

9th International Conference on Fun with Algorithms

FUN 2018, June 13–15, 2018, La Maddalena Island, Italy

Edited by

Hiro Ito

Stefano Leonardi

Linda Pagli

Giuseppe Prencipe



Editors

Hiro Ito
School of Informatics and Engineering
The University of Electro-Communications
itohiro@uec.ac.jp

Stefano Leonardi
Dipartimento di Ing. Informatica Automatica e Gestionale
Sapienza Università di Roma
leonardi@diag.uniroma1.it

Linda Pagli
Dipartimento di Informatica
Università di Pisa
linda.pagli@unipi.it

Giuseppe Prencipe
Dipartimento di Informatica
Università di Pisa
giuseppe.prencipe@unipi.it

ACM Classification 2012

Theory of computation → Complexity classes, Theory of computation → Algorithm design techniques,
Theory of computation → Computability, Theory of computation → Approximation algorithms analysis,
Mathematics of computing → Combinatorics, Mathematics of computing → Combinatorial algorithms,
Computing methodologies

ISBN 978-3-95977-067-5

Published online and open access by

Schloss Dagstuhl – Leibniz-Zentrum für Informatik GmbH, Dagstuhl Publishing, Saarbrücken/Wadern,
Germany. Online available at <http://www.dagstuhl.de/dagpub/978-3-95977-067-5>.

Publication date

June, 2018

Bibliographic information published by the Deutsche Nationalbibliothek

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed
bibliographic data are available in the Internet at <http://dnb.d-nb.de>.

License

This work is licensed under a Creative Commons Attribution 3.0 Unported license (CC-BY 3.0):
<http://creativecommons.org/licenses/by/3.0/legalcode>.

In brief, this license authorizes each and everybody to share (to copy, distribute and transmit) the work
under the following conditions, without impairing or restricting the authors' moral rights:

■ Attribution: The work must be attributed to its authors.

The copyright is retained by the corresponding authors.



Digital Object Identifier: 10.4230/LIPIcs.FUN.2018.0

ISBN 978-3-95977-067-5

ISSN 1868-8969

<http://www.dagstuhl.de/lipics>

LIPICS – Leibniz International Proceedings in Informatics

LIPICS is a series of high-quality conference proceedings across all fields in informatics. LIPICS volumes are published according to the principle of Open Access, i.e., they are available online and free of charge.

Editorial Board

- Luca Aceto (*Chair*, Gran Sasso Science Institute and Reykjavik University)
- Susanne Albers (TU München)
- Chris Hankin (Imperial College London)
- Deepak Kapur (University of New Mexico)
- Michael Mitzenmacher (Harvard University)
- Madhavan Mukund (Chennai Mathematical Institute)
- Anca Muscholl (University Bordeaux)
- Catuscia Palamidessi (INRIA)
- Raimund Seidel (Saarland University and Schloss Dagstuhl – Leibniz-Zentrum für Informatik)
- Thomas Schwentick (TU Dortmund)
- Reinhard Wilhelm (Saarland University)

ISSN 1868-8969

<http://www.dagstuhl.de/lipics>

Contents

| | | |
|---|-------|------|
| Preface | | |
| <i>Hiro Ito, Stefano Leonardi, Linda Pagli, and Giuseppe Prencipe</i> | ..... | 0:ix |

Invited Papers

| | | |
|---------------------------------|-------|---------|
| Mind the Gap | | |
| <i>Martín Farach-Colton</i> | ..... | 1:1–1:1 |
| Evolution of Impossible Objects | | |
| <i>Kokichi Sugihara</i> | ..... | 2:1–2:8 |

Regular Papers

| | | |
|--|-------|------------|
| Who witnesses The Witness? Finding witnesses in The Witness is hard and sometimes impossible | | |
| <i>Zachary Abel, Jeffrey Bosboom, Erik D. Demaine, Linus Hamilton, Adam Hesterberg, Justin Kopinsky, Jayson Lynch, and Mikhail Rudoy</i> | ..... | 3:1–3:21 |
| Tracks from hell – when finding a proof may be easier than checking it | | |
| <i>Matteo Almanza, Stefano Leucci, and Alessandro Panconesi</i> | ..... | 4:1–4:13 |
| How Bad is the Freedom to Flood-It? | | |
| <i>Rémy Belmonte, Mehdi Khosravian Ghadikolaei, Masashi Kiyomi, Michael Lampis, and Yota Otachi</i> | ..... | 5:1–5:13 |
| How long does it take for all users in a social network to choose their communities? | | |
| <i>Jean-Claude Bermond, Augustin Chaintreau, Guillaume Ducoffe, and Dorian Mazauric</i> | ..... | 6:1–6:21 |
| On the Complexity of Two Dots for Narrow Boards and Few Colors | | |
| <i>Davide Bilò, Luciano Gualà, Stefano Leucci, and Neeldhara Misra</i> | ..... | 7:1–7:15 |
| On the PSPACE-completeness of Peg Duotaire and other Peg-Jumping Games | | |
| <i>Davide Bilò, Luciano Gualà, Stefano Leucci, Guido Proietti, and Mirko Rossi</i> | .... | 8:1–8:15 |
| On the Exact Complexity of Polyomino Packing | | |
| <i>Hans L. Bodlaender and Tom C. van der Zanden</i> | ..... | 9:1–9:10 |
| Kings, Name Days, Lazy Servants and Magic | | |
| <i>Paolo Boldi and Sebastiano Vigna</i> | ..... | 10:1–10:13 |
| Computational Complexity of Generalized Push Fight | | |
| <i>Jeffrey Bosboom, Erik D. Demaine, and Mikhail Rudoy</i> | ..... | 11:1–11:21 |
| SUPERSET: A (Super)Natural Variant of the Card Game SET | | |
| <i>Fábio Botler, Andrés Cristi, Ruben Hoeksma, Kevin Schewior, and Andreas Tönnis</i> | ..... | 12:1–12:17 |
| A Cryptographer’s Conspiracy Santa | | |
| <i>Xavier Bultel, Jannik Dreier, Jean-Guillaume Dumas, and Pascal Lafourcade</i> | .... | 13:1–13:13 |



| | |
|--|------------|
| Cooperating in Video Games? Impossible! Undecidability of Team Multiplayer Games <i>Michael J. Coulombe and Jayson Lynch</i> | 14:1–14:16 |
| A Muffin-Theorem Generator <i>Guangqi Cui, John Dickerson, Naveen Durvasula, William Gasarch, Erik Metz, Jacob Prinz, Naveen Raman, Daniel Smolyak, and Sung Hyun Yoo</i> | 15:1–15:19 |
| God Save the Queen <i>Jurek Czyzowicz, Konstantinos Georgiou, Ryan Killick, Evangelos Kranakis, Danny Krizanc, Lata Narayanan, Jaroslav Opatrny, and Sunil Shende</i> | 16:1–16:20 |
| Restricted Power – Computational Complexity Results for Strategic Defense Games <i>Ronald de Haan and Petra Wolf</i> | 17:1–17:14 |
| Computational Complexity of Motion Planning of a Robot through Simple Gadgets <i>Erik D. Demaine, Isaac Grosof, Jayson Lynch, and Mikhail Rudoy</i> | 18:1–18:21 |
| The Computational Complexity of Portal and Other 3D Video Games <i>Erik D. Demaine, Joshua Lockhart, and Jayson Lynch</i> | 19:1–19:22 |
| Faster Evaluation of Subtraction Games <i>David Eppstein</i> | 20:1–20:12 |
| Making Change in 2048 <i>David Eppstein</i> | 21:1–21:13 |
| Pick, Pack, & Survive: Charging Robots in a Modern Warehouse based on Online Connected Dominating Sets <i>Heiko Hamann, Christine Markarian, Friedhelm Meyer auf der Heide, and Mostafa Wahby</i> | 22:1–22:13 |
| Selection Via the Bogo-Method – More on the Analysis of Perversely Awful Randomized Algorithms <i>Markus Holzer and Jan-Tobias Maurer</i> | 23:1–23:21 |
| Herugolf and Makaro are NP-complete <i>Chuzo Iwamoto, Masato Haruishi, and Tatsuaki Ibusuki</i> | 24:1–24:11 |
| The Fewest Clues Problem of Picross 3D <i>Kei Kimura, Takuya Kamehashi, and Toshihiro Fujito</i> | 25:1–25:13 |
| Uniform Distribution On Pachinko <i>Naoki Kitamura, Yuya Kawabata, and Taisuke Izumi</i> | 26:1–26:14 |
| The complexity of speedrunning video games <i>Manuel Lafond</i> | 27:1–27:19 |
| Gender-Aware Facility Location in Multi-Gender World <i>Valentin Polishchuk and Leonid Sedov</i> | 28:1–28:16 |
| Card-Based Zero-Knowledge Proof for Sudoku <i>Tatsuya Sasaki, Takaaki Mizuki, and Hideaki Sone</i> | 29:1–29:10 |

| | |
|--|------------|
| The Complexity of Escaping Labyrinths and Enchanted Forests <i>Florian D. Schwahn and Clemens Thielen</i> | 30:1–30:13 |
| Card-based Protocols Using Triangle Cards <i>Kazumasa Shinagawa and Takaaki Mizuki</i> | 31:1–31:13 |
| The Power of One Secret Agent <i>Tami Tamir</i> | 32:1–32:15 |

■ Preface

FUN with Algorithms is dedicated to the use, design, and analysis of algorithms and data structures, focusing on results that provide amusing, witty but nonetheless original and scientifically profound contributions to the area. Donald Knuth's famous quote captures this spirit nicely:.... *pleasure has probably been the main goal all along. But I hesitate to admit it, because computer scientists want to maintain their image as hard-working individuals who deserve high salaries. Sooner or later society will realise that certain kinds of hard work are in fact admirable even though they are more fun than just about anything else.*

The previous FUNs were held in Elba Island, Italy; in Castiglioncello, Tuscany, Italy; in Ischia Island, Italy; in San Servolo Island, Venice, Italy; in Lipari Island, Sicily, Italy; and in La Maddalena Island, Sardinia, Italy. Special issues of Theoretical Computer Science, Discrete Applied Mathematics, and Theory of Computing Systems were dedicated to them.

This volume contains the papers presented at the 9th International Conference on Fun with Algorithms 2018, held on June 13-5, 2018, on La Maddalena Island, Italy. The call for papers attracted 55 submissions from all over the world, addressing a wide variety of topics, reviewed by three Program Committee members. After a careful reviewing process and a thorough discussion, the committee decided to accept 30 papers. In addition, the program featured two invited talks by Martin Farach-Colton and Kokichi Sugihara. Extended versions of selected papers will appear in a special issue of the journal Theoretical Computer Science.

We thank all authors who submitted their work to FUN 2018, all Program Committee members for their expert assessments and the ensuing discussions, all external reviewers for their kind help, and Atsuki Nagao for taking care of the web management of the conference. We used EasyChair (<http://www.easychair.org/>), that greatly facilitated the entire preparation of the conference, for handling submissions, reviews, the selection of papers, and the production of this volume. Warm thanks also go to Michael Wagner for following carefully the process of proceedings' publication in LIPICS series.

May, 2018

Hiro Ito
Stefano Leonardi
Linda Pagli
Giuseppe Prencipe



■ Conference Organization

Program Committee

Anna Bernasconi, U. Pisa, Italy
Allan Borodin, U. Toronto, Canada
Artur Czumaj, U. Warwick, UK
Erik Demaine, MIT, USA
David Eppstein, U. California Irvine, USA
Guy Even, Tel-Aviv University, Israel
Michele Flammini, GSSI & L'Aquila U., Italy
Rudolf Fleischer, GUtech, Oman
Paola Flocchini, Ottawa U., Canada
Fedor Fomin, U. Bergen, Norway
Naveen Garg, IIT Delhi, India
Fabrizio Grandoni, IDSIA Lugano, Switzerland
Takashi Horiyama, Saitama U., Japan
John Iacono, U. Libre Bruxelles, Belgium
Hiro Ito, UEC, Japan (co-chair)
Marc van Kreveld, Utrecht U., Netherlands
Stefan Langerman, U. Libre Bruxelles, Belgium
Stefano Leonardi, Sapienza U. Rome, Italy
(co-chair)
Anna Lubiw, U. Waterloo, Canada
Flaminia Luccio, Ca' Foscari U. Venice, Italy
S. Muthu Muthukrishnan, Rutgers U., USA
Yoshio Okamoto, UEC, Japan
Mike Paterson, U. Warwick, UK
David Peleg, Weizmann Inst. Sci., Israel
Nadia Pisanti, ERABLE Team INRIA & U.
Pisa, Italy
Geppino Pucci, U. Padova, Italy
Laura Sanità, U. Waterloo, Canada
Aravind Srinivasan, U. Maryland, College Park,
USA
Hideki Tsuiki, Kyoto U., Japan
Ryuhei Uehara, JAIST, Japan
Yushi Uno, Osaka Prefecture U., Japan
Aaron Williams, Bard College at Simon's Rock,
USA

Steering Committee

Erik Demaine, MIT, USA
Fabrizio Grandoni, IDSIA, Switzerland
Linda Pagli, U. Pisa, Italy
Giuseppe Prencipe, U. Pisa, Italy
Nicola Santoro, Carleton U., Canada
Ugo Vaccaro, U. Salerno, Italy

Organizers

Linda Pagli, U. Pisa, Italy
Giuseppe Prencipe, U. Pisa, Italy
Atsuki Nagao, Ochanomizu U., Japan (web
manager)



■ External Reviewers

Afrouz Jabalameli
Akihiro Uejima
Akira Suzuki
Alessio Conte
Andrea Marino
Ben Sach
Claudio Gallicchio
Daniele Frigioni
Davide Bilò
Eyal Kushilevitz
Giovanni Viglietta
Jun Kawahara
Junichi Teruyama
Kazuhsia Seto
Kazuo Iwama
Konstantinos Georgiou
Luca Versari
Luciano Gualà
Pawel orSchmidt
Stefano Leucci
Suguru Tamaki
Tom van der Zanden
Waldo Gálvez
Ziv Scully



List of Authors

Adam Hesterberg
Massachusetts Institute of Technology
United States
achester@mit.edu

Danny Krizanc
Wesleyan University
United States
dkrizanc@wesleyan.edu

Alessandro Panconesi
Sapienza University of Rome
Italy
ale@di.uniroma1.it

David Eppstein
University of California, Irvine
United States
david.eppstein@gmail.com

Andreas Tönnis
Universidad de Chile
Chile
atoennis@uni-bonn.de

Davide Bilò
University of Sassari, Italy
Italy
davide.bilo@uniss.it

Andrés Cristi
Universidad de Chile
Chile
andres.cristi.e@gmail.com

Dorian Mazauric
INRIA
France
dorian.mazauric@inria.fr

Augustin Chaintreau
Columbia University
United States
augustin@cs.columbia.edu

Erik D. Demaine
Massachusetts Institute of Technology
United States
edemaine@mit.edu

Christine Markarian
University of Paderborn
Germany
chrissm@mail.uni-paderborn.de

Erik Metz
University of Maryland
United States
emetz1618@gmail.com

Chuzo Iwamoto
Hiroshima University
Japan
chuzo@hiroshima-u.ac.jp

Evangelos Kranakis
Carleton University Computer Science
Canada
kranakis@scs.carleton.ca

Clemens Thielen
University of Kaiserslautern
Germany
thielen@mathematik.uni-kl.de

Fábio Botler
Universidad de Valparaíso
Chile
fabio.botler@gmail.com

Daniel Smolyak
University of Maryland
United States
dsmolyak@gmail.com

Florian David Schwahn
University of Kaiserslautern
Germany
fschwahn@mathematik.uni-kl.de



Friedhelm Meyer Auf der Heide
Heinz Nixdorf Institute & Department of
Computer Science, University of Paderborn
Germany
fmadh@upb.de

Guangqi Cui
Montgomery Blair High School
United States
bestwillcui@gmail.com

Guido Proietti
Università L'Aquila, Italy and Istituto di Analisi
dei Sistemi ed Informatica, IASI-CNR, Roma
Italy
guido.proietti@univaq.it

Guillaume Ducoffe
ICI
Romania
guillaume.ducoffe@ici.ro

Hans L. Bodlaender
Utrecht University
Netherlands
H.L.Bodlaender@uu.nl

Heiko Hamann
University of Lübeck
Germany
hamann@iti.uni-luebeck.de

Hideaki Sone
Tohoku University
Japan
tm-paper+cardanysone@g-mail.tohoku-
university.jp

Isaac Grosof
Carnegie Mellon University
United States
isaacbg227@gmail.com

Jacob Prinz
University of Maryland
United States
jacobeliasprinz@gmail.com

Jan-Tobias Maurer
"Institut f"ur Informatik, Universit"at Giessen"
Germany
jan.t.maurer@math.uni-giessen.de

Jannik Dreier
LORIA, Université de Lorraine, INRIA, CNRS
France
jannik.dreier@loria.fr

Jaroslav Opatrny
Concordia University
Canada
opatrny@cs.concordia.ca

Jayson Lynch
Massachusetts Institute of Technology
United States
jaysonl@mit.edu

Jean-Claude Bermond
CNRS
France
jean-claude.Bermond@inria.fr

Jean-Guillaume Dumas
Université Grenoble Alpes
France
jean-guillaume.dumas@univ-grenoble-alpes.fr

Jeffrey Bosboom
Massachusetts Institute of Technology
United States
jbosboom@csail.mit.edu

John Dickerson
University of Maryland
United States
john@cs.umd.edu

Joshua Lockhart
University College London
United Kingdom
jlockhart06@qub.ac.uk

Jurek Czyzowicz
Université du Québec en Outaouais
Canada
jurek.czyzowicz@uqo.ca

Justin Kopinsky
Massachusetts Institute of Technology
United States
jkopin@mit.edu

Manuel Lafond
University of Ottawa
Canada
mlafond2@uOttawa.ca

Kazumasa Shinagawa
Tokyo Institute of Technology, AIST
Japan
shinagawa.k.aa@m.titech.ac.jp

Markus Holzer
Institut für Informatik, Universität Giessen
Germany
holzer@informatik.uni-giessen.de

Kei Kimura
Toyohashi University of Technology
Japan
kimura@cs.tut.ac.jp

Masashi Kiyomi
Yokohama City University
Japan
masashi@yokohama-cu.ac.jp

Kevin Schewior
Universidad de Chile
Chile
kschewior@gmail.com

Masato Haruishi
Hiroshima University
Japan

Konstantinos Georgiou
Ryerson University
Canada
konstantinos@ryerson.ca

Matteo Almanza
Sapienza University of Rome
Italy
matteojug@gmail.com

Lata Narayanan
Concordia University
Canada
lata@cs.concordia.ca

Mehdi Khosravian Ghadikolaei
LAMSADE, Université Paris Dauphine
France
m.khosravian@gmail.com

Leonid Sedov
Linkoping University
Sweden
leo@gmail.com

Michael Coulombe
MIT
United States
mcoulomb@mit.edu

Linus Hamilton
Massachusetts Institute of Technology
United States
linyks@gmail.com

Michael Lampis
LAMSADE, Université Paris Dauphine
France
michail.lampis@dauphine.fr

Luciano Gualà
Dipartimento di Matematica, Università di Tor Vergata, Roma
Italy
guala@mat.uniroma2.it

Mikhail Rudoy
Massachusetts Institute of Technology
United States
mrudoy@gmail.com

Mirko Rossi
University of Rome Tor Vergata
Italy
r.mirko25@gmail.com

0:xviii Authors

Mostafa Wahby
University of Lübeck
Germany
wahby@iti.uni-luebeck.de

Ruben Hoeksma
Universität Bremen
Germany
hoeksma@uni-bremen.de

Naoki Kitamura
Nagoya Institute of Technology
Japan
ktmr522@yahoo.co.jp

Ryan Killick
Carleton University
Canada
RyanKillick@cmail.carleton.ca

Naveen Durvasula
Montgomery Blair High School
United States
140.naveen.d@gmail.com

Sebastiano Vigna
University of Milan
Italy
sebastiano.vigna@unimi.it

Naveen Raman
Richard Montgomery High School
United States
nav.j.raman@gmail.com

Stefano Leucci
ETH Zurich
Italy
stefano.leucci@inf.ethz.ch

Neeldhara Misra
Indian Institute of Technology, Gandhinagar
India
mail@neeldhara.com

Sung Hyun Yoo
Bergen County Academies
United States
sunnyyoo812@gmail.com

Paolo Boldi
University of Milan
Italy
paolo.boldi@unimi.it

Sunil Shende
Rutgers University
United States
sunil.shende@rutgers.edu

Pascal Lafourcade
LIMOS, University Clermont Auvergne
France
pascal.lafourcade@udamail.fr

Taisuke Izumi
Nagoya Institute of Technology
Japan
t-izumi@nitech.ac.jp

Petra Wolf
University of Tübingen
Germany
wolfp@informatik.uni-tuebingen.de

Takaaki Mizuki
Tohoku University
Japan
mizuki@cc.tohoku.ac.jp

Rémy Belmonte
The University of Electro-Communications
Japan
remybelmonte@gmail.com

Takuya Kamehashi
Toyohashi University of Technology
Japan
kamehashi@algo.cs.tut.ac.jp

Ronald de Haan
University of Amsterdam
Netherlands
me@ronalddehaan.eu

Tami Tamir
The Interdisciplinary Center
Israel
tami@idc.ac.il

Tatsuaki Ibusuki
Hiroshima University
Japan

Tatsuya Sasaki
Tohoku University
Japan
tatsuya.sasaki.p2@dc.tohoku.ac.jp

Tom van der Zanden
Utrecht University
Netherlands
T.C.vanderZanden@uu.nl

Toshihiro Fujito
Toyohashi University of Technology
Japan
fujito@cs.tut.ac.jp

Valentin Polishchuk
Linkoping University
Sweden
valentin.polishchuk@liu.se

William Gasarch
University of Maryland
United States
gasarch@cs.umd.edu

Xavier Bultel
Université d'Auvergne
France
xavier.bultel@udamail.fr

Yota Otachi
Kumamoto University
Japan
otachi@cs.kumamoto-u.ac.jp

Yuya Kawabata
Nagoya Institute of Technology
Japan
29414043@stn.nitech.ac.jp

Zachary Abel
Massachusetts Institute of Technology
United States
zabel@math.mit.edu

