telikepalli  
Kawamura, Akitoshi  
Kayal, Neeraj  
Keller, Orgad  
Kerber, Michael  
Kesselheim, Thomas  
Khandekar, Rohit  
Kiefer, Stefan  
King, Valerie  
Király, Tamas  
Klauck, Hartmut  
Klein, Philip  
Klima, Ondrej  
Klin, Bartek  
Klivans, Adam  
Kniesburgess, Sebastian  
Kobayashi, Yusuke  
Kobourov, Stephen  
Koebler, Johannes  
Koiran, Pascal  
Kolay, Sudeshna  
Kolliopoulos, Stavros  
Komjathy, Julia  
Kontchakov, Roman  
Kopczyński, Eryk  
Kopelowitz, Tsvi  
Kopparty, Swastik  
Kortsarz, Guy  
Kosowski, Adrian  
Kosub, Sven  
Kothari, Nishad  
Kothari, Pravesh  
Koutis, Ioannis  
Koutsopoulos, Andreas  
Kovacs, Annamaria  
Kratsch, Stefan  
Krcal, Jan  
Kretinsky, Jan  
Krishnaswamy, Ravishankar  
Krivosija, Amer  
Krug, Robert  
Krysta, Piotr  
Kucera, Antonin  
Kulikov, Alexander  
Kulkarni, Janardhan  
Kulkarni, Raghav  
Kumar, Akash  
Kumar, Amit  
Kumar, K. Narayan

Kuperberg, Denis  
 Kurz, Denis  
 Kyropoulou, Maria  
 Labourel, Arnauld  
 Lachish, Oded  
 Laekhanukit, Bundit  
 Lagniez, Jean Marie  
 Lanik, Jan  
 Laura, Luigi  
 Lauria, Massimo  
 Lauriere, Mathieu  
 Laursen, Simon  
 Lauser, Alexander  
 Le Gall, Francois  
 Le Scouarnec, Nicolas  
 Lee, James  
 Lee, Troy  
 Leonardos, Nikos  
 Lerays, Virginie  
 Leroux, Jerome  
 Levavi, Ariel  
 Levin, Asaf  
 Levy, Jean-Jacques  
 Lewenstein, Moshe  
 Li, Jian  
 Li, Minming  
 Li, Shi  
 Li, Yi  
 Li, Yingkai  
 Libert, Benoit  
 Libkin, Leonid  
 Lime, Didier  
 Lin, Anthony Widjaja  
 Lin, Chengyu  
 Liu, Feng-Hao  
 Llana, Luis  
 Lodaya, Kamal  
 Lohrey, Markus  
 Lopez-Ortiz, Alejandro  
 Loreti, Michele  
 Lotker, Zvi  
 Lovett, Shachar  
 Lozin, Vadim  
 Lu, Pinyan  
 Lu, Steve  
 Lucier, Brendan  
 Löding, Christof  
 M.S., Ramanujan  
 Ma, Minghui  
 Magniez, Frederic  
 Mahdian, Mohammad  
 Mahmoody, Mohammad  
 Makarychev, Konstantin  
 Makarychev, Yury  
 Maletti, Andreas  
 Malizia, Enrico  
 Mallmann-Trenn, Frederik  
 Manea, Florin  
 Maneva, Elitza  
 Mansour, Yishay  
 Mardare, Radu  
 Markey, Nicolas  
 Markou, Euripides  
 Martens, Wim  
 Martin, Barnaby  
 Martin, Russell  
 Marx, Dániel  
 Marx, Maarten  
 Masopust, Tomas  
 Mathieson, Luke  
 Matulef, Kevin  
 May, Alexander  
 Mayr, Richard  
 McColl, Robert  
 McGregor, Andrew  
 McSherry, Frank  
 Megow, Nicole  
 Meier, Arne  
 Meiklejohn, Sarah  
 Meir, O.  
 Mendel, Manor  
 Meng, Xianmeng  
 Mens, Irini-Eleftheria  
 Mertzios, George  
 Meunier, Pierre-Etienne  
 Miao, Peihan  
 Michail, Dimitrios  
 Michalak, Tomasz  
 Mignot, Ludovic  
 Milanic, Martin

Milchtaich, Igal  
 Miltersen, Peter Bro  
 Misra, Pranabendu  
 Molinero, Xavier  
 Monemizadeh, Morteza  
 Monmege, Benjamin  
 Montanaro, Ashley  
 Montecchiani, Fabrizio  
 Montenegro, Ravi  
 Moore, Cristopher  
 Moran, Tal  
 Morere, Philippe  
 Morris, Ben  
 Morsy, Ehab  
 Moseley, Benjamin  
 Movahedi, Mahnush  
 Mucha, Marcin  
 Munagala, Kamesh  
 Munteanu, Alexander  
 Murawski, Andrzej  
 Murlak, Filip  
 Muscholl, Anca  
 Mvprao  
 Nagaj, Daniel  
 Nanongkai, Danupon  
 Narayan Kumar, K.  
 Narodytka, Nina  
 Natale, Emanuele  
 Nathan, Lemons  
 Navara, Mirko  
 Navarra, Alfredo  
 Nederlof, Jesper  
 Neiman, Ofer  
 Nekrich, Yakov  
 Newman, Alantha  
 Nguyen, Hung Son  
 Nguyen, Huy  
 Nguyen, Trung Thanh  
 Niehren, Joachim  
 Nielsen, Jesper Sindahl  
 Niewerth, Matthias  
 Nikishkin, Vladimir  
 Nikolettseas, Sotiris  
 Nikolov, Aleksandar  
 Nissim, Kobbi

Niwinski, Damian  
 Nordstrom, Jakob  
 Novotný, Petr  
 Nowotka, Dirk  
 Nutov, Zeev  
 Nuñez Chiroque, Luis  
 O'Donnell, Ryan  
 O'Neill, Adam  
 Obdrzalek, Jan  
 Ogierman, Adrian  
 Olesen, Mads C.  
 Oliveira, Igor  
 Onak, Krzysztof  
 Ong, Luke  
 Ortega-Mallén, Yolanda  
 Ortmann, Mark  
 Ossona De Mendez, Patrice  
 Oualhadj, Youssouf  
 Paes Leme, Renato  
 Pagh, Rasmus  
 Palomino, Miguel  
 Paluch, Katarzyna  
 Pan, Jiangwei  
 Pan, Jiaxin  
 Panagiotou, Konstantinos  
 Panangaden, Prakash  
 Pandey, Omkant  
 Panigrahi, Debmalya  
 Papadopoulos, Dimitrios  
 Papakonstantinou, Periklis  
 Paparas, Dimitris  
 Parys, Pawel  
 Pasquale, Francesco  
 Pastro, Valerio  
 Patt-Shamir, Boaz  
 Paulusma, Daniel  
 Pauly, Arno  
 Pavan, A.  
 Peikert, Christopher  
 Peng, Pan  
 Peressotti, Marco  
 Peretz, Ron  
 Perez, Guillermo  
 Perifel, Sylvain  
 Perrin, Dominique

Peserico, Enoch  
 Pettie, Seth  
 Peña, Ricardo  
 Picaronny, Claudine  
 Pieris, Andreas  
 Pighizzini, Giovanni  
 Pilipczuk, Marcin  
 Pilipczuk, Michal  
 Pin, Jean-Eric  
 Plandowski, Wojciech  
 Polychroniadou, Antigoni  
 Pottier, François  
 Pottonen, Olli  
 Pous, Damien  
 Pozzato, Gian Luca  
 Prabhakar, Pavithra  
 Praveen, M.  
 Price, Eric  
 Pruhs, Kirk  
 Pucci, Geppino  
 Pulina, Luca  
 Pérez, Jorge A.  
 Qiang, Ruixin  
 Qiao, Youming  
 Quyen, Vuong Anh  
 Rabani, Yuval  
 Rabie, Mikael  
 Raecke, Harald  
 Raghavendra, Prasad  
 Raghunathan, Ananth  
 Raghvendra, Sharathkumar  
 Rahaman, Anisur  
 Rampersad, Narad  
 Raskin, Jean-François  
 Raz, Ran  
 Regev, Oded  
 Rehak, Vojtech  
 Reynier, Pierre-Alain  
 Riba, Colin  
 Richerby, David  
 Riondato, Matteo  
 Robinson, Peter  
 Roditty, Liam  
 Rodriguez, Ismael  
 Roetteler, Martin  
 Roland, Jérémie  
 Romano, Paolo  
 Ron, Dana  
 Rosa-Velardo, Fernando  
 Rosołek, Robert  
 Rossi, Gianluca  
 Rossmanith, Peter  
 Rosulek, Michael  
 Rothvoss, Thomas  
 Rubin, Natan  
 Rubio, Fernando  
 Ruppert, Eric  
 Saad, George  
 Sablik, Mathieu  
 Sack, Joshua  
 Sadrzadeh, Mehrnoosh  
 Saha, Chandan  
 Salvati, Sylvain  
 Sammartino, Matteo  
 Sangnier, Arnaud  
 Sankur, Ocan  
 Santaroni, Federico  
 Santhanam, Rahul  
 Santocanale, Luigi  
 Santos, Nuno  
 Saptharishi, Ramprasad  
 Sarkar, Susmit  
 Satti, Srinivasa Rao  
 Sau, Ignasi  
 Sauerwald, Thomas  
 Saurabh, Saket  
 Sawada, Joe  
 Saxena, Nitin  
 Scarpa, Giannicola  
 Scheder, Dominik  
 Schmidt, Melanie  
 Schmidt-Schauß, Manfred  
 Schmitz, Sylvain  
 Schneider, Stefan  
 Schroder, Dominique  
 Schröder, Lutz  
 Schuster, Martin  
 Schwartz, Roy  
 Schweikardt, Nicole  
 Schwiegelshohn, Chris

Schwoon, Stefan  
 Servais, Frédéric  
 Servedio, Rocco  
 Seshadhri, C.  
 Setzer, Alexander  
 Shah, Rahul  
 Shah, Simoni  
 Shamir, Ohad  
 Sharma, Vikram  
 Shen, Alexandre  
 Shenoy R., Gautham  
 Shpilka, Amir  
 Shraibman, Adi  
 Sidiropoulos, Anastasios  
 Siebertz, Sebastian  
 Sikdar, Somnath  
 Silva, Alexandra  
 Silvestri, Riccardo  
 Singh, Mohit  
 Sitchinava, Nodari  
 Sitters, Rene  
 Skowron, Piotr  
 Sokolova, Ana  
 Solomon, Shay  
 Sommer, Christian  
 Sousi, Perla  
 Spoerhase, Joachim  
 Sramek, Rastislav  
 Srinivasan, Srikanth  
 Srivastava, Piyush  
 Srivathsan, B.  
 Stachowiak, Grzegorz  
 Staiger, Ludwig  
 Stainer, Julien  
 Starikovskaya, Tatiana  
 Stefankovic, Daniel  
 Stehle, Damien  
 Stephan, Frank  
 Stergiou, Christos  
 Stoddard, Greg  
 Strassburger, Lutz  
 Straubing, Howard  
 Strefler, Mario  
 Strejcek, Jan  
 Strothmann, Thim

Struth, Georg  
 Su, Le  
 Suchy, Ondrej  
 Sun, Xiaoming  
 Sun, Xiaorui  
 Suomela, Jukka  
 Suresh, S.P.  
 Syrgkanis, Vasilis  
 Sénizergues, Géraud  
 Ta-Shma, Amnon  
 Tamaki, Suguru  
 Tamir, Tami  
 Tan, Li-Yang  
 Tang, Bo  
 Tao, Yufei  
 Tarjan, Robert  
 Tavenas, Sébastien  
 Telle, Jan Arne  
 Terhal, Barbara  
 Terui, Kazushige  
 Terzi, Evimaria  
 Thaler, Justin  
 Thanh, Nguyen  
 Thapper, Johan  
 Thiagarajan, P.S.  
 Thilikos, Dimitrios  
 Thorup, Mikkel  
 Thraves, Christopher  
 Toledo, Sivan  
 Toledoii, Sivan  
 Tompits, Hans  
 Torres Vieira, Hugo  
 Torunczyk, Szymon  
 Toruńczyk, Szymon  
 Trevisan, Luca  
 Trivedi, Ashutosh  
 Tschudi, Daniel  
 Tulsiani, Madhur  
 Uehara, Ryuhei  
 Ulus, Dogan  
 Umans, Chris  
 Umboh, Seeun  
 Uno, Yushi  
 Upadhyay, Jalaj  
 Valiant, Gregory

Valiente, Gabriel  
 Valiron, Benoît  
 van Breugel, Franck  
 van Melkebeek, Dieter  
 Van Melkebeek, Dieter  
 van Stee, Rob  
 Varacca, Daniele  
 Vassilevska Williams, Virginia  
 Vegh, Laszlo  
 Velickovic, Boban  
 Venkitasubramaniam,  
     Muthuramakrishnan  
 Ventre, Carmine  
 Verschae, Jose  
 Vidick, Thomas  
 Viet Tung, Hoang  
 Viglietta, Giovanni  
 Vijayaraghavan, Aravindan  
 Vilaça, Xavier  
 Visconti, Ivan  
 Viswanathan, Mahesh  
 Vogler, Walter  
 Volkovich, Ilya  
 Vrgoc, Domagoj  
 Wachter-Zeh, Antonia  
 Wahlström, Magnus  
 Walter, Tobias  
 Walukiewicz, Igor  
 Wang, Juntao  
 Wang, Kainan  
 Wanka, Rolf  
 Watson, Thomas  
 Wee, Hoeteck  
 Weinstein, Omri  
 Weiss, Armin  
 Westermann, Matthias  
 Whistler, William  
 Wieder, Udi  
 Wiese, Andreas  
 Wilkinson, Bryan T.  
 Wilson, David  
 Winslow, Andrew  
 Witek, Maximilian  
 Witkowski, Piotr  
 Wollan, Paul  
 Wong, Prudence W.H.  
 Woodruff, David  
 Wootters, Mary  
 Wright, John  
 Wrochna, Marcin  
 Wu, Xiaodi  
 Wulff-Nilsen, Christian  
 Wullschleger, Juerg  
 Xia, Ge  
 Xiao, Tao  
 Xie, Ning  
 Xing, Chaoping  
 Xu, Xiaoming  
 Xue, Guoliang  
 Yamada, Shota  
 Yamakami, Tomoyuki  
 Yamauchi, Yukiko  
 Yang, Kaiyu  
 Yao, Penghui  
 Yaroslavtsev, Grigory  
 Ye, Tao  
 Yekhanin, Sergey  
 Yi, Ke  
 Yiannakopoulos, Yiannis  
 Yin, Yitong  
 Yoshida, Yuichi  
 Young, Max  
 Yu, Huacheng  
 Yuen, Tsz Hon  
 Zacharias, Thomas  
 Zamani, Mahdi  
 Zang, Wenan  
 Zeh, Norbert  
 Zhang, Bingsheng  
 Zhang, Chihao  
 Zhang, Hongyang  
 Zhang, Jialin  
 Zhang, Jie  
 Zhang, Jin  
 Zhang, Shengyu  
 Zhang, Wuzhou  
 Zhang, Yong  
 Zhao, Zhiguang  
 Zhou, Hong-Sheng  
 Zhou, Yuan



Zhu, Zeyuan Allen  
Ziegler, Martin  
Zimand, Marius  
Ziv-Ukelson, Michal

Zivny, Stanislav  
Zuckerman, David  
Zwick, Uri  
Zych, Anna

## Invited Talks

# Overcoming the Intractability Obstacle in Unsupervised Learning

Sanjeev Arora

Computer Science, Princeton University

**Abstract.** Unsupervised learning—*i.e.*, learning with unlabeled data—is increasingly important given today’s data deluge. Most natural problems in this domain—*e.g.* for models such as mixture models, HMMs, graphical models, topic models and sparse coding/dictionary learning — are NP-hard. Therefore researchers in practice use either heuristics or convex relaxations with no concrete approximation bounds. Several nonconvex heuristics work well in practice, which is also a mystery.

Recently, a sequence of results has shown that rigorous approaches leading to polynomial running time are possible for several of these problems. These involve sidestepping worst-case complexity via special assumptions on the input. Some of this work—*e.g.* for topic models—even leads to practical running times (50x faster than previous approaches). It has even become possible to analyse nonconvex optimization heuristics such as alternating minimization or kSVD.

The talk will be a survey of these new results, including topic modeling, sparse coding, and deep learning.

# On the Glass Ceiling Effect in Social Networks

Claire Mathieu

CNRS, École Normale Supérieure

**Abstract.** The glass ceiling may be defined as “the unseen, yet unbreakable barrier that keeps minorities and women from rising to the upper rungs of the corporate ladder, regardless of their qualifications or achievements.” Although undesirable, it is well documented that many societies and organizations exhibit a glass ceiling. In this paper we formally define and study the glass ceiling effect in social networks and provide a natural mathematical model that (partially) explains it. We propose a biased preferential attachment model that has two type of nodes, and is based on three well known social phenomena:

- i) rich get richer (preferential attachment),
- ii) minority of females (or other group) in the network, and
- iii) homophily (preference to bond with similar people).

We prove that our model exhibits a strong glass ceiling effect and that all three conditions are necessary, *i.e.*, removing any one of them, will cause the model not to exhibit a glass ceiling effect. Additionally we present empirical evidence of student–mentor networks of researchers that exhibits all the above properties: female minority, preferential attachment, homophily and a glass ceiling.

Joint work with Chen Avin, Barbara Keller, Zvi Lotker, David Peleg, and Yvonne-Anne Pignolet.

# Table of Contents – Part I

## Invited Talks

Sporadic Solutions to Zero-One Exclusion Tasks . . . . .	1
<i>Eli Gafni and Maurice Herlihy</i>	
Verifying and Synthesizing Software with Recursive Functions (Invited Contribution) . . . . .	11
<i>Viktor Kuncak</i>	

## Track A: Algorithms, Complexity, and Games

Weak Parity . . . . .	26
<i>Scott Aaronson, Andris Ambainis, Kaspars Balodis, and Mohammad Bavarian</i>	
Consequences of Faster Alignment of Sequences . . . . .	39
<i>Amir Abboud, Virginia Vassilevska Williams, and Oren Weimann</i>	
Distance Labels with Optimal Local Stretch . . . . .	52
<i>Ittai Abraham and Shiri Chechik</i>	
Time-Expanded Packings . . . . .	64
<i>David Adjiashvili, Sandro Bosio, Robert Weismantel, and Rico Zenklusen</i>	
Deterministic Rectangle Enclosure and Offline Dominance Reporting on the RAM . . . . .	77
<i>Peyman Afshani, Timothy M. Chan, and Konstantinos Tsakalidis</i>	
The Tropical Shadow-Vertex Algorithm Solves Mean Payoff Games in Polynomial Time on Average . . . . .	89
<i>Xavier Allamigeon, Pascal Benchimol, and Stéphane Gaubert</i>	
Tighter Relations between Sensitivity and Other Complexity Measures . . . . .	101
<i>Andris Ambainis, Mohammad Bavarian, Yihan Gao, Jieming Mao, Xiaoming Sun, and Song Zuo</i>	
On Hardness of Jumbled Indexing . . . . .	114
<i>Amihod Amir, Timothy M. Chan, Moshe Lewenstein, and Noa Lewenstein</i>	
Morphing Planar Graph Drawings Optimally . . . . .	126
<i>Patrizio Angelini, Giordano Da Lozzo, Giuseppe Di Battista, Fabrizio Frati, Maurizio Patrignani, and Vincenzo Roselli</i>	

Incremental Algorithm for Maintaining DFS Tree for Undirected Graphs . . . . .	138
<i>Surender Baswana and Shahbaz Khan</i>	
On the Role of Shared Randomness in Simultaneous Communication . . .	150
<i>Mohammad Bavarian, Dmitry Gavinsky, and Tsuyoshi Ito</i>	
Short PCPs with Projection Queries . . . . .	163
<i>Eli Ben-Sasson and Emanuele Viola</i>	
Star Partitions of Perfect Graphs . . . . .	174
<i>René van Bevern, Robert Bredereck, Laurent Bulteau, Jiehua Chen, Vincent Froese, Rolf Niedermeier, and Gerhard J. Woeginger</i>	
Coordination Mechanisms for Selfish Routing over Time on a Tree . . . . .	186
<i>Sayan Bhattacharya, Janardhan Kulkarni, and Vahab Mirrokni</i>	
On Area-Optimal Planar Graph Drawings . . . . .	198
<i>Therese Biedl</i>	
Shortest Two Disjoint Paths in Polynomial Time . . . . .	211
<i>Andreas Björklund and Thore Husfeldt</i>	
Listing Triangles . . . . .	223
<i>Andreas Björklund, Rasmus Pagh, Virginia Vassilevska Williams, and Uri Zwick</i>	
On DNF Approximators for Monotone Boolean Functions . . . . .	235
<i>Eric Blais, Johan Håstad, Rocco A. Servedio, and Li-Yang Tan</i>	
Internal DLA: Efficient Simulation of a Physical Growth Model (Extended Abstract) . . . . .	247
<i>Karl Bringmann, Fabian Kuhn, Konstantinos Panagiotou, Ueli Peter, and Henning Thomas</i>	
Lower Bounds for Approximate LDCs . . . . .	259
<i>Jop Briët, Zeev Dvir, Guangda Hu, and Shubhangi Saraf</i>	
Holographic Algorithms Beyond Matchgates . . . . .	271
<i>Jin-Yi Cai, Heng Guo, and Tyson Williams</i>	
Testing Probability Distributions Underlying Aggregated Data . . . . .	283
<i>Clément Canonne and Ronitt Rubinfeld</i>	
Parallel Repetition of Entangled Games with Exponential Decay via the Superposed Information Cost . . . . .	296
<i>André Chailloux and Giannicola Scarpa</i>	
The Bose-Hubbard Model is QMA-complete . . . . .	308
<i>Andrew M. Childs, David Gosset, and Zak Webb</i>	

Characterization of Binary Constraint System Games . . . . .	320
<i>Richard Cleve and Rajat Mittal</i>	
Fast Algorithms for Constructing Maximum Entropy Summary Trees . . .	332
<i>Richard Cole and Howard Karloff</i>	
Thorp Shuffling, Butterflies, and Non-markovian Couplings . . . . .	344
<i>Artur Czumaj and Berthold Vöcking</i>	
Dynamic Complexity of Directed Reachability and Other Problems . . . .	356
<i>Samir Datta, William Hesse, and Raghav Kulkarni</i>	
One Tile to Rule Them All: Simulating Any Tile Assembly System with a Single Universal Tile . . . . .	368
<i>Erik D. Demaine, Martin L. Demaine, Sándor P. Fekete, Matthew J. Patitz, Robert T. Schweller, Andrew Winslow, and Damien Woods</i>	
Canadians Should Travel Randomly . . . . .	380
<i>Erik D. Demaine, Yanning Huang, Chung-Shou Liao, and Kunihiko Sadakane</i>	
Efficiency Guarantees in Auctions with Budgets . . . . .	392
<i>Shahar Dobzinski and Renato Paes Leme</i>	
Parameterized Complexity of Bandwidth on Trees . . . . .	405
<i>Markus Sortland Dregi and Daniel Lokshтанov</i>	
Testing Equivalence of Polynomials under Shifts . . . . .	417
<i>Zeev Dvir, Rafael Mendes de Oliveira, and Amir Shpilka</i>	
Optimal Analysis of Best Fit Bin Packing . . . . .	429
<i>György Dósa and Jiří Sgall</i>	
Light Spanners . . . . .	442
<i>Michael Elkin, Ofer Neiman, and Shay Solomon</i>	
Semi-Streaming Set Cover (Extended Abstract) . . . . .	453
<i>Yuval Emek and Adi Rosén</i>	
Online Stochastic Reordering Buffer Scheduling . . . . .	465
<i>Hossein Esfandiari, MohammadTaghi Hajiaghayi, Mohammad Reza Khani, Vahid Liaghat, Hamid Mahini, and Harald Räcke</i>	
Demand Queries with Preprocessing . . . . .	477
<i>Uriel Feige and Shlomo Jozeph</i>	
Algorithmic Aspects of Regular Graph Covers with Applications to Planar Graphs . . . . .	489
<i>Jiří Fiala, Pavel Klavík, Jan Kratochvíl, and Roman Nedela</i>	

Public vs Private Coin in Bounded-Round Information . . . . .	502
<i>Mark Braverman and Ankit Garg</i>	
En Route to the Log-Rank Conjecture: New Reductions and Equivalent Formulations . . . . .	514
<i>Dmitry Gavinsky and Shachar Lovett</i>	
Improved Submatrix Maximum Queries in Monge Matrices . . . . .	525
<i>Pawel Gawrychowski, Shay Mozes, and Oren Weimann</i>	
For-All Sparse Recovery in Near-Optimal Time . . . . .	538
<i>Anna C. Gilbert, Yi Li, Ely Porat, and Martin J. Strauss</i>	
Families with Infants: A General Approach to Solve Hard Partition Problems . . . . .	551
<i>Alexander Golovnev, Alexander S. Kulikov, and Ioan Mihajlin</i>	
Changing Bases: Multistage Optimization for Matroids and Matchings . . . . .	563
<i>Anupam Gupta, Kunal Talwar, and Udi Wieder</i>	
Near-Optimal Online Algorithms for Prize-Collecting Steiner Problems . . . . .	576
<i>MohammadTaghi Hajiaghayi, Vahid Liaghat, and Debmalya Panigrahi</i>	
Nearly Linear-Time Model-Based Compressive Sensing . . . . .	588
<i>Chinmay Hegde, Piotr Indyk, and Ludwig Schmidt</i>	
Breaking the PPSZ Barrier for Unique 3-SAT . . . . .	600
<i>Timon Hertli</i>	
Privately Solving Linear Programs . . . . .	612
<i>Justin Hsu, Aaron Roth, Tim Roughgarden, and Jonathan Ullman</i>	
How Unsplittable-Flow-Covering Helps Scheduling with Job-Dependent Cost Functions . . . . .	625
<i>Wiebke Höhn, Julián Mestre, and Andreas Wiese</i>	
Why Some Heaps Support Constant-Amortized-Time Decrease-Key Operations, and Others Do Not . . . . .	637
<i>John Iacono and Özgür Özkan</i>	
Partial Garbling Schemes and Their Applications . . . . .	650
<i>Yuval Ishai and Hoeteck Wee</i>	
On the Complexity of Trial and Error for Constraint Satisfaction Problems . . . . .	663
<i>Gábor Ivanyos, Raghav Kulkarni, Youming Qiao, Miklos Santha, and Arthi Sundaram</i>	



Information Theoretical Cryptogenography . . . . .	676
<i>Sune K. Jakobsen</i>	
The Complexity of Somewhat Approximation Resistant Predicates . . . . .	689
<i>Subhash Khot, Madhur Tulsiani, and Pratik Worah</i>	
Approximate Nonnegative Rank Is Equivalent to the Smooth Rectangle Bound . . . . .	701
<i>Gillat Kol, Shay Moran, Amir Shpilka, and Amir Yehudayoff</i>	
Distance Oracles for Time-Dependent Networks . . . . .	713
<i>Spyros Kontogiannis and Christos Zaroliagis</i>	
Efficient Indexing of Necklaces and Irreducible Polynomials over Finite Fields . . . . .	726
<i>Swastik Kopparty, Mrinal Kumar, and Michael Saks</i>	
Coloring Relatives of Interval Overlap Graphs via On-line Games . . . . .	738
<i>Tomasz Krawczyk and Bartosz Walczak</i>	
Superpolynomial Lower Bounds for General Homogeneous Depth 4 Arithmetic Circuits . . . . .	751
<i>Mrinal Kumar and Shubhangi Saraf</i>	
Testing Forest-Isomorphism in the Adjacency List Model . . . . .	763
<i>Mitsuru Kusumoto and Yuichi Yoshida</i>	
Parameterized Approximation Schemes Using Graph Widths . . . . .	775
<i>Michael Lampis</i>	
FPTAS for Weighted Fibonacci Gates and Its Applications . . . . .	787
<i>Pinyan Lu, Menghui Wang, and Chihao Zhang</i>	
Parameterized Algorithms to Preserve Connectivity . . . . .	800
<i>Manu Basavaraju, Fedor V. Fomin, Petr Golovach, Pranabendu Misra, M.S. Ramanujan, and Saket Saurabh</i>	
Nonuniform Graph Partitioning with Unrelated Weights . . . . .	812
<i>Konstantin Makarychev and Yury Makarychev</i>	
Precedence-Constrained Scheduling of Malleable Jobs with Preemption . . . . .	823
<i>Konstantin Makarychev and Debmalya Panigrahi</i>	
Unbounded Entanglement Can Be Needed to Achieve the Optimal Success Probability . . . . .	835
<i>Laura Mančinska and Thomas Vidick</i>	
QCSP on Semicomplete Digraphs . . . . .	847
<i>Petar Dapić, Petar Marković, and Barnaby Martin</i>	

Fast Pseudorandomness for Independence and Load Balancing [Extended Abstract] . . . . .	859
<i>Raghu Meka, Omer Reingold, Guy N. Rothblum, and Ron D. Rothblum</i>	
Determining Majority in Networks with Local Interactions and Very Small Local Memory . . . . .	871
<i>George B. Mertzios, Sotiris E. Nikolettseas, Christoforos L. Raptopoulos, and Paul G. Spirakis</i>	
Lower Bounds for Oblivious Subspace Embeddings . . . . .	883
<i>Jelani Nelson and Huy L. Nguyễn</i>	
On Input Indistinguishable Proof Systems . . . . .	895
<i>Rafail Ostrovsky, Giuseppe Persiano, and Ivan Visconti</i>	
Secure Computation Using Leaky Tokens . . . . .	907
<i>Manoj Prabhakaran, Amit Sahai, and Akshay Wadia</i>	
An Improved Interactive Streaming Algorithm for the Distinct Elements Problem . . . . .	919
<i>Hartmut Klauck and Ved Prakash</i>	
A Faster Parameterized Algorithm for Treedepth . . . . .	931
<i>Felix Reidl, Peter Rossmanith, Fernando Sánchez Villaamil, and Somnath Sikdar</i>	
Pseudorandom Graphs in Data Structures . . . . .	943
<i>Omer Reingold, Ron D. Rothblum, and Udi Wieder</i>	
Sampling-Based Proofs of Almost-Periodicity Results and Algorithmic Applications . . . . .	955
<i>Eli Ben-Sasson, Noga Ron-Zewi, Madhur Tulsiani, and Julia Wolf</i>	
The Mondschein Sequence . . . . .	967
<i>Jens M. Schmidt</i>	
Balanced Allocations: A Simple Proof for the Heavily Loaded Case . . . . .	979
<i>Kunal Talwar and Udi Wieder</i>	
Close to Uniform Prime Number Generation with Fewer Random Bits . . . . .	991
<i>Pierre-Alain Fouque and Mehdi Tibouchi</i>	
Optimal Strong Parallel Repetition for Projection Games on Low Threshold Rank Graphs . . . . .	1003
<i>Madhur Tulsiani, John Wright, and Yuan Zhou</i>	
Sparser Random 3-SAT Refutation Algorithms and the Interpolation Problem (Extended Abstract) . . . . .	1015
<i>Iddo Zameret</i>	

On Learning, Lower Bounds and (un)Keeping Promises . . . . .	1027
<i>Ilya Volkovich</i>	
Certificates in Data Structures . . . . .	1039
<i>Yaoyu Wang and Yitong Yin</i>	
Optimal Query Complexity for Estimating the Trace of a Matrix . . . . .	1051
<i>Karl Wimmer, Yi Wu, and Peng Zhang</i>	
Faster Separators for Shallow Minor-Free Graphs via Dynamic Approximate Distance Oracles . . . . .	1063
<i>Christian Wulff-Nilsen</i>	
Spatial Mixing of Coloring Random Graphs . . . . .	1075
<i>Yitong Yin</i>	
<b>Author Index</b> . . . . .	1087

## Table of Contents – Part II

### Track B: Logic, Semantics, Automata, and Theory of Programming

Symmetric Groups and Quotient Complexity of Boolean Operations . . . .	1
<i>Jason Bell, Janusz Brzozowski, Nelma Moreira, and Rogério Reis</i>	
Handling Infinitely Branching WSTS . . . . .	13
<i>Michael Blondin, Alain Finkel, and Pierre McKenzie</i>	
Transducers with Origin Information . . . . .	26
<i>Mikołaj Bojańczyk</i>	
Weak MSO+U with Path Quantifiers over Infinite Trees . . . . .	38
<i>Mikołaj Bojańczyk</i>	
On the Decidability of MSO+U on Infinite Trees . . . . .	50
<i>Mikołaj Bojańczyk, Tomasz Gogacz, Henryk Michalewski, and Michał Skrzypczak</i>	
A Coalgebraic Foundation for Coinductive Union Types . . . . .	62
<i>Marcello Bonsangue, Jurriaan Rot, Davide Ancona, Frank de Boer, and Jan Rutten</i>	
Turing Degrees of Limit Sets of Cellular Automata . . . . .	74
<i>Alex Borello, Julien Cervelle, and Pascal Vanier</i>	
On the Complexity of Temporal-Logic Path Checking . . . . .	86
<i>Daniel Bundala and Joël Ouaknine</i>	
Parameterised Linearisability . . . . .	98
<i>Andrea Cerone, Alexey Gotsman, and Hongseok Yang</i>	
Games with a Weak Adversary . . . . .	110
<i>Krishnendu Chatterjee and Laurent Doyen</i>	
The Complexity of Ergodic Mean-payoff Games . . . . .	122
<i>Krishnendu Chatterjee and Rasmus Ibsen-Jensen</i>	
Toward a Structure Theory of Regular Infinitary Trace Languages . . . . .	134
<i>Namit Chaturvedi</i>	
Unary Pushdown Automata and Straight-Line Programs . . . . .	146
<i>Dmitry Chistikov and Rupak Majumdar</i>	

Robustness against Power is PSpace-complete . . . . .	158
<i>Egor Derevenetc and Roland Meyer</i>	
A Nivat Theorem for Weighted Timed Automata and Weighted Relative Distance Logic . . . . .	171
<i>Manfred Droste and Vitaly Perevoshchikov</i>	
Computability in Anonymous Networks: Revocable vs. Irrecoverable Outputs . . . . .	183
<i>Yuval Emek, Jochen Seidel, and Roger Wattenhofer</i>	
Coalgebraic Weak Bisimulation from Recursive Equations over Monads . . . . .	196
<i>Sergey Goncharov and Dirk Pattinson</i>	
Piecewise Boolean Algebras and Their Domains . . . . .	208
<i>Chris Heunen</i>	
Between Linearizability and Quiescent Consistency: Quantitative Quiescent Consistency . . . . .	220
<i>Radha Jagadeesan and James Riely</i>	
Bisimulation Equivalence of First-Order Grammars . . . . .	232
<i>Petr Jančár</i>	
Context Unification is in PSPACE . . . . .	244
<i>Artur Jež</i>	
Monodic Fragments of Probabilistic First-Order Logic . . . . .	256
<i>Jean Christoph Jung, Carsten Lutz, Sergey Goncharov, and Lutz Schröder</i>	
Stability and Complexity of Minimising Probabilistic Automata . . . . .	268
<i>Stefan Kiefer and Björn Wachter</i>	
Kleene Algebra with Equations . . . . .	280
<i>Dexter Kozen and Konstantinos Mamouras</i>	
All-Instances Termination of Chase is Undecidable . . . . .	293
<i>Tomasz Gogacz and Jerzy Marcinkowski</i>	
Non-uniform Polytime Computation in the Infinitary Affine Lambda-Calculus . . . . .	305
<i>Damiano Mazza</i>	
On the Positivity Problem for Simple Linear Recurrence Sequences . . . . .	318
<i>Joël Ouaknine and James Worrell</i>	
Ultimate Positivity is Decidable for Simple Linear Recurrence Sequences . . . . .	330
<i>Joël Ouaknine and James Worrell</i>	

Going Higher in the First-Order Quantifier Alternation Hierarchy on Words . . . . .	342
<i>Thomas Place and Marc Zeitoun</i>	
Hardness Results for Intersection Non-Emptiness . . . . .	354
<i>Michael Wehar</i>	
Branching Bisimilarity Checking for PRS . . . . .	363
<i>Qiang Yin, Yuxi Fu, Chaodong He, Mingzhang Huang, and Xiuting Tao</i>	

## Track C: Foundations of Networked Computing

Labeling Schemes for Bounded Degree Graphs . . . . .	375
<i>David Adjiashvili and Noy Rotbart</i>	
Bounded-Angle Spanning Tree: Modeling Networks with Angular Constraints . . . . .	387
<i>Rom Aschner and Matthew J. Katz</i>	
Distributed Computing on Core-Periphery Networks: Axiom-Based Design . . . . .	399
<i>Chen Avin, Michael Borokhovich, Zvi Lotker, and David Peleg</i>	
Fault-Tolerant Rendezvous in Networks . . . . .	411
<i>J��r��mie Chalopin, Yoann Dieudonn��, Arnaud Labourel, and Andrzej Pelc</i>	
Data Delivery by Energy-Constrained Mobile Agents on a Line . . . . .	423
<i>J��r��mie Chalopin, Riko Jacob, Mat��š Mihal��k, and Peter Widmayer</i>	
The Power of Two Choices in Distributed Voting . . . . .	435
<i>Colin Cooper, Robert Els��sser, and Tomasz Radzik</i>	
Jamming-Resistant Learning in Wireless Networks . . . . .	447
<i>Johannes Dams, Martin Hoefer, and Thomas Kesselheim</i>	
Facility Location in Evolving Metrics . . . . .	459
<i>David Eisenstat, Claire Mathieu, and Nicolas Schabanel</i>	
Solving the ANTS Problem with Asynchronous Finite State Machines . . . . .	471
<i>Yuval Emek, Tobias Langner, Jara Uitto, and Roger Wattenhofer</i>	
Near-Optimal Distributed Approximation of Minimum-Weight Connected Dominating Set . . . . .	483
<i>Mohsen Ghaffari</i>	
Randomized Rumor Spreading in Dynamic Graphs . . . . .	495
<i>George Giakkoupis, Thomas Sauerwald, and Alexandre Stauffer</i>	

Online Independent Set Beyond the Worst-Case: Secretaries, Prophets, and Periods . . . . .	508
<i>Oliver Göbel, Martin Hoefer, Thomas Kesselheim, Thomas Schleiden, and Berthold Vöcking</i>	
Optimal Competitiveness for Symmetric Rectilinear Steiner Arborescence and Related Problems . . . . .	520
<i>Erez Kantor and Shay Kutten</i>	
Orienting Fully Dynamic Graphs with Worst-Case Time Bounds . . . . .	532
<i>Tsvi Kopelowitz, Robert Krauthgamer, Ely Porat, and Shay Solomon</i>	
Does Adding More Agents Make a Difference? A Case Study of Cover Time for the Rotor-Router . . . . .	544
<i>Adrian Kosowski and Dominik Pająk</i>	
The Melbourne Shuffle: Improving Oblivious Storage in the Cloud . . . . .	556
<i>Olga Ohrimenko, Michael T. Goodrich, Roberto Tamassia, and Eli Upfal</i>	
Sending Secrets Swiftly: Approximation Algorithms for Generalized Multicast Problems . . . . .	568
<i>Afshin Nikzad and R. Ravi</i>	
Bypassing Erdős’ Girth Conjecture: Hybrid Stretch and Sourcewise Spanners . . . . .	608
<i>Merav Parter</i>	
<b>Author Index . . . . .</b>	<b>621</b>