

Commenced Publication in 1973

Founding and Former Series Editors:

Gerhard Goos, Juris Hartmanis, and Jan van Leeuwen

Editorial Board

David Hutchison

Lancaster University, Lancaster, UK

Takeo Kanade

Carnegie Mellon University, Pittsburgh, PA, USA

Josef Kittler

University of Surrey, Guildford, UK

Jon M. Kleinberg

Cornell University, Ithaca, NY, USA

Friedemann Mattern

ETH Zurich, Zürich, Switzerland

John C. Mitchell

Stanford University, Stanford, CA, USA

Moni Naor

Weizmann Institute of Science, Rehovot, Israel

C. Pandu Rangan

Indian Institute of Technology, Madras, India

Bernhard Steffen

TU Dortmund University, Dortmund, Germany

Demetri Terzopoulos

University of California, Los Angeles, CA, USA

Doug Tygar

University of California, Berkeley, CA, USA

Gerhard Weikum

Max Planck Institute for Informatics, Saarbrücken, Germany

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

Emilio Di Giacomo · Anna Lubiw (Eds.)

Graph Drawing and Network Visualization

23rd International Symposium, GD 2015
Los Angeles, CA, USA, September 24–26, 2015
Revised Selected Papers

Editors

Emilio Di Giacomo
Università degli Studi di Perugia
Perugia
Italy

Anna Lubiw
School of Computer Science
University of Waterloo
Waterloo, ON
Canada

ISSN 0302-9743 ISSN 1611-3349 (electronic)
Lecture Notes in Computer Science
ISBN 978-3-319-27260-3 ISBN 978-3-319-27261-0 (eBook)
DOI 10.1007/978-3-319-27261-0

Library of Congress Control Number: 2015955866

LNCS Sublibrary: SL1 – Theoretical Computer Science and General Issues

Springer Cham Heidelberg New York Dordrecht London

© Springer International Publishing Switzerland 2015

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.

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media
(www.springer.com)

Preface

This volume contains the papers presented at the 23rd International Symposium on Graph Drawing and Network Visualization (GD 2015), which took place September 24–26, 2015, in Los Angeles, California, USA. The conference was hosted by California State University at Northridge, with Csaba Tóth as chair of the Organizing Committee. A total of 86 participants from 12 countries attended the conference.

This year the symposium added “Network Visualization” to its name to better emphasize the focus of the conference both on the combinatorial and algorithmic aspects of graph drawing, and on the design of visualization systems and interfaces.

Paper submissions were divided into three tracks plus a poster track: Track 1 for combinatorial and algorithmic aspects; Track 2 for experimental, applied, and network visualization aspects; and Track 3 for shorter notes and demos. All tracks were handled by a single Program Committee. The total number of submissions was 77 papers and nine posters. At least three Program Committee members reviewed each submission and the Program Committee then accepted 42 papers and eight posters, for acceptance rates of 24/42 in Track 1, 11/22 in Track 2, 7/13 in Track 3, and 8/9 posters. In addition to the papers, these proceedings include a two-page description of each poster.

GD 2015 was preceded by a two-day graduate workshop on “Recent Trends in Graph Drawing: Curves, Graphs, and Intersections.” A report about the workshop is included in the proceedings.

There were two invited talks at GD 2015. Herbert Edelsbrunner of the Institute of Science and Technology, Austria, talked about “Shape, Homology, Persistence, and Stability.” Kwan-Liu Ma of the University of California at Davis, USA, talked about “Emerging Topics in Network Visualization.” Abstracts of both talks are included in these proceedings.

Springer sponsored awards for best paper in each of Track 1 and Track 2, plus a best presentation award and a best poster award. The Program Committee voted to give the best paper award in Track 1 to “Drawing Graphs Using a Small Number of Obstacles,” by M. Balko, J. Cibulka, and P. Valtr, and in Track 2 to “An Incremental Layout Method for Visualizing Online Dynamic Graphs,” by T. Crnovrsanin, J. Chu, and K.-L. Ma. The participants of the conference voted to give the best presentation award to M. Löffler for his presentation of the paper “Realization of Simply Connected Polygonal Linkages and Recognition of Unit Disk Contact Trees” and the best poster award to P. Angelini, G. Da Lozzo, G. Di Battista, F. Frati, M. Patrignani, and I. Rutter for their poster entitled “On the Relationship Between Map Graphs and Clique Planar Graphs.”

Following tradition, the 22nd Annual Graph Drawing Contest was held during the conference. The contest had two parts, each with two categories: Creative Topics (Graph Classes and Tic Tac Toe) and Live Challenge (Automatic Category and Manual Category). Awards were made in each of the four categories. A report about the contest is included in the proceedings.

Many people and organizations contributed to the success of GD 2015. We thank the Program Committee members and the additional reviewers for carefully reviewing the submitted papers and posters and for putting together a strong and interesting program. Thanks to all the authors for choosing GD 2015 as the publication venue for their research.

We warmly thank the Organizing Committee, Bernardo Ábrego, Silvia Fernández-Merchant, Csaba Tóth, and all the volunteers from the California State University at Northridge, who put a lot of time and effort into the organization of GD 2015. This year's Contest Committee was chaired by Maarten Löffler, Utrecht University. We thank the committee for preparing interesting and challenging problems.

GD 2015 thanks its sponsors, "diamond" sponsor California State University at Northridge, "gold" sponsors Tom Sawyer Software and yWorks, "silver" sponsor Microsoft, and "bronze" sponsor Springer. Their generous support helps ensure the continued success of this conference.

The 24th International Symposium on Graph Drawing and Network Visualization (GD 2016) will take place September 19–21, 2016, in Athens, Greece. Yifan Hu and Martin Nöllenberg will co-chair the Program Committee, and Antonios Symvonis will chair the Organizing Committee.

October 2015

Emilio Di Giacomo
Anna Lubiw

Organization

Program Committee

| | |
|---------------------------------|---|
| Carla Binucci | University of Perugia, Italy |
| Prosenjit Bose | Carleton University, Canada |
| Giuseppe Di Battista | Roma Tre University, Italy |
| Emilio Di Giacomo (Co-chair) | University of Perugia, Italy |
| Vida Dujmović | University of Ottawa, Canada |
| Tim Dwyer | Monash University, Australia |
| Fabrizio Frati | Roma Tre University, Italy |
| Michael Goodrich | University of California, Irvine, USA |
| Nathalie Henry Riche | Microsoft Research, USA |
| Yifan Hu | Yahoo Labs, USA |
| Michael Kaufmann | University of Tübingen, Germany |
| Andreas Kerren | Linnaeus University, Sweden |
| Anna Lubiw (Co-chair) | University of Waterloo, Canada |
| Tamara Munzner | University of British Columbia, Canada |
| Stephen North | Infovisible LLC, USA |
| Martin Nöllenburg | Karlsruhe Institute of Technology, Germany |
| Yoshio Okamoto | University of Electro-Communications, Japan |
| Ignaz Rutter | Karlsruhe Institute of Technology, Germany |
| Maria Saumell | University of West Bohemia, Czech Republic |
| Marcus Schaefer | DePaul University, USA |
| Heidrun Schumann | University of Rostock, Germany |
| Geza Toth | Rényi Institute, Hungary |
| Jarke van Wijk | Eindhoven University of Technology, The Netherlands |
| Alexander Wolff | University of Würzburg, Germany |

Organizing Committee

| | |
|---------------------------|--|
| Bernardo Ábrego | California State University at Northridge, USA |
| Silvia Fernández-Merchant | California State University at Northridge, USA |
| Csaba D. Tóth (Chair) | California State University at Northridge, USA |

Graph Drawing Contest Committee

| | |
|-------------------------|--|
| Philipp Kindermann | University of Würzburg, Germany |
| Maarten Löffler (Chair) | Utrecht University, The Netherlands |
| Lev Nachmanson | Microsoft Research, USA |
| Ignaz Rutter | Karlsruhe Institute of Technology, Germany |

Additional Reviewers

Aichholzer, Oswin
Angelini, Patrizio
Bekos, Michael
Bläsius, Thomas
Bruckdorfer, Till
Da Lozzo, Giordano
Di Bartolomeo, Marco
Di Donato, Valentino
Didimo, Walter
van Dijk, Thomas C.
Feng, Wendy
Fink, Martin
Fulek, Radoslav
Gansner, Emden
Grilli, Luca
Hasunuma, Toru
Hernandez, Gregorio
Kainen, Paul
Khoury, Marc
Kieffer, Steven
Kindermann, Philipp
Klein, Karsten
Kleist, Linda
Kobourov, Stephen
Kucher, Kostiantyn
Kusters, Vincent
Lee, Bongshin
Lipp, Fabian
Liu, Qingsong
Löffler, Maarten
Mchedlidze, Tamara
Mondal, Debajyoti

Montecchiani, Fabrizio
Morin, Pat
Nayyeri, Amir
Niedermann, Benjamin
Ozeki, Kenta
Park, Ji-Won
Patrignani, Maurizio
Pizzonia, Maurizio
Prutkin, Roman
Radermacher, Marcel
Raftopoulou, Chrysanthi
Richter, Bruce
Roselli, Vincenzo
Schreiber, Falk
Sheffer, Adam
Shermer, Thomas
Shi, Conglei
Smorodinsky, Shakhar
Song, Qi
Spisla, Christiane
Strash, Darren
Ueckerdt, Torsten
van den Elzen, Stef
van Renssen, Andr
Verbeek, Kevin
Vesonder, Gregg
Yamanaka, Katsuhisa
Yang, Yalong
Yoghourdjian, Vahan
Zielke, Christian
Zimmer, Björn

Sponsors

Diamond Sponsor



Gold Sponsors



Silver Sponsor



Bronze Sponsor



Invited Talks

Shape, Homology, Persistence, and Stability

Herbert Edelsbrunner

Institute of Science and Technology, Austria

Abstract. My personal journey to the fascinating world of geometric forms started more than 30 years ago with the invention of alpha shapes in the plane. It took about 10 years before we generalized the concept to higher dimensions, we produced working software with a graphics interface for the three-dimensional case. At the same time, we added homology to the computations. Needless to say that this foreshadowed the inception of persistent homology, because it suggested the study of filtrations to capture the scale of a shape or data set. Importantly, this method has fast algorithms. The arguably most useful result on persistent homology is the stability of its diagrams under perturbations.

Emerging Topics in Network Visualization

Kwan-Liu Ma

University of California at Davis, USA

Abstract. Visualizing networks commonly found in a wide variety of applications, such as bioinformatics, computer security, social networks, telecommunication, transportation systems, etc., can lead to important insights. While visualizing small, static networks is relatively easy to do, larger and more complex networks present many challenges. In particular, real-world network data are almost all time-varying, and effective techniques for visualizing and analyzing networks evolving over time are lacking. I will discuss emerging topics in network visualization using research results that my group has produced as examples.

Contents

Large and Dynamic Graphs

| | |
|---|----|
| GraphMaps: Browsing Large Graphs as Interactive Maps. | 3 |
| <i>Lev Nachmanson, Roman Prutkin, Bongshin Lee, Nathalie Henry Riche, Alexander E. Holroyd, and Xiaoji Chen</i> | |
| An Incremental Layout Method for Visualizing Online Dynamic Graphs | 16 |
| <i>Tarik Crnovrsanin, Jacqueline Chu, and Kwan-Liu Ma</i> | |
| Drawing Large Graphs by Multilevel Maxent-Stress Optimization. | 30 |
| <i>Henning Meyerhenke, Martin Nöllenburg, and Christian Schulz</i> | |
| A Million Edge Drawing for a Fistful of Dollars. | 44 |
| <i>Alessio Arleo, Walter Didimo, Giuseppe Liotta, and Fabrizio Montecchiani</i> | |
| Faster Force-Directed Graph Drawing with the Well-Separated Pair Decomposition | 52 |
| <i>Fabian Lipp, Alexander Wolff, and Johannes Zink</i> | |

Crossing Numbers

| | |
|--|----|
| The Degenerate Crossing Number and Higher-Genus Embeddings | 63 |
| <i>Marcus Schaefer and Daniel Štefankovič</i> | |
| On Degree Properties of Crossing-Critical Families of Graphs | 75 |
| <i>Drago Bokal, Mojca Bračič, Marek Derňár, and Petr Hliněný</i> | |
| Genus, Treewidth, and Local Crossing Number | 87 |
| <i>Vida Dujmović, David Eppstein, and David R. Wood</i> | |
| Hanani-Tutte for Radial Planarity | 99 |
| <i>Radoslav Fulek, Michael Pelsmajer, and Marcus Schaefer</i> | |

Experiments

| | |
|---|-----|
| Drawing Planar Cubic 3-Connected Graphs with Few Segments: Algorithms and Experiments. | 113 |
| <i>Alexander Igamberdiev, Wouter Meulemans, and André Schulz</i> | |
| The Book Embedding Problem from a SAT-Solving Perspective. | 125 |
| <i>Michael A. Bekos, Michael Kaufmann, and Christian Zielke</i> | |

| | |
|--|-----|
| Size- and Port-Aware Horizontal Node Coordinate Assignment. | 139 |
| <i>Ulf Rüegg, Christoph Daniel Schulze, John Julian Carstens, and Reinhard von Hanxleden</i> | |

Area, Bends, Crossings

| | |
|--|-----|
| Small-Area Orthogonal Drawings of 3-Connected Graphs | 153 |
| <i>Therese Biedl and Jens M. Schmidt</i> | |
| Simultaneous Embeddings with Few Bends and Crossings | 166 |
| <i>Fabrizio Frati, Michael Hoffmann, and Vincent Kusters</i> | |
| Rook-Drawing for Plane Graphs | 180 |
| <i>David Auber, Nicolas Bonichon, Paul Dorbec, and Claire Pennarun</i> | |
| On Minimizing Crossings in Storyline Visualizations. | 192 |
| <i>Irina Kostitsyna, Martin Nöllenburg, Valentin Polishchuk, André Schulz, and Darren Strash</i> | |
| Maximizing the Degree of (Geometric) Thickness- t Regular Graphs | 199 |
| <i>Christian A. Duncan</i> | |

Intersection Representations

| | |
|--|-----|
| On the Zarankiewicz Problem for Intersection Hypergraphs | 207 |
| <i>Nabil H. Mustafa and János Pach</i> | |
| Intersection-Link Representations of Graphs | 217 |
| <i>Patrizio Angelini, Giordano Da Lozzo, Giuseppe Di Battista, Fabrizio Frati, Maurizio Patrignani, and Ignaz Rutter</i> | |
| Combinatorial Properties of Triangle-Free Rectangle Arrangements and the Squarability Problem | 231 |
| <i>Jonathan Klawitter, Martin Nöllenburg, and Torsten Ueckerdt</i> | |

Applications

| | |
|--|-----|
| Displaying User Behavior in the Collaborative Graph Visualization System OnGraX | 247 |
| <i>Björn Zimmer and Andreas Kerren</i> | |
| Confluent Orthogonal Drawings of Syntax Diagrams | 260 |
| <i>Michael J. Bannister, David A. Brown, and David Eppstein</i> | |
| KOJAPH: Visual Definition and Exploration of Patterns in Graph Databases . . . | 272 |
| <i>Walter Didimo, Francesco Giacchè, and Fabrizio Montecchiani</i> | |

Drawings with Crossings

2-Layer Fan-Planarity: From Caterpillar to Stegosaurus 281
*Carla Binucci, Markus Chimani, Walter Didimo, Martin Gronemann,
 Karsten Klein, Jan Kratochvíl, Fabrizio Montecchiani,
 and Ioannis G. Tollis*

Recognizing and Drawing IC-Planar Graphs 295
*Franz J. Brandenburg, Walter Didimo, William S. Evans,
 Philipp Kindermann, Giuseppe Liotta, and Fabrizio Montecchiani*

Simple Realizability of Complete Abstract Topological Graphs Simplified . . . 309
Jan Kynčl

The Utility of Untangling 321
Vida Dujmović

Polygons and Convexity

Representing Directed Trees as Straight Skeletons 335
*Oswin Aichholzer, Therese Biedl, Thomas Hackl, Martin Held,
 Stefan Huber, Peter Palfrader, and Birgit Vogtenhuber*

Drawing Graphs with Vertices and Edges in Convex Position. 348
Ignacio García-Marco and Kolja Knauer

Drawing Graphs Using a Small Number of Obstacles 360
Martin Balko, Josef Cibulka, and Pavel Valtr

Vertical Visibility Among Parallel Polygons in Three Dimensions. 373
Radoslav Fulek and Rados Radoicic

Drawing Graphs on Point Sets

Alternating Paths and Cycles of Minimum Length. 383
William S. Evans, Giuseppe Liotta, Henk Meijer, and Stephen Wismath

On Embeddability of Buses in Point Sets 395
*Till Bruckdorfer, Michael Kaufmann, Stephen G. Kobourov,
 and Sergey Pupyrev*

A Universal Point Set for 2-Outerplanar Graphs 409
*Patrizio Angelini, Till Bruckdorfer, Michael Kaufmann,
 and Tamara Mchedlidze*

Linear-Size Universal Point Sets for One-Bend Drawings. 423
Maarten Löffler and Csaba D. Tóth

Contact Representations

Recognizing Weighted Disk Contact Graphs. 433
Boris Klemz, Martin Nöllenburg, and Roman Prutkin

Realization of Simply Connected Polygonal Linkages and Recognition
of Unit Disk Contact Trees. 447
*Clinton Bowen, Stephane Durocher, Maarten Löffler, Anika Rounds,
André Schulz, and Csaba D. Tóth*

Towards Characterizing Graphs with a Sliceable Rectangular Dual 460
Vincent Kusters and Bettina Speckmann

Pixel and Voxel Representations of Graphs 472
*Md. Jawaherul Alam, Thomas Bläsius, Ignaz Rutter, Torsten Ueckerdt,
and Alexander Wolff*

User Studies

A Tale of Two Communities: Assessing Homophily in Node-Link
Diagrams 489
Wouter Meulemans and André Schulz

Shape-Based Quality Metrics for Large Graph Visualization 502
Peter Eades, Seok-Hee Hong, Karsten Klein, and An Nguyen

On the Readability of Boundary Labeling 515
*Lukas Barth, Andreas Gemsa, Benjamin Niedermann,
and Martin Nöllenburg*

Graph Drawing Contest

Graph Drawing Contest Report. 531
*Philipp Kindermann, Maarten Löffler, Lev Nachmanson,
and Ignaz Rutter*

Graduate Workshop Report

Graduate Workshop Recent Trends in Graph Drawing: Curves, Graphs,
and Intersections 541
*Bernardo M. Ábrego, Silvia Fernández-Merchant,
and Csaba D. Tóth*

Posters

L-Visibility Drawings of IC-Planar Graphs 545
Giuseppe Liotta and Fabrizio Montecchiani

On the Relationship Between Map Graphs and Clique Planar Graphs 548
*Patrizio Angelini, Giordano Da Lozzo, Giuseppe Di Battista,
 Fabrizio Frati, Maurizio Patrignani, and Ignaz Rutter*

PED User Study 551
Till Bruckdorfer, Michael Kaufmann, and Simon Leibfle

SVEN: An Alternative Storyline Framework for Dynamic Graph
 Visualization 554
Dustin L. Arendt

Knuthian Drawings of Series-Parallel Flowcharts 556
Michael T. Goodrich, Timothy Johnson, and Manuel Torres

Gestalt Principles in Graph Drawing 558
Stephen G. Kobourov, Tamara Mchedlidze, and Laura Vonessen

Drawing Graphs Using Body Gestures. 561
Yeganeh Bahoo, Andrea Bunt, Stephane Durocher, and Sahar Mehrpour

Augmenting Planar Straight Line Graphs to 2-Edge-Connectivity 563
*Hugo Alves Akitaya, Jonathan Castello, Yauheniya Lahoda,
 Anika Rounds, and Csaba D. Tóth*

Author Index 565