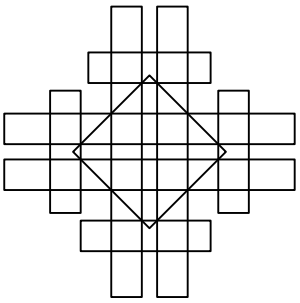
34th International Symposium on Computational Geometry

SoCG 2018, June 11–14, 2018, Budapest, Hungary

Edited by

Bettina Speckmann

Csaba D. Tóth



LIPICS

Editors

Bettina Speckmann	Csaba D. Tóth
TU Eindhoven	Cal State Northridge
Eindhoven	Los Angeles, CA
The Netherlands	USA
b.speckmann@tue.nl	csaba.toth@csun.edu

ACM Classification 2012
Theory of computation → Computational geometry, Mathematics of computing → Combinatorics, Theory of computation → Design and analysis of algorithms

ISBN 978-3-95977-066-8

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/978-3-95977-066-8.

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.

Digital Object Identifier: 10.4230/LIPIcs.SoCG.2018.0

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.

ISSN 1868-8969

http://www.dagstuhl.de/lipics

Contents

Papers

34th International Symposium on Computational Geometry (SoCG 2018).
Editors: Bettina Speckmann and Csaba D. Tóth
Leibniz International Proceedings in Informatics
LIPICS Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

Multimedia Exposition

Foreword

The 34th International Symposium on Computational Geometry (SoCG) will be held in Budapest, Hungary, June 11–14, 2018, as part of the Computational Geometry Week. A record number of 206 papers have been submitted to SoCG 2018. After a thorough review process, in which each paper has been evaluated by three or more independent reviewers, the Program Committee accepted 73 papers for presentation at SoCG. These proceedings contain extended abstracts of the accepted papers, limited to 13 pages plus references. If any supporting material (e.g., proofs or experimental details) does not fit in the page limit, the full paper is available at a public repository, which is referenced in the extended abstract.

The Best Paper Award goes to the paper "Shellability is NP-complete" by Xavier Goaoc, Pavel Paták, Zuzana Patáková, Martin Tancer, and Uli Wagner. The Best Student Presentation Award will be determined and announced at the symposium, based on ballots cast by the attendees.

A selection of papers, recommended by the Program Committee, have been invited to forthcoming special issues of *Discrete & Computational Geometry* and the *Journal of Computational Geometry*, dedicated to the best papers of the symposium.

In addition to the technical papers, there were five submissions to the multimedia exposition (three videos and two applets). All five were reviewed and four were accepted for presentation. The extended abstracts that describe these submissions are included in this proceedings volume. The multimedia content can be found at `http://www.computational-geometry.org`.

We thank the authors of all submitted papers and multimedia presentations. We are grateful to the members of the SoCG Program Committee, the Multimedia Committee, and 340 additional reviewers for their dedication and expertise that ensure the high quality of the papers in these proceedings. We would also like to thank the Proceedings Chair, Wouter Meulemans, for his meticulous work preparing the final proceedings. Many other people contributed to the success of SoCG 2018 and the entire CG Week. We especially thank the local organizers, all members of the Workshop and YRF Committees, and the Computational Geometry Steering Committee.

Bettina Speckmann
Program Committee, co-chair
TU Eindhoven

Csaba D. Tóth
Program Committee, co-chair
Cal State Northridge

Xavier Goaoc
Multimedia Committee, chair
Université Paris-Est Marne-la-Vallée

34th International Symposium on Computational Geometry (SoCG 2018).
Editors: Bettina Speckmann and Csaba D. Tóth
Leibniz International Proceedings in Informatics
LIPICS Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

Conference Organization

SoCG Program Committee

Luis Barba *(ETH Zürich, Switzerland)*
Pavle V.M. Blagojević *(FU Berlin, Germany, and Mathematical Institute of SASA, Serbia)*
Karl Bringmann *(Max-Planck-Institut für Informatik, Germany)*
Siu-Wing Cheng *(Hong Kong University of Science and Technology, China)*
Khaled Elbassioni *(Masdar Institute, United Arab Emirates)*
Jeff Erickson *(University of Illinois at Urbana-Champaign, USA)*
Fabrizio Frati *(Roma Tre University, Italy)*
Jie Gao *(Stony Brook University, USA)*
Andreas Holmsen *(KAIST, Republic of South Korea)*
Minghui Jiang *(Utah State University, USA)*
Michael Kerber *(TU Graz, Austria)*
David Mount *(University of Maryland, USA)*
Elizabeth Munch *(Michigan State University, USA)*
Steve Oudot *(INRIA Saclay, France)*
Dömötör Pálvölgyi *(Eötvös Loránd University, Hungary)*
Benjamin Raichel (*University of Texas at Dallas, USA)*
Orit E. Raz *(University of British Columbia, Canada)*
Bettina Speckmann *(co-chair, TU Eindhoven, the Netherlands)*
Andrew Suk *(University of California, San Diego, USA)*
Csaba D. Tóth *(co-chair, California State University Northridge and Tufts University, USA)*
Shira Zerbib *(University of Michigan and MSRI, USA)*

SoCG Proceedings Chair

Wouter Meulemans *(TU Eindhoven, the Netherlands)*

Multimedia Program Committee

Satyan Devadoss *(University of San Diego, USA)*
Anne Driemel *(TU Eindhoven, the Netherlands)*
Xavier Goaoc *(chair, Université Paris-Est Marne-la-Vallée, France)*
Francis Lazarus *(CNRS, France)*
Mira Shalah *(Stanford University, USA)*
Frank Staals *(Utrecht University, the Netherlands)*
Ileana Streinu *(Smith College, USA)*

Workshop Program Committee

Maarten Löffler *(Utrecht University, the Netherlands)*
Brittany Terese Fasy *(Montana State University, USA)*
Suresh Venkatasubramanian *(University of Utah, USA)*
Carola Wenk *(chair, Tulane University, USA)*

34th International Symposium on Computational Geometry (SoCG 2018).
Editors: Bettina Speckmann and Csaba D. Tóth
Leibniz International Proceedings in Informatics
LIPICS Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

Young Researchers Forum Program Committee

Peyman Afshani *(Aarhus University, Denmark)*
Chao Chen *(CUNY Queens College, USA)*
Elena Khramtcova *(Université Libre de Bruxelles, Belgium)*
Irina Kostitsyna *(TU Eindhoven, the Netherlands)*
Jon Lenchner *(IBM Research, Africa, USA)*
Nabil Mustafa *(ESIEE Paris, France)*
Amir Nayyeri *(Oregon State University, USA)*
Don Sheehy *(chair, University of Connecticut, USA)*
Haitao Wang *(Utah State University, USA)*
Yusu Wang *(The Ohio State University, USA)*

Local Organizing Committee

Imre Bárány *(Rényi Institute of Mathematics, Hungary, and University College London, UK)*
Balázs Keszegh *(Rényi Institute of Mathematics, Hungary)*
Dezső Miklós *(Rényi Institute of Mathematics, Hungary)*
Márton Naszódi *(Eötvös Loránd University, Hungary)*
János Pach *(chair, Rényi Institute of Mathematics, Hungary, and EPFL, Switzerland)*
Dömötör Pálvölgyi *(Eötvös Loránd University, Hungary)*
Géza Tóth *(Rényi Institute of Mathematics, Hungary)*

Steering Committee (2016-)

Erin Chambers *(Saint Louis University, USA)*
Dan Halperin *(secretary, Tel Aviv University, Israel)*
Marc van Kreveld *(Utrecht University, the Netherlands)*
Joseph S. B. Mitchell *(treasurer, Stony Brook University, USA)*
David Mount *(University of Maryland, USA)*
Monique Teillaud *(chair, INRIA Nancy – Grand Est, France)*

Additional Reviewers

Mohammad Ali Abam
Amir Abboud
Ahmed Abdelkader
Mikkel Abrahamsen
Aditya Acharya
Eyal Ackerman
Michal Adamaszek
Henry Adams
Peyman Afshani
Hee-Kap Ahn
Oswin Aichholzer
Hugo Akitaya
Alexandr Andoni
Patrizio Angelini
Boris Aronov
Sunil Arya
Sergey Avvakumov
Sang Won Bae
Martin Balko
Sayan Bandyapadhyay
Bahareh Banyassady
Jérémy Barbay
Danielle Barnes
Yair Bartal
Abdul Basit
Ulrich Bauer
Michael Bekos
Ioana Bercea
Sergey Bereg
Mark de Berg
Nicolas Berkouk
Therese Biedl
Ahmad Biniaz
Christopher Bishop
Thomas Bläsius
Jean-Daniel Boissonnat
Nicolas Bonichon
Édouard Bonnet
Prosenjit Bose
Magnus Botnan
Cornelius Brand
Mickaël Buchet
Kevin Buchin
Maike Buchin
Boris Bukh
Sergiy Butenko
Sergio Cabello
Mathieu Carrière
Michael Catanzaro
Parinya Chalermsook
Erin Chambers
T.-H. Hubert Chan
Timothy M. Chan
Hsien-Chih Chang
Yi-Jun Chang
John Chaussard
Frédéeric Chazal
Chao Chen
Otfried Cheong
Markus Chimani
Aruni Choudhary
Jérémy Cochoy
Vincent Cohen-Addad
David Cohen-Steiner
René Corbet
Bruno Courcelle
Justin Curry
Guilherme D. Da Fonseca
Giordano Da Lozzo
Gábor Damásdi
Philip Dasler
Jean-Lou De Carufel
Olivier Devillers
Hu Ding
Jiaxin Ding
Vincent Divol
Paweł Dłotko
Michael Gene Dobbins
Anne Driemel
Adrian Dumitrescu
Herbert Edelsbrunner
David Eisenstat
Marek Elias
Ioannis Emiris
Alina Ene
David Eppstein
Esther Ezra
Sándor Fekete
Dan Feldman
Stefan Felsner
Alejandro Flores Velazco
Steven Fortune
Kyle Fox
Dirk Frettlöh
Florian Frick
Sorelle Friedler
Ulderico Fugacci
Radoslav Fulek
Bernd Gärtner
Ellen Gasparovic
Daniel Gerbner
Robert Ghrist
Panos Giannopoulos
Anna Gilbert
Chad Giusti
Marc Glisse
Xavier Goaoc
Chaim Goodman-Strauss
Lee-Ad Gottlieb
Sathish Govindarajan
Kasper Green Larsen
Martin Gronemann
Anupam Gupta
Dan Halperin
Sariel Har-Peled
David Harris
Meng He
Martin Henk
Greg Henselman
John Hershberger
Darryl Hill
Michael Hoffmann
Ivor Hoog V.D.
Ingrid Hotz
Tamas Hubai
Alfredo Hubard
R. Inkulu
Martin Jaggi
Bruno Jartoux
Slobodan Jelić
Ross J. Kang
Iyad Kanj

34th International Symposium on Computational Geometry (SoCG 2018).
Editors: Bettina Speckmann and Csaba D. Tóth
Leibniz International Proceedings in Informatics
LIPICS Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

Haim Kaplan
Roman Karasev
Matthew Katz
Ken-Ichi Kawarabayashi
Mark Keil
Chaya Keller
Balázs Keszegh
Ralph Keusch
Elena Khramtcova
Minki Kim
Guy Kindler
David Kirkpatrick
Sándor Kisfaludi-Bak
Steven Klee
Michal Kleinbort
Matias Korman
Dániel Korándi
Miroslav Kramar
Marc van Kreveld
Sebastian Krinninger
Slava Krushkal
Nirman Kumar
Piyush Kumar
Marvin Künnemann
Andrey Kupavskii
Vitaliy Kurlin
O-Joung Kwon
Jan Kynčl
Jean-Philippe Labbé
Theo Lacombe
Zsolt Lángi
Seunghun Lee
Erik Jan van Leeuwen
Johannes Lengler
Michael Lesnick
David Letscher
Rachel Levanger
Christos Levcopoulos
Bernard Lidicky
Patrick Lin
Chih-Hung Liu
Anna Lubiw
Ben Lund
Alexander Magazinov
Johann Makowsky
Yuchen Mao
Vasileios Maroulas
Leonardo Martínez-Sandoval
Domagoj Matijević
Tyler Mayer
Gregory McColm
Ali Mehrabi
Arnaud de Mesmay
Abhishek Methuku
Frédéric Meunier
Tamás Mezei
Samuel Micka
Tillmann Miltzow
Mojgan Mirzaei
Majid Mirzanezhad
Joseph S. B. Mitchell
Dylan Molho
Debajyoti Mondal
Fabrizio Montecchiani
Shay Moran
Pat Morin
Dmitriy Morozov
Shay Mozes
Wolfgang Mülzer
Nabil Mustafa
Zoltán Nagy
Waleed Najy
Márton Naszódi
Amir Nayyeri
Ofer Neiman
Yakov Nekrich
Eran Nevo
Trung Thanh Nguyen
Arnur Nigmetov
Gabriel Nivasch
Jerri Nummenpalo
André Nusser
Joseph O'Rourke
Eunjin Oh
Yoshio Okamoto
Aurélien Ooms
Tim Ophelders
Arnau Padrol
Rasmus Pagh
Gaiane Panina
Evanthia Papadopoulou
Dimitris Papailiopoulos
Amit Patel
Maurizio Patrignani
Pavel Paták
Zuzana Patáková
Michael Pelsmajer
Richard Peng
Jose Perea
Ljubomir Perkovic
Thang Pham
Jeff Phillips
Alexander Pilz
Rom Pinchasi
Cosmin Pohoata
Alexey Pokrovskiy
Marc Pouget
Lionel Pournin
Eric Price
Siddharth Pritam
Kent Quanrud
Sharath Raghvendra
Rajiv Raman
Bhaskar Ray Chaudhury
Saurabh Ray
Ilya Razenshteyn
André van Renssen
Bruce Richter
Vanessa Robins
Liam Roditty
Marcel Roeloffzen
Edgardo Roldan-Pensado
Vincenzo Roselli
Günter Rote
Alan Roytman
Natan Rubin
Ignaz Rutter
Yogish Sabharwal
Michael Sagraloff
Gelasio Salazar
Francisco Santos
Rik Sarkar
Radmila Sazdanovic
Marcus Schaefer
Jean-Marc Schlenker
Christiane Schmidt
Patrick Schnider
Hannah Schreiber
Matthias Schymura
Don Sheehy
Adam Sheffer
Thomas Shermer
Jonathan Shewchuk
Ilya Shkredov

Anastasios Sidiropoulos
Vin de Silva
Francesco Silvestri
René Sitters
Arkadiy Skopenkov
Mikhail Skopenkov
Primoz Skraba
Michiel Smid
Shakhar Smorodinsky
Pablo Soberon
Israela Solomon
Kiril Solovey
Jonathan Spreer
Frank Staals
Frank van der Stappen
Daniel Štefankovič
Anastasios Stefanou
Miloš Stojaković
Darren Strash
Christopher Sukhu
He Sun
Shuhao Tan
Martin Tancer
Raphael Tinarrage
Hans Raj Tiwary
István Tomon
Christopher Tralie
Konstantinos Tsakalidis
Katharine Turner
Géza Tóth
Torsten Ueckerdt
Jérôme Urhausen
Greg Van Buskirk
Kasturi Varadarajan
Mikael Vejdemo-Johansson
Kevin Verbeek
Sander Verdonschot
Antoine Vigneron
Máté Vizer
Hubert Wagner
Uli Wagner
Bartosz Walczak
Haitao Wang
Shiyu Wang
Weifu Wang
Yusu Wang
Oren Weimann
Shmuel Weinberger
Rene Weller
Mathijs Wintraecken
Ching Wong
Matthew Wright
Christian Wulff-Nilsen
Ge Xia
Jinhui Xu
Ke Yi
Fang-Yi Yu
Jingjin Yu
Yelena Yuditsky
Joshua Zahl
Alireza Zarei
Frank de Zeeuw
Meirav Zehavi
Ahad N. Zehmakan

Acknowledgement of Support

We are grateful to Rényi Institute of Mathematics for hosting and sponsoring CG Week 2018, and to the Hungarian Academy of Sciences (MTA) and the National Science Foundation (NSF) for their support.

34th International Symposium on Computational Geometry (SoCG 2018).
Editors: Bettina Speckmann and Csaba D. Tóth
Leibniz International Proceedings in Informatics
LIPICS Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

Invited Talk

Stories Are Not Just Words: How Visualization Helps Us to Explain, Reason, Explore and Remember

Jo Wood
giCentre
City, University of London
United Kingdom

Abstract

From Euclid's *Elements* and Liu Hui's *The Sea Island Mathematical Manual* through Decartes and Euler to Mandlebrot and Wolfram, we have always used images to assist telling stories about geometry. The long history of *proof without words* demonstrates that images alone can sometimes tell convincing mathematical stories. In a parallel history we have for millennia used careful geometric projection onto a plane to tell cartographic stories of discoveries made, lands yet visited and battles to be fought. In this talk I explore some of the examples and theory of storytelling using visualization and cartography in order to evaluate whether computational geometers have anything to gain through visual storytelling and whether some problems that persist in visual storytelling might be solvable by computational geometers.

I explore the coupling of textual narrative and visualization to support explanation and reasoning as well as more open-ended exploration by considering the *literate programming* approach advocated by Donald Knuth, the *computational essays* of Stephen Wolfram and the newly emerging paradigm of *literate visualization*. These are most readily seen in notebook environments of data science such as *R-Notebook*, *Jupyter Lab* and most recently *Observable*. I illustrate literate visualization with examples from these environments as well as one newly developed by the giCentre – *litvis*. I argue that visual approaches to computation are valuable as they support a shift from a dialogue between person and computer to one between people.

2012 ACM Subject Classification Human-centered computing → Information visualization

Keywords and phrases Literate visualization, geovisualization, storytelling, literate programming

34th International Symposium on Computational Geometry (SoCG 2018).
Editors: Bettina Speckmann and Csaba D. Tóth

Leibniz International Proceedings in Informatics
Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

Invited Talk
Circle Squaring and Other Combinatorial Problems in Geometric Measure Theory

András Máthé
Mathematics Institute
University of Warwick
Coventry, United Kingdom

Abstract

I will survey some results and open problems in geometric measure theory of combinatorial flavour.

The famous Banach-Tarski paradox states that in the three dimensional space a ball of radius one can be partitioned into finitely many (non-measurable) pieces that can be rearranged (applying rotations and translations) to obtain a ball of radius 2. On the other hand, Tarski's circle squaring problem asked if it was possible to partition a disc in the plane into finitely many pieces and rearrange these to obtain the square (of the same area). This was shown to be possible by Laczkovich in 1990. I will talk about the recent results that show that this "circle squaring" is possible by using pieces that are Lebesgue measurable, or even Borel (by Marks and Unger).

I will also mention some results and questions about patterns in fractal sets and a problem about the fractal analogue of the Szemerédi-Trotter theorem of point-line incidences.

2012 ACM Subject Classification Mathematics of computing → Mathematical analysis, Mathematics of computing → Matchings and factors, Mathematics of computing → Graph algorithms

Keywords and phrases circle squaring, equidecompositions, fractals, point-line incidences

34th International Symposium on Computational Geometry (SoCG 2018).
Editors: Bettina Speckmann and Csaba D. Tóth


Leibniz International Proceedings in Informatics
Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany