

THE INTERNATIONAL JOURNAL OF THE EUROGRAPHICS ASSOCIATION

# COMPUTER GRAPHICS *forum*

VOLUME 41 NUMBER 1 FEBRUARY 2022



ISSN 0167-7055



delivered by  
**WILEY**  
**EUROGRAPHICS**  
**DIGITAL LIBRARY**  
www.eg.org diglib.eg.org

## EDITORIAL INFORMATION

### Editors

Bedrich Benes  
Professor of Computer Graphics Technology and Computer Science,  
Purdue University  
E-mail: bbenes@purdue.edu  
Web: <http://hpcg.purdue.edu/bbenes/>

Pierre Alliez  
Senior Research Scientist, Inria Sophia Antipolis – Méditerranée, France  
E-mail: pierre.alliez@inria.fr  
Web: <http://www-sop.inria.fr/members/Pierre.Alliez>

### Editorial Board

Wolfgang Aigner  
*St. Poelten University of Applied Sciences, Austria (2019–2022)*  
Michael Barton  
*Basque Center for Applied Mathematics, Spain (2019–2022)*  
Maximino Bessa  
*INESC TEC University of Porto, Portugal (2021–2024)*  
David Bommes  
*University of Bern, Switzerland (2019–2022)*  
Adrien Bousseau  
*Inria, France (2021–2024)*  
Martin Cadik  
*Brno University of Technology, Czech Republic (2019–2022)*  
Hamish Carr  
*University of Leeds, United Kingdom (2019–2022)*  
Angel Xuan Chang  
*Simon Fraser University, Canada (2021–2024)*  
Victor Chen  
*Purdue University, USA (2021–2024)*  
Julie Digne  
*LIRIS, France (2021–2024)*  
Jiri Filip  
*Institute of Information Theory and Automation, Czech Republic (2021–2024)*  
Hongbo Fu  
*City University Hong Kong, Hong Kong (2021–2024)*  
Eric Galin  
*CNRS, France (2019–2022)*  
Toshiya Hachisuka  
*Aarhus University, Denmark (2019–2022)*

Markus Hadwiger  
*King Abdullah University of Science and Technology, Saudi Arabia (2019–2022)*  
Ye Hing  
*Nanyang Technological University, Singapore (2019–2022)*  
Klaus Hildebrandt  
*TU Delft, Netherlands (2019–2022)*  
Jia-Bing Huang  
*Virginia Tech, USA (2021–2024)*  
Jin Huang  
*Zhejiang University, China (2019–2022)*  
Alec Jacobson  
*University of Toronto, Canada (2021–2024)*  
Andreas Kerren  
*Linnaeus University, Sweden (2019–2022)*  
Theodore Kim  
*Yale University, USA (2021–2024)*  
Paul Kry  
*McGill University, Canada (2021–2024)*  
Yukun Lai  
*Cardiff University, United Kingdom*  
Yebin Liu  
*Tsinghua University, China (2021–2024)*  
Rachel McDonnell  
*Trinity College Dublin, Ireland (2021–2024)*  
Pooran Memari  
*École Polytechnique, France (2021–2024)*  
Przemyslaw Musialski  
*New Jersey Institute of Technology, USA (2021–2024)*  
Manuel M. Oliveira  
*Universidade Federal do Rio Grande do Sul, Brazil (2021–2024)*

Julien Pettre, Inria  
*France (2019–2022)*  
Soren Pirk  
*University of Konstanz, Germany (2019–2022)*  
Voicu Popescu  
*Purdue University (2021–2024)*  
Tania Pouli  
*IRT b-com, France (2021–2024)*  
Daniel Ritchie  
*Brown University, USA (2021–2024)*  
Pradeep Sen  
*University of California, Santa Barbara, USA (2019–2022)*  
Hubert P. H. Shum  
*University of Durham, United Kingdom (2019–2022)*  
Barbara Solenthaler  
*ETH Zurich, Switzerland (2019–2022)*  
Markus Steinberger  
*Graz University of Technology, Austria (2019–2022)*  
Daniel Sykora  
*Czech Technical University in Prague, Czech Republic (2019–2022)*  
Melanie Tory  
*Northeastern University, USA (2019–2022)*  
Ivan Viola  
*King Abdullah University of Science and Technology, Saudi Arabia (2019–2022)*  
Yunhai Wang  
*Shandong University, China (2021–2024)*  
Ofir Weber  
*Bar-Ilan University, Israel (2019–2022)*

## GENERAL INFORMATION

*Computer Graphics Forum*, (Print ISSN: 0167–7055; Online ISSN: 1467–8659), is an international journal reporting research, new developments and activities in all areas of computer graphics. Basic research will be covered as well as the use of computer graphics in various application areas. While scientific papers on new developments are the major area of interest, state-of-the-art surveys, algorithms, books to review and reports on current events and activities in computer graphics are also welcome. *Computer Graphics Forum* is the official journal of the Eurographics Association.

**Publisher:** *Computer Graphics Forum* is published by John Wiley & Sons Ltd.

**Journal Customer Services:** For ordering information, claims and any enquiry concerning your journal subscription please go to <https://wolsupport.wiley.com/s/contactsupport?tabset-a7d10=2> or contact your nearest office.

**Americas:** Email: [cs-journals@wiley.com](mailto:cs-journals@wiley.com); Tel: +1 781 388 8598 or +1 800 835 6770 (toll free in the USA & Canada).

**Europe, Middle East and Africa:** Email: [cs-journals@wiley.com](mailto:cs-journals@wiley.com); Tel: +44 (0) 1865 778315.

**Asia Pacific:** Email: [cs-journals@wiley.com](mailto:cs-journals@wiley.com); Tel: +65 6511 8000.

**Japan:** For Japanese speaking support, Email: [cs-japan@wiley.com](mailto:cs-japan@wiley.com)

**Visit our Online Customer Help** at <https://wolsupport.wiley.com/s/contactsupport?tabset-a7d10=2>

**Information for subscribers:** *Computer Graphics Forum* is published in eight issues per year. Subscription prices for 2022 are:

	Europe	UK	The Americas	ROW
Premium Institutional:	€1101	£869	US \$1427	US \$1569

Prices are exclusive of tax. Asia-Pacific GST, Canadian GST and European VAT will be applied at the appropriate rates. For more information on current tax rates, please go to <https://onlinelibrary.wiley.com/library-info/products/price-lists/payment>. The price includes online access to the current and all online back files to January 1st 2018, where available. For other pricing options, including access information and terms and conditions, please visit <https://onlinelibrary.wiley.com/library-info/products/price-lists>. Terms of use can be found here: <https://onlinelibrary.wiley.com/terms-and-conditions>.

This journal is published in an online-only format.

*Computer Graphics Forum* accepts articles for Open Access publication. Please visit <https://authorservices.wiley.com/author-resources/Journal-Authors/open-access/hybrid-open-access.html> for further information about Open Access.

**Production Editor:** Amit Bansal (Email: [cgf@wiley.com](mailto:cgf@wiley.com)).

**Copyright and Copying:** Copyright © 2022 The Eurographics Association and John Wiley & Sons Ltd. All rights reserved. No part of this publication may be reproduced, stored or transmitted in any form or by any means without the prior permission in writing from the copyright holder. Authorization to photocopy items for internal and personal use is granted by the copyright holder for libraries and other users registered with their local Reproduction Rights Organisation (RRO), e.g. Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923, USA ([www.copyright.com](http://www.copyright.com)), provided the appropriate fee is paid directly to the RRO. This consent does not extend to other kinds of copying such as copying for general distribution, for advertising or promotional purposes, for republication, for creating new collective works or for resale. Permissions for such reuse can be obtained using the RightsLink “Request Permissions” link on Wiley Online Library. Special requests should be addressed to [permissions@wiley.com](mailto:permissions@wiley.com)

Wiley’s Corporate Citizenship initiative seeks to address the environmental, social, economic, and ethical challenges faced in our business and which are important to our diverse stakeholder groups. Since launching the initiative, we have focused on sharing our content with those in need, enhancing community philanthropy, reducing our carbon impact, creating global guidelines and best practices for paper use, establishing a vendor code of ethics, and engaging our colleagues and other stakeholders in our efforts.

Follow our progress at [www.wiley.com/go/citizenship](http://www.wiley.com/go/citizenship)

**Disclaimer:** The Publisher, Eurographics Association and Editors cannot be held responsible for errors or any consequences arising from the use of information contained in this journal; the views and opinions expressed do not necessarily reflect those of the Publisher, Eurographics Association and Editors, neither does the publication of advertisements constitute any endorsement by the Publisher, Eurographics Association and Editors of the products advertised.

**Abstracting and Indexing Services:** The Journal is indexed by Inspec; Personal Alert; The Engineering Index Monthly. For information on Abstracting and Indexing services, please go to the *Computer Graphics Forum* website at [wileyonlinelibrary.com](http://wileyonlinelibrary.com). *Computer Graphics Forum* is covered in *SciSearch*® and *Research Alert*®.

This journal is available online. Visit [wileyonlinelibrary.com/journal/cgf](http://wileyonlinelibrary.com/journal/cgf) to search the articles and register for table of contents e-mail alerts. For submission instructions, subscription and all other information visit: [wileyonlinelibrary.com/journal/cgf](http://wileyonlinelibrary.com/journal/cgf)

**Cover illustration:** “Bubble flower” by Yoshiki Kaminaka, Yuki Mikamoto and Kazufumi Kaneda.

## CONTENTS

---

Editorial	5
<b>Articles</b>	
At-Most-Hexa Meshes <i>Dennis R. Bukenberger, Marco Tarini and Hendrik P. A. Lensch</i>	7
Embedding QR Code onto Triangulated Meshes using Horizon Based Ambient Occlusion <i>György Papp, Miklós Hoffmann and Ildikó Papp</i>	29
Economic Upper Bound Estimation in Hausdorff Distance Computation for Triangle Meshes <i>Yicun Zheng, Haoran Sun, Xinguo Liu, Hujun Bao and Jin Huang</i>	46
Seamless Parametrization of Spheres with Controlled Singularities <i>Zohar Levi</i>	57
EHR STAR: The State-Of-the-Art in Interactive EHR Visualization <i>Q. Wang and R.S. Laramée</i>	69
Comparison of Modern Omnidirectional Precise Shadowing Techniques Versus Ray Tracing <i>Jozef Kobrtek, Tomas Milet, Michal Tóth and Adam Herout</i>	106
A Survey on Deep Learning for Skeleton-Based Human Animation <i>Lucas Mourot, Ludovic Hoyet, François Le Clerc, François Schnitzler and Pierre Hellier</i>	122
Dynamic Diffuse Global Illumination Resampling <i>Zander Majercik, Thomas Müller, Alexander Keller, Derek Nowrouzezahrai and Morgan McGuire</i>	158
Path Guiding Using Spatio-Directional Mixture Models <i>Ana Dodik, Marios Papas, Cengiz Öztireli and Thomas Müller</i>	172
Shadow Layers for Participating Media <i>François Desrichard, David Vanderhaeghe and Mathias Paulin</i>	190
Immersive Analytics with Abstract 3D Visualizations: A Survey <i>Mathias Kraus, Johannes Fuchs, Björn Sommer, Karsten Klein, Ulrich Engelke, Daniel Keim and Falk Schreiber</i>	201
Design and Evaluation Study of Visual Analytics Decision Support Tools in Air Traffic Control <i>E. Zohrevandi, C. A. L. Westin, J. Lundberg and A. Ynnerman</i>	230
Visual Analysis of Two-Phase Flow Displacement Processes in Porous Media <i>Steffen Frey, Stefan Scheller, Nikolaos Karadimitriou, Dongwon Lee, Guido Reina, Holger Steeb and Thomas Ertl</i>	243
Stroke-Based Drawing and Inbetweening with Boundary Strokes <i>Jie Jiang, Hock Soon Seah and Hong Ze Liew</i>	257
Using Position-Based Dynamics for Simulating Mitral Valve Closure and Repair Procedures <i>Lars Walczak, Joachim Georgii, Lennart Tautz, Mathias Neugebauer, Isaac Wamala, Simon Sündermann, Volkmar Falk and Anja Hennemuth</i>	270
A Stereo Matching Algorithm for High-Precision Guidance in a Weakly Textured Industrial Robot Environment Dominated by Planar Facets <i>Hui Wei and Lingjiang Meng</i>	288
Augmenting Digital Sheet Music through Visual Analytics <i>Mathias Müller, Daniel Fürst, Hanna Hauptmann, Daniel A. Keim and Mennatallah El-Assady</i>	301
Complex Functional Maps: A Conformal Link Between Tangent Bundles <i>Nicolas Donati, Etienne Corman, Simone Melzi and Maks Ovsjanikov</i>	317
Evaluating Data-type Heterogeneity in Interactive Visual Analyses with Parallel Axes <i>José Matute and Lars Linsen</i>	335

Modelling Surround-aware Contrast Sensitivity for HDR Displays <i>Shinyoung Yi, Daniel S. Jeon, Ana Serrano, Se-Yoon Jeong, Hui-Yong Kim, Diego Gutierrez and Min H. Kim</i>	350
Placing Arrows in Directed Graph Layouts: Algorithms and Experiments <i>Carla Binucci, Walter Didimo, Michael Kaufmann, Giuseppe Liotta and Fabrizio Montecchiani</i>	364
GlassNet: Label Decoupling-based Three-stream Neural Network for Robust Image Glass Detection <i>Chengyu Zheng, Ding Shi, Xuefeng Yan, Dong Liang, Mingqiang Wei, Xin Yang, Yanwen Guo and Haoran Xie</i>	377
Feature-Adaptive and Hierarchical Subdivision Gradient Meshes <i>J. Zhou, G.J. Hetingga, S. Houwink and J. Kosinka</i>	389
A Survey of Tasks and Visualizations in Multiverse Analysis Reports <i>Brian D. Hall, Yang Liu, Yvonne Jansen, Pierre Dragicevic, Fanny Chevalier and Matthew Kay</i>	402
Learning Camera Control in Dynamic Scenes from Limited Demonstrations <i>R. Hanocka, J. Assa, D. Cohen-Or and R. Giryas</i>	427
Graphical Tools for Visualization of Missing Data in Large Longitudinal Phenomena <i>Edgar Jiménez and Rodrigo Macías</i>	438
A Generative Framework for Image-based Editing of Material Appearance using Perceptual Attributes <i>J. Delanoy, M. Lagunas, J. Condor, D. Gutierrez and B. Masia</i>	453
A Survey on Cross-Virtuality Analytics <i>B. Fröhler, C. Anthes, F. Pointecker, J. Friedl, D. Schwajda, A. Riegler, S. Tripathi, C. Holzmann, M. Brunner, H. Jodlbauer, H.-C. Jetter and C. Heinzl</i>	465
Real-Time Microstructure Rendering with MIP-Mapped Normal Map Samples <i>Haowen Tan, Junqiu Zhu, Yanning Xu, Xiangxu Meng, Lu Wang and Ling-Qi Yan</i>	495
<b>Report</b>	
Cover Image 2022: Bubble flower <i>Yoshiki Kaminaka, Yuki Mikamoto and Kazufumi Kaneda</i>	507

## NOTES FOR AUTHORS

We welcome novel contributions from all over the world on any aspect of computer graphics. All papers are refereed, typically by three international referees, and referees' comments are passed back to the authors. It is relatively rare for a paper to be accepted without at least some changes being required. Contributors should be prepared to revise their paper accordingly.

Papers for the conference issue should be sent directly to the Programme Chairs according to the details given in the current Call for Papers. Papers of high merit which do not fit the conference programme may still be published in a regular issue; refereeing is to the same standard for all issues.

*The rest of these notes are for contributors to the regular issues:*

**Style of presentation:** Use the house style of the journal. Wherever possible, prepare your paper with our LaTeX macros, available at <https://www.eg.org/index.php/publications/guidelines>. We strongly encourage authors to use the LaTeX macros. Even if you do not want to use macros, you can obtain our Style Guide in the same way.

Try to get the layout, use of headings, etc. as close as possible to that used in the Journal. Note in particular the format used for references, both within the text and in the reference list, as references are very difficult to correct later. References should be listed in the order in which they first appear within the main text; consequently, the first citation of each paper will be in numerical order in the text.

We have no objection to your submitting material in one-column format but keep in mind that the paper will eventually be set in two columns. This is especially important when planning display material, such as program fragments, as it is difficult for the typesetter to know where to break lines. Such material must be limited to a maximum of 39 characters per line, including spaces.

Where you cannot match the style exactly, please use something that is close enough to make marking-up easy.

**Language and spelling:** The journal language is English. If you are not a regular or native English-speaker, it is a good idea to find such a colleague to ready your paper through to you. We use English, rather than American, spelling.

**Length of contributions:** The length of a full paper will typically be between 5 and 12 journal pages. Shorter papers are also accepted however, and are refereed to the same general standard as full length papers.

**Title page:** The first page should supply the paper title and the name, full affiliation address, and email address of each author. The affiliation(s) given should be those at which the work was performed. Present address(es), if different, should be indicated.

If the paper has been previously presented at a technical meeting, the name, date and location of the meeting and the name of the sponsoring organization should be given. However, the journal will not normally publish previously presented papers unless their distribution was limited and the material is exceptional.

**Abstract:** the abstract is an important component of your paper. Please include 150–200 words which faithfully reflect the content of your paper.

**ACM Computing Classification System:** All papers should be classified into one or more categories of the ACM Computing Classification System (ACM CCS, found at <http://www.acm.org/class>). Please also supply a short list of **Keywords**.

**Illustrations:** All illustrations should be supplied as TIFF or EPS files, at the size they are to appear in print, with clear labelling and the appropriate caption. Authors' original illustrations will be used in all cases as artwork can not be re-drawn. **Colour** illustration should be as CMYK-separated EPS files, one file for each figure. Please ensure all illustrations are referred to in the text of the paper.

**Tables:** Give tables a title and table number. Avoid complex tables.

**Footnotes:** For technical reasons we cannot include footnotes on the first page of the published paper. Avoid footnotes as much as possible. Try to incorporate footnote material into the text, e.g. parenthetically or as a "remark" or "note".

**Acknowledgements:** Acknowledgements of funding support may be given in a separate section at the end of paper. Any references to commercial organization or proprietary articles may also be given here, but references should not be mentioned elsewhere except when necessary to identify a specific piece of equipment, etc. Personal acknowledgements should also appear in this section.

**Proof:** The corresponding author will receive an e-mail alert containing a link to a website. The proof can be downloaded as a PDF file from this site. It is important to understand that this is not an opportunity to make revisions to your paper and extensive changes will be charged at a cost.

**Exclusive Licence Form:** Copyright of all material published resides with the Eurographics Association and John Wiley & Sons Ltd. If your paper is accepted, the author identified as the formal corresponding author for the paper will receive an email prompting them to login into Author Services; where via the Wiley Author Licensing Service (WALS) they will be able to complete the license agreement on behalf of all authors on the paper. It is the contact author's responsibility to obtain permission to use any copyright material used in the paper and to include all relevant acknowledgements.

Material under review and consideration for publication in the journal, or material that has been formally accepted, may be used elsewhere by the author except in a formal journal, periodical, book, or other copyrighted publication. If it is presented at a professional meeting or distributed as a report, it is requested that the submission to this journal and its status be acknowledged by a suitable citation or comment such as "Submitted for publication in *Computer Graphics Forum*" or "Accepted for publication in *Computer Graphics Forum*". Once the material has been prepared in publication format by the publisher, the permission of the Eurographics Association is required for any use of the material.

**Submitting papers:** *Computer Graphics Forum* has adopted ScholarOne Manuscripts, for online manuscript submission and peer review. This system brings with it a whole host of benefits including:

- Quick and easy submission
- Administration centralised and reduced
- Significant decrease in peer review times

All submissions to the journal must be submitted online at <http://mc.manuscriptcentral.com/cgf>. Full instructions and support are available on the site and a user ID and password can be obtained on the first visit. If you require assistance then click the **Get Help Now** link which appears at the top right of every ScholarOne Manuscripts page.

**Double submission:** The Chief Editors regularly exchange information about all papers in progress with the Editors of other journals. We are not prepared to consider papers which are being considered for other journals, conferences or other public output, whether the papers are the same or similar in content. The Chief Editors reserve the right to reject or to suspend consideration of any paper in this category.

**Revised manuscript:** When the paper has been revised in line with the referees' comments, you should send the relevant files for the paper electronically in final form, together with all associated illustration files, to the Chief Editor.

**Submission of additional electronic materials:** *Computer Graphics Forum* is also available electronically to EG members through the EG Digital Library at [diglib.eg.org](http://diglib.eg.org). Authors can and are therefore encouraged to submit multimedia attachments such as movies, virtual worlds, presentations, etc. that illustrate or support their contributions to the Eurographics Digital Library. Authors of accepted papers are also encouraged to optimize their papers for electronic delivery of content. For more instructions please refer to the URL <https://www.eg.org/index.php/publications/guidelines>.