

*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

Friedemann Mattern, Switzerland

Moni Naor, Israel

Bernhard Steffen, Germany

Doug Tygar, USA

Takeo Kanade, USA

Jon M. Kleinberg, USA

John C. Mitchell, USA

C. Pandu Rangan, India

Demetri Terzopoulos, USA

Gerhard Weikum, Germany

## Advanced Research in Computing and Software Science

Subline of Lecture 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, *TU Munich, Germany*

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

Bernhard Steffen, *University of Dortmund, Germany*

Deng Xiaotie, *Peking University, Beijing, China*

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


More information about this series at <http://www.springer.com/series/7407>


Barbara Catania · Rastislav Kráľovič  
Jerzy Nawrocki · Giovanni Pighizzini (Eds.)

# SOFSEM 2019: Theory and Practice of Computer Science


45th International Conference on Current Trends  
in Theory and Practice of Computer Science  
Nový Smokovec, Slovakia, January 27–30, 2019  
Proceedings

*Editors*

Barbara Catania   
University of Genoa  
Genoa, Italy

Rastislav Kráľovič   
Comenius University  
Bratislava, Slovakia

Jerzy Nawrocki  
Poznań University of Technology  
Poznań, Poland

Giovanni Pighizzini   
Università degli Studi di Milano  
Milan, Italy

ISSN 0302-9743                      ISSN 1611-3349 (electronic)  
Lecture Notes in Computer Science  
ISBN 978-3-030-10800-7              ISBN 978-3-030-10801-4 (eBook)  
<https://doi.org/10.1007/978-3-030-10801-4>

Library of Congress Control Number: 2018965781

LNCS Sublibrary: SL1 – Theoretical Computer Science and General Issues

© Springer Nature Switzerland AG 2019

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.

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.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG  
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

# Preface

This volume contains the invited and contributed papers selected for presentation at SOFSEM 2019, the 45th International Conference on Current Trends in Theory and Practice of Computer Science, which was held during January 27–30, 2019, in Nový Smokovec, High Tatras, Slovakia.

SOFSEM (originally SOFTware SEMinar) is an annual international winter conference devoted to the theory and practice of computer science. Its aim is to present the latest developments in research for professionals from academia and industry working in leading areas of computer science. While being a well-established and fully international conference, SOFSEM also maintains the best of its original Winter School aspects, such as a high number of invited talks, in-depth coverage of selected research areas, and ample opportunities to discuss and exchange new ideas. SOFSEM 2019 was organized around the following three tracks:

- Foundations of Theoretical Computer Science (chair Giovanni Pighizzini)
- Foundations of Data Science and Engineering (chair Barbara Catania)
- Foundations of Software Engineering (chair Jerzy Nawrocki)

With these three tracks, SOFSEM 2019 covered the latest advances in both theoretical and applied research in leading areas of computer science.

An integral part of SOFSEM 2019 was the traditional Student Research Forum (chair Roman Špánek) organized with the aim of giving students feedback on both the originality of their scientific results and on their work in progress. The papers presented at the Student Research Forum are published in separate local proceedings.

The SOFSEM 2019 Program Committee (PC) consisted of 70 international experts, representing the track areas with outstanding expertise. The committee undertook the task of assembling a scientific program for the SOFSEM audience by selecting from the 92 submissions entered in the EasyChair system in response to the call for papers. The submissions were carefully reviewed with approximately three reviews per paper, and thoroughly discussed. Following strict criteria of quality and originality, 35 papers were accepted for presentation as regular research papers. Additionally, based on the recommendation of the chair of the Student Research Forum, seven papers were accepted for presentation in the Student Research Forum.

SOFSEM 2019 added a new page to the tradition of SOFSEM dating back to 1974, which was possible thanks to the effort of many people. As editors of these proceedings, we are grateful to everyone who contributed to the scientific program of the conference. We would like to thank the invited speakers Uwe Assmann, Francesco Bonchi, Flavio Chierichetti, Christos Kapoutsis, Mirosław Staron, and Martin Theobald for presenting their work to the audience of SOFSEM 2019. We thank all authors who submitted their papers for consideration. Many thanks go to the PC, and to all external referees, for their precise and detailed reviewing of the submissions. The work of the PC was carried out using the EasyChair system, and we gratefully

acknowledge this contribution. Special thanks are due to Roman Špánek for his expert preparation and handling of the Student Research Forum, and to the SOFSEM Steering Committee headed by Július Štuller, for its support throughout the preparation of the conference.

We are also indebted to the Organizing Committee led by Dana Pardubská.

Finally we want to thank the Slovak Society for Computer Science, and the Faculty of Mathematics, Physics and Informatics of the Comenius University in Bratislava for their invaluable support.

January 2019

Barbara Catania  
Rastislav Kráľovič  
Jerzy Nawrocki  
Giovanni Pighizzini

# Organization

## Steering Committee

Barbara Catania	University of Genoa, Italy
Mirosław Kutylowski	Wrocław University of Technology, Poland
Tiziana Margaria-Steffen	University of Limerick, Ireland
Branislav Rován	Comenius University, Slovakia
Petr Šaloun	Technical University of Ostrava, Czech Republic
Július Štuller (Chair)	Academy of Sciences, Prague, Czech Republic
Jan van Leeuwen	Utrecht University, The Netherlands

## Program Committee

### Program Chair

Rastislav Kráľovič	Comenius University, Slovakia
--------------------	-------------------------------

### Track Chairs

Barbara Catania	University of Genoa, Italy
Giovanni Pighizzini	University of Milan, Italy
Jerzy Nawrocki	Poznań University of Technology, Poland

### Student Research Forum Chair

Roman Špánek	Technical University of Liberec, Czech Republic
--------------	---

## Program Committee

Fabio Anselmi	Italian Institute of Technology, Italy
Ladjel Bellatreche	ISAE-ENSMA, Poitiers, France
Mária Bieliková	Slovak University of Technology in Bratislava, Slovakia
Stefan Biffl	Vienna University of Technology, Austria
Miklós Biró	Software Competence Center Hagenberg, Austria
Joan Boyar	University of Southern Denmark, Denmark
Stephane Bressan	National University of Singapore, Singapore
Francesco Buccafurri	University of Reggio Calabria, Italy
Davide Buscaldi	LIPN, Université Paris 13, Sorbonne Paris Cité, France
Barbara Catania	University of Genoa, Italy
Alfredo Cuzzocrea	University of Trieste, Italy
Jurek Czyzowicz	Université du Québec en Outaouais, Canada
Adam Dabrowski	Poznań University of Technology, Poland
Johann Eder	Alpen Adria Universität Klagenfurt, Austria

Michele Flammini	Gran Sasso Science Institute and University of L'Aquila, Italy
Paola Flocchini	University of Ottawa, Canada
Pierre Fraigniaud	CNRS and University of Paris Diderot, France
Johann Gamper	Free University of Bozen-Bolzano, Italy
Leszek Gasieniec	University of Liverpool, UK
Pawel Gawrychowski	University of Wroclaw, Poland
Loukas Georgiadis	University of Ioannina, Greece
Giovanna Guerrini	University of Genoa, Italy
Inge Li Gørtz	Technical University of Denmark, Denmark
Yo-Sub Han	Yonsei University, South Korea
Theo Härder	TU Kaiserslautern, Germany
Gabriel Istrate	West University of Timisoara, Romania, and the eAustria Research Institute, Austria
Mirjana Ivanovic	University of Novi Sad, Serbia
Johan Jeuring	Open Universiteit Nederland and Universiteit Utrecht, The Netherlands
Jarkko Kari	University of Turku, Finland
Ralf Klasing	CNRS and University of Bordeaux, France
Dennis Komm	ETH Zurich, Switzerland
Georgia Koutrika	Athena Research Center, Greece
Rastislav Kráľovič	Comenius University, Bratislava, Slovakia
Orna Kupferman	Hebrew University, Israel
Martin Kutrib	Institut für Informatik, Universität Giessen, Germany
Martin Lange	University of Kassel, Germany
Julia Lawall	Inria/LIP6, France
Andrzej Lingas	Lund University, Sweden
Lech Madeyski	Wroclaw University of Science and Technology, Poland
Yannis Manolopoulos	Open University of Cyprus, Cyprus
Tomáš Masopust	Palacký University, Olomouc, Czech Republic
Elvira Mayordomo	Universidad de Zaragoza, Spain
Paolo Missier	Newcastle University, UK
Nelma Moreira	University of Porto, Portugal
Xavier Muñoz	Universitat Politècnica de Catalunya, Spain
Jerzy Nawrocki	Poznań University of Technology, Poland
Boris Novikov	St.-Petersburg University, Russia
Mirosław Ochodek	Poznań University of Technology, Poland
Dana Pardubská	Comenius University, Slovakia
Andrea Pietracaprina	University of Padua, Italy
Giovanni Pighizzini	University of Milan, Italy
Andrei Popescu	Middlesex University London, UK
Rajeev Raman	University of Leicester, UK
Gunter Saake	University of Magdeburg, Germany
Philippe Schnoebelen	CNRS, France
Shinnosuke Seki	The University of Electro-Communications, Japan



Arseny Shur	Ural Federal University, Russia
Daniel Stefankovic	University of Rochester, USA
Krzysztof Stencel	University of Warsaw, Poland
Ernest Teniente	Universitat Politècnica de Catalunya, Spain
Martin Theobald	University of Luxembourg, Luxembourg
Panos Vassiliadis	University of Ioannina, Greece
Valentino Vranić	Slovak University of Technology in Bratislava, Slovakia
Dorothea Wagner	Karlsruhe Institute of Technology, Germany
Bruce Watson	Stellenbosch University, South Africa
Abuzer Yakaryilmaz	University of Latvia, Latvia
Tomoyuki Yamakami	University of Fukui, Japan
Christos Zaroliagis	Computer Technology Institute and Department of Computer Engineering & Informatics, University of Patras, Greece
Norbert Zeh	Dalhousie University, Canada
Wolf Zimmermann	Martin Luther University Halle-Wittenberg, Germany

## Organization Chair

Dana Pardubská	Comenius University, Slovakia
----------------	-------------------------------

## Organizing Institutions

Slovak Society for Computer Science  
Faculty of Mathematics, Physics, and Informatics, Comenius University in Bratislava,  
Slovakia

## Additional Reviewers

Aceto, Luca	Fabrega, Josep
Aloisio, Alessandro	Fiol, Miquel Angel
Badouel, Eric	Forišek, Michal
Balkenius, Christian	Fribourg, Laurent
Bampas, Evangelos	Gainutdinova, Aida
Barth, Lukas	Georgiou, Konstantinos
Berg, Christian	Giannis, Konstantinos
Bilò, Davide	Gualandi, Stefano
Böckenhauer, Hans-Joachim	Guillon, Bruno
Cho, Da-Jung	Hundesagen, Norbert
Czyzewski, Andrzej	Jajcayova, Tatiana
Das, Shantanu	Kapoutsis, Christos
Demri, Stéphane	Kawachi, Akinori
Dimokas, Nikos	Killick, Ryan

Kim, Hwee  
Ko, Sang-Ki  
Komusiewicz, Christian  
Kowaluk, Mirosław  
Krüger, Jacob  
Kľuka, Ján  
Li, Yang  
Loff, Bruno  
Luetngen, Gerald  
Malcher, Andreas  
Mchedlidze, Tamara  
Meister, Andreas  
Mráz, František  
Noceti, Nicoletta  
Pająk, Dominik  
Papadopoulos, Charis  
Plachetka, Tomáš  
Prigioniero, Luca  
Prūsis, Krišjānis  
Rafailidis, Dimitrios

Raghavendra Rao, B. V.  
Rástočný, Karol  
Rogalewicz, Adam  
Rovetta, Stefano  
Salehi, Özlem  
Salo, Ville  
San Felice, Mário César  
Schmidt, Paweł  
Toft, Bjarne  
Tomás, Ana Paula  
Tsichlas, Kostas  
Tzouramanis, Theodoros  
Ueckerdt, Torsten  
van Ee, Martijn  
Villagra, Marcos  
Vinci, Cosimo  
Wehnert, Sabine  
Wendlandt, Matthias  
Wong, Tom  
Zetzsche, Georg

# Contents

Cross-Layer Adaptation in Multi-layer Autonomic Systems (Invited Talk) . . .	1
<i>Uwe Aßmann, Dominik Grzelak, Johannes Mey, Dmytro Pukhkaiev, René Schöne, Christopher Werner, and Georg Püschel</i>	
Distance-Based Community Search (Invited Talk Extended Abstract) . . . . .	21
<i>Francesco Bonchi</i>	
Minicomplexity: <i>Some Motivation, Some History, and Some Structure</i> (Invited Talk Extended Abstract). . . . .	28
<i>Christos A. Kapoutsis</i>	
Action Research in Software Engineering: Metrics' Research Perspective (Invited Talk). . . . .	39
<i>Mirosław Staron</i>	
From Big Data to Big Knowledge: Large-Scale Information Extraction Based on Statistical Methods (Invited Talk) . . . . .	50
<i>Martin Theobald</i>	
Sorting Networks on Restricted Topologies . . . . .	54
<i>Indranil Banerjee, Dana Richards, and Igor Shinkar</i>	
Minimum Reload Cost Graph Factors . . . . .	67
<i>Julien Baste, Didem Gözüpek, Mordechai Shalom, and Dimitrios M. Thilikos</i>	
Stable Divisorial Gonality is in NP . . . . .	81
<i>Hans L. Bodlaender, Marieke van der Wegen, and Tom C. van der Zanden</i>	
Coalition Resilient Outcomes in Max $k$ -Cut Games . . . . .	94
<i>Raffaello Carosi, Simone Fioravanti, Luciano Gualà, and Gianpiero Monaco</i>	
Phase Transition in Matched Formulas and a Heuristic for Biclique Satisfiability . . . . .	108
<i>Miloš Chromý and Petr Kučera</i>	
On Infinite Prefix Normal Words . . . . .	122
<i>Ferdinando Cicalese, Zsuzsanna Lipták, and Massimiliano Rossi</i>	
Priority Scheduling in the Bamboo Garden Trimming Problem. . . . .	136
<i>Mattia D'Emidio, Gabriele Di Stefano, and Alfredo Navarra</i>	

Patrolling on Dynamic Ring Networks. . . . .	150
<i>Shantanu Das, Giuseppe A. Di Luna, and Leszek A. Gasieniec</i>	
Gathering of Robots in a Grid with Mobile Faults. . . . .	164
<i>Shantanu Das, Nikos Giachoudis, Flaminia L. Luccio, and Euripides Markou</i>	
Probabilistic Parameterized Polynomial Time . . . . .	179
<i>Nils Donselaar</i>	
On Matrix Ins-Del Systems of Small Sum-Norm. . . . .	192
<i>Henning Fernau, Lakshmanan Kuppusamy, and Indhumathi Raman</i>	
Separation Logic with Linearly Compositional Inductive Predicates and Set Data Constraints . . . . .	206
<i>Chong Gao, Taolue Chen, and Zhilin Wu</i>	
On the Complexity of Optimal Matching Reconfiguration . . . . .	221
<i>Manoj Gupta, Hitesh Kumar, and Neeldhara Misra</i>	
Forbidden Directed Minors, Directed Path-Width and Directed Tree-Width of Tree-Like Digraphs . . . . .	234
<i>Frank Gurski and Carolin Rehs</i>	
Existence Versus Exploitation: The Opacity of Backdoors and Backbones Under a Weak Assumption. . . . .	247
<i>Lane A. Hemaspaandra and David E. Narváez</i>	
On Point Set Embeddings for $k$ -Planar Graphs with Few Bends per Edge . . .	260
<i>Michael Kaufmann</i>	
Enumerating Connected Induced Subgraphs: Improved Delay and Experimental Comparison . . . . .	272
<i>Christian Komusiewicz and Frank Sommer</i>	
Multi-stranded String Assembling Systems. . . . .	285
<i>Martin Kutrib and Matthias Wendlandt</i>	
Towards Automatic Comparison of Cloud Service Security Certifications. . . .	298
<i>Martin Labaj, Karol Rástočný, and Daniela Chudá</i>	
On the Expressive Power of $GF(2)$ -Grammars . . . . .	310
<i>Vladislav Makarov and Alexander Okhotin</i>	
An Efficient Algorithm for Combining Verification and Validation Methods. . . . .	324
<i>Icela Mendoza, Uéverton Souza, Marcos Kalinowski, Ruben Interian, and Leonardo Gresta Paulino Murta</i>	

Robustness Radius for Chamberlin-Courant on Restricted Domains . . . . . 341  
*Neeldhara Misra and Chinmay Sonar*

On the Complexity of Color-Avoiding Site and Bond Percolation . . . . . 354  
*Roland Molontay and Kitti Varga*

Lackadaisical Quantum Walks with Multiple Marked Vertices . . . . . 368  
*Nikolajs Nahimovs*

A 116/13-Approximation Algorithm for  $L(2, 1)$ -Labeling  
of Unit Disk Graphs . . . . . 379  
*Hiroataka Ono and Hisato Yamanaka*

Minimizing the Cost of Team Exploration . . . . . 392  
*Dorota Osula*

Two-Head Finite-State Acceptors with Translucent Letters . . . . . 406  
*Benedek Nagy and Friedrich Otto*

Do Null-Type Mutation Operators Help Prevent Null-Type Faults? . . . . . 419  
*Ali Parsai and Serge Demeyer*

Towards Combining Multitask and Multilingual Learning . . . . . 435  
*Matus Pikuliak, Marian Simko, and Maria Bielikova*

On the Size of Logical Automata . . . . . 447  
*Martin Raszyk*

Bayesian Root Cause Analysis by Separable Likelihoods . . . . . 461  
*Maciej Skorski*

Algorithms and Complexity Results for the Capacitated Vertex  
Cover Problem . . . . . 473  
*Sebastiaan B. van Rooij and Johan M. M. van Rooij*

Comparative Expressiveness of Product Line Calculus of Communicating  
Systems and 1-Selecting Modal Transition Systems . . . . . 490  
*Mahsa Varshosaz and Mohammad Reza Mousavi*

A Hierarchy of Polynomial Kernels . . . . . 504  
*Jouke Witteveen, Ralph Bottesch, and Leen Torenvliet*

Behavioral Strengths and Weaknesses of Various Models  
of Limited Automata . . . . . 519  
*Tomoyuki Yamakami*

Locality Sensitive Hashing Schemes, Similarities, and Distortion  
(Invited Talk) . . . . . 531  
*Flavio Chierichetti*

**Author Index** . . . . . 533