## Lecture Notes in Computer Science

1027

Edited by G. Goos, J. Hartmanis and J. van Leeuwen

Advisory Board: W. Brauer D. Gries J. Stoer

# **Graph Drawing**

Symposium on Graph Drawing, GD '95 Passau, Germany, September 20-22, 1995 Proceedings



Series Editors

Gerhard Goos Universität Karlsruhe Vincenz-Priessnitz-Straße 3, D-76128 Karlsruhe, Germany

Juris Hartmanis
Department of Computer Science, Cornell University
4130 Upson Hall, Ithaca, NY 14853, USA

Jan van Leeuwen Department of Computer Science, Utrecht University Padualaan 14, 3584 CH Utrecht, The Netherlands

Volume Editor

Franz J. Brandenburg Lehrstuhl für Informatik, Universität Passau Innstraße 33, D-94030 Passau, Germany

Cataloging-in-Publication data applied for

#### Die Deutsche Bibliothek - CIP-Einheitsaufnahme

Graph drawing: proceedings / Symposium on Graph Drawing, GD '95, Passau Germany, September 20 - 22, 1995. Franz J. Brandenburg (ed.). - Berlin; Heidelberg; New York; Barcelona; Budapest; Hong Kong; London; Milan; Paris; Santa Clara; Singapore; Tokyo: Springer, 1995 (Lecture notes in computer science; Vol. 1027) ISBN 3-540-60723-4
NE: Brandenburg, Franz J. [Hrsg.]; GD <1995, Passau>; GT

CR Subject Classification (1991): G.2.2, F2.2, D.2.2, I.3.5, J.6, H.5.2 1991 Mathematics Subject Classification: 05Cxx, 68R10, 90C35, 94C15

ISBN 3-540-60723-4 Springer-Verlag Berlin Heidelberg New York

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, re-use of illustrations, recitation, broadcasting, reproduction on microfilms or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer-Verlag. Violations are liable for prosecution under the German Copyright Law.

© Springer-Verlag Berlin Heidelberg 1996 Printed in Germany

Typesetting: Camera-ready by author SPIN 10512376 06/3142 - 5 4 3 2 1 0 Printed on acid-free paper

#### **Preface**

Graph Drawing addresses the problem of visualizing structural information. More specifically, it is concerned with the construction of geometric representations of abstract graphs and networks. The automatic generation of drawings of graphs has important applications in key computer science technologies such as database design, software engineering, VLSI, network design, and visual interfaces, and also in engineering, production planning, chemistry, and biology. The range of issues being investigated in graph drawing includes algorithms, graph theory, order theory, graphic languages, applications, and practical systems. A great deal of research in graph drawing is motivated by applications to systems for viewing graphs and interacting with graphs. The interaction between theoretical advances and implemented solutions is an important part of the area of graph drawing.

Graph Drawing '95 (GD'95) was held in Passau, Germany, on September 20-22, 1995. It was preceded by the GD'94 DIMACS International Workshop in Princeton, USA (1994), the GD'93 ALCOM Workshop in Paris, France (1993), and the GD'92 Work Meeting in Rome, Italy (1992).

In response to the call for papers and demos for GD'95, the program committee received 88 submissions. Six submissions applied for both categories. This indicates the strong and growing interest in the area. All but six submissions were received electronically. Each submission was refereed and evaluated by at least four program committee members, or their referees, with six members on the average. The program committee made its final selection via email, from July 10 to 14. It selected 40 papers and 12 demos.

The technical program of GD'95 consisted of 12 sessions and included the presentation of all papers, all but two demonstrations, and a poster gallery with 8 poster displays. Also, in conjunction with GD'95, there was a graph-drawing contest with prizes awarded at the workshop. This volume contains the accepted papers and descriptions of the demos of GD'95, and a report on the graph-drawing contest.

GD'95 gathered 127 participants from 14 countries from all over the world, again with a significant presence of participants with industrial affiliations. The presentations of the papers and the demos were excellent. All presentations were attended by almost all participants with intensive discussions immediately afterwards. There was a stimulating atmosphere at GD'95.

We wish to thank the many people who contributed to the success of the symposium: all authors of submitted papers, demos, and posters, the program committee members, and their referees, and the organizers of the graph-drawing contest. We are grateful to the sponsors of GD'95, particularly to the Deutsche Forschungsgemeinschaft, and the Bayerische Staatsministerium für Unterricht, Kultus, Wissenschaft und Kunst for providing financial support to the symposium, and to the Universität Passau for offering the use of their facilities. This helped to keep the conference fees low. Special thanks go to the symposium secretaries Susanne Lenz and Renate Schönberger for their excellent settlement of the registration and local arrangements, and to Andreas Stübinger for a perfect handling of all submissions, notifications, and final papers as the GD'95 postmaster.

Passau, October 1995

Franz J. Brandenburg

#### Organizer:

Franz J. Brandenburg (University of Passau, Germany)

#### **Program Committee:**

Franz J. Brandenburg, chair (University of Passau, Germany)

Peter Eades (University of Newcastle, Australia)

Jürgen Ebert (University of Koblenz, Germany)

Michael Kaufmann (University of Tübingen, Germany)

Jan Kratochvíl (Charles University of Prague, Czech Republic)

Anna Lubiw (University of Waterloo, Canada)

Joe Marks (Mitsubishi Electric Research Labs., Cambridge, USA)

Kozo Sugiyama (Fujitsu Labs., Shizuoka, Japan)

Roberto Tamassia (Brown University, Providence, USA)

Ioannis G. Tollis (University of Texas at Dallas, USA)

#### **Graph-Drawing Contest Organizers:**

Peter Eades (University of Newcastle, Australia)

Joe Marks (Mitsubishi Electric Research Labs., Cambridge, USA)

#### **Local Arrangements:**

Susanne Lenz Renate Schönberger Franz J. Brandenburg

#### **Demo Arrangements:**

Fred Dichtl Frank Heyder Andreas Stübinger

### Supported by:

Universität Passau, Passau

Deutsche Forschungsgemeinschaft, Bonn

Bayerisches Staatsministerium für

Unterricht, Kultus, Wissenschaft und Kunst, München

Volksbank-Raiffeisenbank Passau-Freyung eG, Passau

SUN Microsystems GmbH, Grasbrunn

Bavaria Computer Systeme, Passau

AT&T Bell Laboratories, Murray Hill

Mitsubishi Electric Research Laboratories, Cambridge

Tom Sawyer Software, Berkeley

Silicon Graphics GmbH, Grasbrunn

Begegnungszentrum der Wissenschaft Schloß Neuburg, Neuburg

Fremdenverkehrsverein Passau, Passau

Buchhandlung Pustet, Passau

#### **Contents**

Quasi-Planar Graphs Have a Linear Number of Edges
Universal 3-Dimensional Visibility Representations for Graphs 8 H. Alt, M. Godau and S. Whitesides
KGB: A Customizable Graph Browser
Adocs: a Drawing System for Generic Combinatorial Structures 24 <i>F. Bertault</i>
New Lower Bounds for Orthogonal Graph Drawings
The Effect of Graph Layout on Inference from Social Network Data 40 <i>J. Blythe, C. McGrath and D. Krackhardt</i>
Drawing Nice Projections of Objects in Space
Optimal Algorithms to Embed Trees in a Point Set
An Experimental Comparison of Force-Directed and Randomized Graph Drawing Algorithms
On the Complexity of Recognizing Intersection and Touching Graphs of Disks
Fast Interactive 3-D Graph Visualization
GD-Workbench: A System for Prototyping and Testing Graph Drawing Algorithms 111 L. Buti, G. Di Battista, G. Liotta, E. Tassinari, F. Vargiu and L. Vismara
CABRI-Graph: A Tool for Research and Teaching in Graph Theory

fraph Folding: Extending Detail and Context Viewing into a Tool for Subgraph Comparisons	127
Upward Numbering Testing for Triconnected Graphs	140
On a Visibility Representation of Graphs	152
3D Graph Drawing with Simulated Annealing	162
The Botanical Beauty of Random Binary Trees	166
The Strength of Weak Proximity	178
COMAIDE: Information Visualization using Cooperative 3D Diagram Layout D. Dodson	190
Vertex Splitting and Tension-Free Layout	202
Drawing Stressed Planar Graphs in Three Dimensions	212
Graph-Drawing Contest Report	224
New Results on a Visibility Representation of Graphs in 3D	234
Generalized Fisheye Views of Graphs	242
Drawing High Degree Graphs with Low Bend Numbers U. Fößmeier and M. Kaufmann	254
The Drawing of Configurations	267

Upward Drawings on Planes and Spheres	277
Grid Embedding of 4-Connected Plane GraphsX. He	287
Recognizing Leveled-Planar Dags in Linear Time	300
Contact Graphs of Curves	312
On Representations of Some Thickness-Two Graphs	324
Drawing Force-Directed Graphs Using Optigraph	333
Exact and Heuristic Algorithms for 2-Layer Straightline Crossing Minimization	337
Constraint-Based Spring-Model Algorithm for Graph Layout T. Kamps, J. Kleinz and J. Read	349
Layout Algorithms of Graph-Like Diagrams for GRADE Windows Graphic Editors	361
Grid Intersection and Box Intersection Graphs on Surfaces  J. Kratochvíl and T. Przytycka	365
How to Draw Outerplanar Minimum Weight Triangulations	373
Portable Graph Layout and Editing	385
A Parallel Simulated Annealing Algorithm for Generating 3D Layouts of Undirected Graphs  B. Monien, F. Ramme and H. Salmen	396
Incremental Layout in DynaDAG	409
Issues in Interactive Orthogonal Graph Drawing	419

Automatic Drawing of Compound Digraphs for a Real-Time Power System Simulator	431
Validating Graph Drawing Aesthetics	435
A Fast Heuristic for Hierarchical Manhattan Layout	447
CLAX - A Visualized Compiler	459
Crossing Numbers of Meshes	463
Directed Graphs Drawing by Clan-Based Decomposition FS. Shieh and C.L. McCreary	472
TOSCANA Management System for Conceptual Data	483
Graph Layout Adjustment Strategies	487
A Generic Compound Graph Visualizer/Manipulator: D-ABDUCTOR	500
Generating Customized Layouts  X. Wang and I. Miyamoto	504
GOVE: Grammar-Oriented Visualisation Environment	516
SWAN: A Data Structure Visualization System	520
Author Index	525