

**EuroVis 2019**  
**Eurographics / IEEE VGTC Conference on Visualization 2019**

Porto, Portugal  
June 3 – 7, 2019

---

Organized by



EUROGRAPHICS  
THE EUROPEAN ASSOCIATION  
FOR COMPUTER GRAPHICS



IEEE Visualization and Graphics Technical Committee

---

**General Chairs**

Alfredo Ferreira – INESC-ID, Instituto Superior Técnico, Universidade de Lisboa  
Joaquim A. Jorge – INESC-ID, Instituto Superior Técnico, Universidade de Lisboa

**Full Papers Chairs**

Michael Gleicher – University of Wisconsin  
Ivan Viola – KAUST  
Heike Leitte – TU Kaiserslautern

**STARs Chairs**

Robert S. Laramée – Swansea University  
Steffen Oeltze – Dept. of Neurology, University of Magdeburg  
Michael Sedlmair – Jacobs University

**Short Papers Chairs**

Jimmy Johansson – Linköping University  
Filip Sadlo – Heidelberg University  
G. Elisabeta Marai – University of Illinois at Chicago

**Posters Chairs**

João Madeiras Pereira – Universidade de Lisboa  
Renata Raidou – TU Wien

## Organizers and Sponsors



## Preface

EuroVis 2019, the 21th Eurographics / IEEE VGTC Conference on Visualization, was held in Porto, Portugal, on June 3-7, 2019. The proceedings are published as a special issue of the Eurographics Computer Graphics Forum journal. The conference, which started in 1990 as the Eurographics Workshop on Visualization in Scientific Computing and was called VisSym after 1999, has been known as EuroVis since 2005. EuroVis attracts contributions that broadly cover the field of visualization. Topics include visualization techniques for spatial data, such as volumetric, tensor, and vector field datasets, and for non-spatial data, such as graphs, text, and high-dimensional datasets. EuroVis also covers the theory of visualization, hardware acceleration, large datasets, perception, interaction, user studies, information visualization, visual analytics, and many application areas of visualization.

After the submission deadline in early December 2018, 189 manuscripts were reviewed in a two-stage process that resulted in 59 accepted papers and an acceptance rate of 31.2%. During the first review cycle, each paper was reviewed by at least four reviewers. The 77 primary and secondary reviewers were members of the International Program Committee (IPC) and each selected at least one additional tertiary reviewer from outside the IPC. The IPC meanwhile represents the global visualization community quite well, including members from Australia, Brazil, Asia, US, and Europe. The IPC at EuroVis is a rather dynamic committee with regular rotations after a three-year period. The review process was double-blind for tertiary reviewers: only the members of the IPC and the chairs knew the identity of the authors. A great effort was made to identify and prevent conflicts of interest at all levels, and all reviewers were asked to read and agree to the IEEE Visualization and Graphics Technical Committee (VGTC) ethics guidelines. After all the reviews were completed, the primary reviewer led an online discussion among all reviewers and was responsible for writing a summary review and recommendation. These discussions were lively, significantly helping to find a consensus. During the discussion phase, the reviews were also made available to the authors, who had the opportunity to write a response to the papers chairs. Both exchange formats, discussions and review response, were lively used and significantly helped to find a consensus. Based on the reviewers' recommendations, the individual reviews, the online discussions, the authors' review response, and after a thorough deliberation by the paper chairs, 59 papers were conditionally accepted. Three additional papers were invited for a fast-track review process to Computer Graphics Forum for possible publication in a future issue. In the second review cycle, the revised papers were again carefully reviewed by the primary reviewers, and due to the significant improvements 58 papers were finally accepted for publication. One paper opted for a major revision. We helped to shape the reviews to be as constructive as possible to also provide the authors of rejected papers with substantial feedback for their further research.

We are thankful to everybody who helped to make the event possible. We thank the IPC members for their careful and timely work in all stages of the reviewing process and the tertiary reviewers for providing in-depth assessments of the submissions. We thank our invited speakers Paul A. Navrátil and Jeffrey Heer. We thank the chairs of the short paper track, Jimmy Johansson, Filip Sadlo, G. Elisabeta Marai, the chairs of the STARs, Robert S. Laramée, Steffen Oeltze, Michael Sedlmair, and the chairs of the Posters track, João Madeiras Pereira, Renata Raidou, for their great efforts in their corresponding tracks that make EuroVis such a successful conference. We also thank all the chairs of the co-located workshops, and Stefanie Behnke, who has been very helpful throughout all the process of publication of this journal. We also would like to thank the authors of all submitted papers and all conference attendees.

Finally, a special thanks goes to Alfredo Ferreira, Joaquim A. Jorge, António Coelho, Luís Paulo Santos for the entire organization of EuroVis 2019.

## International Programme Committee

Wolfgang Aigner – FH St. Pölten, Austria  
Daniel Archambault – University of Swansea, UK  
David Auber – INRIA, France  
Peter Bak – IBM, Israel  
Fabian Beck – University of Duisburg-Essen, Germany  
Johanna Beyer – Harvard, School of Engineering and Applied Sciences, USA  
Timo Bremer – Lawrence Livermore National Laboratory, USA  
Roxana Bujack – LANL (Los Alamos National Lab), USA  
Michael Burch – TU Eindhoven, The Netherlands  
Hamish Carr – University of Leeds, UK  
Remco Chang – Tufts University, USA  
Wei Chen – Zhejiang University, China  
Min Chen – Oxford University, UK  
Jian Chen – Ohio State University, USA  
Matthew Cooper – Linköping University, Sweden  
Achim Ebert – University of Kaiserslautern, Germany  
Alireza Entazari – University of Florida, Computer and Information Science and Engineering, USA  
Thomas Ertl – Stuttgart, Germany  
Carla Dal Sasso Freitas – Universidade Federal do Rio Grande do Sul, Brazil  
Christoph Garth – University of Kaiserslautern, Germany  
Enrico Gobbetti – CRS4, Italy  
Eduard Gröller – Vienna University of Technology, Austria  
Markus Hadwiger – KAUST, Saudi Arabia  
Chuck Hansen – Utah, USA  
Lane Harrison – WPI, USA  
Helwig Hauser – University of Bergen, Norway  
Christopher Healey – NCSU, Raleigh, USA  
Ingrid Hotz – Linköping University, Sweden  
Tobias Isenberg – INRIA, France  
Stefan Jänicke – University of Leipzig, Germany  
Alark Joshi – University of San Francisco, USA  
Andreas Kerren – Linnaeus University, Sweden  
Robert Kosara – Tableau, USA  
Barbora Kozlíková – Masaryk University, Brno, Czech Republic  
Michael Krone – University of Tübingen, Germany  
Jens Krüger – University of Duisburg-Essen, Germany  
David Laidlaw – Brown University, USA  
Kai Lawonn – University of Koblenz, Germany

## International Programme Committee

Joshua Levine – University of Arizona, USA  
Lars Linsen – Westfälische Wilhelms-Universität Münster, Germany  
Shixia Liu – Tsinghua University, China  
Zhicheng Liu – Adobe Systems, USA  
Ross Maciejewski – Arizona State University, USA  
Kresimir Matkovic – VRVis, Austria  
Miriah Meyer – University of Utah, USA  
Gabriel Mistelbauer – University of Magdeburg, Germany  
Torsten Möller – University of Vienna, Austria  
Klaus Mueller – Stony Brook University, USA  
Vijay Natarajan – Indian Institute of Science, Department of Computer Science and Automation, India  
Renato Pajarola – University of Zurich, Switzerland  
Penny Rheingans – UMBC, USA  
Jonathan Roberts – Bangor University, UK  
Paul Rosenthal – TU Chemnitz, Germany  
Giuseppe Santucci – Sapienza University of Rome, Italy  
Tobias Schreck – Graz University of Technology, Austria  
Claudio Silva – NYU-Poly, USA  
Mike Sips – GFZ German Research Centre for Geosciences, Germany  
Noeska Smit – University of Bergen, Norway  
Veronika Solteszova – University of Bergen, Norway  
Beatriz Sousa Santos – University of Aveiro, Portugal  
Marc Streit – JK University Linz, Austria  
Danielle Szafir – University of Colorado Boulder, USA  
Alexandru Telea – University of Groningen, The Netherlands  
Christian Tominski – University of Rostock, Germany  
Melanie Tory – Tableau Research, USA  
Xavier Tricoche – Purdue, USA  
Pere-Pau Vazquez – Barcelona Tech, Spain  
Manuela Waldner – TU Vienna, Austria  
Yunhai Wang – Shandong University, China  
Chaoli Wang – University of Notre Dame, USA  
Gunther Weber – Berkeley Lab, USA  
Daniel Weiskopf – University of Stuttgart, Germany  
Rüdiger Westermann – TU München, Germany  
Thomas Wischgoll – Wright State University, USA  
Jo Wood – City University of London, UK  
Hsiang-Yun Wu – TU Wien, Austria

## Reviewers

Afonso, Ana Paula	Coimbra, Danilo Barbosa	Gracanin, Denis
Agus, Marco	Collins, Christopher	Gschwandtner, Theresia
Ahmed, Reyan	Coltekin, Arzu	Gumhold, Stefan
Albo, Yael	Comba, Joao Dihl	Günther, Tobias
Alexander, Eric	Cordeil, Maxime	Günther, David
Alsallakh, Bilal	Correll, Michael	Hearst, Marti
Alspaugh, Sara	Dachselt, Raimund	Hege, Hans-Christian
Angelini, Marco	Dang, Tommy	Heimerl, Florian
Athawale, Tushar	Demiralp, Cagatay	Heinzl, Christoph
Bach, Benjamin	Devkota, Sabin	Hernández, Benjamín
Badam, Sriram Karthik	Diehl, Stephan	Hinrichs, Uta
Bailly, Gilles	Diehl, Alexandra	Hlawitschka, Mario
Baum, Daniel	Dietrich, Carlos	Hofmann, Lutz
Beecham, Roger	Döllner, Jürgen	Höllt, Thomas
Behrisch, Michael	Dou, Wenwen	Hong, Seokhee
Bekker, Henk	Du, Ruofei	Hong, Sungsoo (Ray)
Berger, Matthew	Dunne, Cody	Hoon, Niels de
Bergner, Steven	Dwyer, Tim	Huang, Zhaosong
Bernard, Jürgen	Dykes, Jason	Humayoun, Shah Rukh
Bertini, Enrico	Edge, Darren	Hurter, Christophe
Bezerianos, Anastasia	Eggert, Daniel	Isaacs, Katherine
Bhatia, Harsh	Eilemann, Stefan	Isenberg, Petra
Blascheck, Tanja	El-Assady, Mennatallah	Itoh, Masahiko
Blumenschein, Michael	Elmqvist, Niklas	Jackson, Bret
Bolte, Fabian	Elshehaly, Mai	Jadhav, Shreeraj
Boorboor, Saeed	Everts, Maarten	Jeong, Dong Hyun
Borgo, Rita	Falk, Martin	Kalantari, Leila
Borkin, Michelle	Fan, Chaoran	Kalkofen, Denis
Bors, Christian	Faust, Rebecca	Kanzler, Mathias
Bourqui, Romain	Fekete, Jean-Daniel	Kaufman, Shaked
Boy, Jeremy	Fisher, Danyel	Khan, Taimur
Brehmer, Matthew	Fisher, Brian	Kindlmann, Gordon
Bruckner, Stefan	Fonseca, Manuel J.	Klemm, Paul
Byška, Jan	Forbes, Angus	Kobourov, Stephen
Cabello, Sergio	Frey, Steffen	Koch, Steffen
Cappers, B.C.M. (Bram)	Fuchs, Georg	Koop, David
Carmo, Maria Beatriz	Garderen, Mereke van	Kozlikova, Barbora
Chan, Gromit Yeuk-Yin	Gehlenborg, Nils	Krause, Josua
Chang, Kerry Shih-Ping	Giachetti, Andrea	Krekhov, Andrey
Chen, Guoning	Giesen, Joachim	Krüger, Robert
Chen, Siming	Giot, Romain	Kumar, Ayush
Chen, Bing-Yu	Gleicher, Michael	Kumpf, Alexander
Chen, Yang	Goffin, Pascal	Kwon, Oh-Hyun
Cheng, Hsueh-Chien	Gomez-Nieto, Erick	Lage, Marcos
Chevalier, Fanny	Gonçalves, Daniel	Lam, Heidi
Childs, Hank	Gosink, Luke	Lanir, Joel
Cho, Kyunghyun	Gou, Liang	Laramée, Robert
Choo, Jaegul	Gove, Robert	Lavrentiev, Valery
Cmentowski, Sebastian	Goyal, Dushyant	Law, Po-Ming

## Reviewers

Lee, Doris Jung-Lin	Pezzotti, Nicola	Stoppel, Sergej
Lee, Sungkil	Pfeiffer, Linda	Strobel, Hendrik
Lekschas, Fritz	Pinaud, Bruno	Sultanum, Nicole
Lex, Alexander	Pintore, Giovanni	Summa, Brian
Lindow, Norbert	Piringer, Harald	Sun, Maoyuan
Liu, Shusen	Pirsiavash, Hamed	Tam, Gary
Liu, Mengchen	Poco, Jorge	Tatu, Andrada
Liu, Yang	Potter, Kristi	Taylor, Russell M.
Ljung, Patric	Preuß, Daniel	Theussl, Thomas
Lu, Min	Prouzeau, Arnaud	Thom, Dennis
Lu, Yafeng	Pugmire, David	Thompson, John
Lundström, Claes	Quan, Nguyen	Thöny, Matthias
L'Yi, Sehi	Raidou, Renata Georgia	Trapp, Matthias
Ma, Yuxin	Raji, Mohammad	Trimm, David
Ma, Bo	Rautek, Peter	Turkay, Cagatay
Maljovec, Dan	Reda, Khairi	University, Kevin
Masood, Talha Bin	Renoust, Benjamin	Velez, Maria
McKenna, Sean	Rensink, Ronald	Vilanova, Anna
Merino, Leonel	Richer, Gaëlle	Viola Rojas, Ivan
Meuschke, Monique	Röber, Niklas	Vital, Emilio
Micallef, Luana	Rodgers, Peter	Vrotsou, Katerina
Michalski, Michael	Rosen, Paul	Vuillemot Brazil, Romain
Miksch, Silvia	Ruchikachorn, Puripant	Wald, Ingo
Milios, Evangelos	Rupprecht, Franca	Wall, Emily
Ming, Yao	Sadlo, Filip	Wallner, Günter
Minghim, Rosane	Sallaberry, Arnaud	Wang, Zeyu
Misue, Kazuo	Sanyal, Jibo	Wang, Ji
Molchanov, Vladimir	Sarikaya, Alper	Wang, Xiting
Moreland, Kenneth	Scheidegger, Carlos	Wang, Feng
Mosca, Abigail	Schloss, Karen	Wang, Xiaoyi
Motschnig, Renate	Schmalstieg, Dieter	Wang, Zhe
Mueller, Thomas	Schmidt, Johanna	Wang, Bei
Mühlbacher, Thomas	Schmidt, Christoph	Wattenberg, Martin
Nacenta, Miguel	Schneider, Jens	Weaver, Chris
Nagel, Till	Schorer, Karl-Michael	Weber, Gerhard
Nahmias, Liad	Schultz, Thomas	Weinkauff, Tino
Nedel, Luciana	Schulz, Hans-Jörg	Wetering, Huub van de
Neuroth, Tyson	Sedlmair, Michael	Wiebel, Alexander
Nocke, Thomas	Setlur, Vidya	Willett, Wesley
Nothelfer, Christine	Shi, Lei	Wodo, Olga
Oliveira, Maria Cristina F. de	Shudler, Sergei	Wolff, Alexander
Onoue, Yosuke	Sicat, Ronell	Wongsuphasawat, Kanit
Ošlejšek, Radek	Singun, Amando	Wu, Yingcai
Ottley, Alvitta	Skraba, Primoz	Wu, Jieting
Park, Ji Hwan	Sorger, Johannes	Xia, Jiazhi
Patel, Daniel	Spechtenhauser, Florian	Xie, Cong
Paulovich, Fernando	Sreevalsan, Jaya	Xu, Kai
Peltonen, Jaakko	Srinivasan, Arjun	Xu, Panpan
Penn, Gerald	Stein, Manuel	Yang, Yalong
Perer, Adam	Stone, John	Ynnerman, Anders

## TABLE OF CONTENTS

### Best Paper Award Nominees

<i>V-Awake: A Visual Analytics Approach for Correcting Sleep Predictions from Deep Learning Models</i>	1
Humberto Simon Garcia Caballero, Michel A. Westenberg, Binyam Gebre, and Jarke J. van Wijk	
<i>Optimizing Stepwise Animation in Dynamic Set Diagrams</i>	13
Kazuyo Mizuno, Hsiang-Yun Wu, Shigeo Takahashi, and Takeo Igarashi	
<i>Interactive Visualization of Flood and Heavy Rain Simulations</i>	25
Daniel Cornel, Andreas Buttinger-Kreuzhuber, Artem Konev, Zsolt Horváth, Michael Wimmer, Raimund Heidrich, and Jürgen Waser	
<i>Follow The Clicks: Learning and Anticipating Mouse Interactions During Exploratory Data Analysis</i>	41
Alvitta Ottley, Roman Garnett, and Ran Wan	
<i>A Framework for GPU-accelerated Exploration of Massive Time-varying Rectilinear Scalar Volumes</i>	53
Fabio Marton, Marco Agus, and Enrico Gobetti	

### Analysis Applications and Systems

<i>Latent Space Cartography: Visual Analysis of Vector Space Embeddings</i>	67
Yang Liu, Eunice Jun, Qisheng Li, and Jeffrey Heer	
<i>Multiple Views: Different Meanings and Collocated Words</i>	79
Jonathan C. Roberts, Hayder Mahdi Al-maneea, Peter W. S. Butcher, Robert Lew, Geraint Paul Rees, Nirwan Sharma, and Ana Frankenberg-Garcia	
<i>DIVA: Exploration and Validation of Hypothesized Drug-Drug Interactions</i>	95
Tabassum Kakar, Xiao Qin, Elke A. Rundensteiner, Lane Harrison, Sanjay K. Sahoo, and Suranjan De	
<i>CV3: Visual Exploration, Assessment, and Comparison of CVs</i>	107
Velitchko Andreev Filipov, Alessio Arleo, Paolo Federico, and Silvia Miksch	
<i>VIAN: A Visual Annotation Tool for Film Analysis</i>	119
Gaudenz Halter, Rafael Ballester-Ripoll, Barbara Flueckiger, and Renato Pajarola	

### Analysis and Decision Making

<i>An Ontological Framework for Supporting the Design and Evaluation of Visual Analytics Systems</i>	131
Min Chen and David S. Ebert	
<i>Characterizing Exploratory Visual Analysis: A Literature Review and Evaluation of Analytic Provenance in Tableau</i>	145
Leilani Battle and Jeffrey Heer	
<i>Investigating Effects of Visual Anchors on Decision-Making about Misinformation</i>	161
Ryan Wesslen, Sashank Santhanam, Alireza Karduni, Isaac Cho, Samira Shaikh, and Wenwen Dou	
<i>An Exploratory User Study of Visual Causality Analysis</i>	173
Chi-Hsien Eric Yen, Aditya Parameswaran, and Wai-Tat Fu	



## TABLE OF CONTENTS

<i>A User-based Visual Analytics Workflow for Exploratory Model Analysis</i>	185
Dylan Cashman, Shah Rukh Humayoun, Florian Heimerl, Kendall Park, Subhajit Das, John R. Thompson, Bahador Saket, Abigail Mosca, John Stasko, Alex Endert, Michael Gleicher, and Remco Chang	
<b>Analysis Techniques</b>	
<i>Toward Understanding Representation Methods in Visualization Recommendations through Scatterplot Construction Tasks</i>	201
Sehi L'Yi, Youli Chang, DongHwa Shin, and Jinwook Seo	
<i>Oui! Outlier Interpretation on Multi-dimensional Data via Visual Analytics</i>	213
Xun Zhao, Weiwei Cui, Yanhong Wu, Haidong Zhang, Huamin Qu, and Dongmei Zhang	
<i>ClustMe: A Visual Quality Measure for Ranking Monochrome Scatterplots based on Cluster Patterns</i>	225
Mostafa M. Abbas, Michaël Aupetit, Michael Sedlmair, and Halima Bensmail	
<i>SurgeryCuts: Embedding Additional Information in Maps without Occluding Features</i>	237
Marco Angelini, Juri Buchmüller, Daniel A. Keim, Philipp Meschenmoser, and Giuseppe Santucci	
<i>Visualizing for the Non-Visual: Enabling the Visually Impaired to Use Visualization</i>	249
Jinho Choi, Sanghun Jung, Deok Gun Park, Jaegul Choo, and Niklas Elmqvist	
<b>Vectors and Features</b>	
<i>The Dependent Vectors Operator</i>	261
Lutz Hofmann and Filip Sadlo	
<i>A Visual Tool for the Analysis of Algorithms for Tomographic Fiber Reconstruction in Materials Science</i>	273
Bernhard Fröhler, Tim Elberfeld, Torsten Möller, Hans-Christian Hege, Johannes Weissenböck, Jan De Beenhouwer, Jan Sijbers, Johann Kastner, and Christoph Heinzl	
<i>Robust Reference Frame Extraction from Unsteady 2D Vector Fields with Convolutional Neural Networks</i>	285
Byungsoo Kim and Tobias Günther	
<i>An Interactive Visualization System for Large Sets of Phase Space Trajectories</i>	297
Tyson A. Neuroth, Franz Sauer, and Kwan-Liu Ma	
<b>Higher-Order Data Types</b>	
<i>Visualization of Equivalence in 2D Bivariate Fields</i>	311
Boyan Zheng, Bastian Rieck, Heike Leitte, and Filip Sadlo	
<i>Towards Glyphs for Uncertain Symmetric Second-Order Tensors</i>	325
Tim Gerrits, Christian Rössl, and Holger Theisel	
<i>Robust Extraction and Simplification of 2D Symmetric Tensor Field Topology</i>	337
Jochen Jankowai, Bei Wang, and Ingrid Hotz	
<i>Visualization Support for Developing a Matrix Calculus Algorithm: A Case Study</i>	351
Joachim Giesen, Julien Klaus, Sören Laue, and Ferdinand Schreck	

## TABLE OF CONTENTS

<i>Examining Implicit Discretization in Spectral Schemes</i>	363
P. Samuel Quinan, Lace M. K. Padilla, Sarah H. Creem-Regehr, and Miriah Meyer	
<b>Time Series</b>	
<i>Bridging the Data Analysis Communication Gap Utilizing a Three-Component Summarized Line Graph</i>	375
Calvin Yau, Morteza Karimzadeh, Chittayong Surakitbanharn, Niklas Elmqvist, and David S. Ebert	
<i>ChronoCorrelator: Enriching Events with Time Series</i>	387
Martijn A.M.M. van Dortmont, Stef van den Elzen, and Jarke J. van Wijk	
<i>Visual-Interactive Preprocessing of Multivariate Time Series Data</i>	401
Jürgen Bernard, Marco Hutter, Heiko Reinemuth, Hendrik Pfeifer, Christian Bors, and Jörn Kohlhammer	
<b>Biomedical Applications and Ray Tracing</b>	
<i>A Geometric Optimization Approach for the Detection and Segmentation of Multiple Aneurysms</i>	413
Kai Lawonn, Monique Meuschke, Ralph Wickenhöfer, Bernhard Preim, and Klaus Hildebrandt	
<i>Interactive Volumetric Visual Analysis of Glycogen-derived Energy Absorption in Nanometric Brain Structures</i>	427
Marco Agus, Corrado Calì, Ali K. Al-Awami, Enrico Gobbetti, Pierre J. Magistretti, and Markus Hadwiger	
<i>Analysis of Long Molecular Dynamics Simulations Using Interactive Focus+Context Visualization</i>	441
Jan Byška, Thomas Trautner, Sérgio M. Marques, Jiří Damborský, Barbora Kozlíková, and Manuela Waldner	
<i>Scalable Ray Tracing Using the Distributed FrameBuffer</i>	455
Will Usher, Ingo Wald, Jefferson Amstutz, Johannes Günther, Carson Brownlee, and Valerio Pascucci	
<i>Ray Tracing Generalized Tube Primitives: Method and Applications</i>	467
Mengjiao Han, Ingo Wald, Will Usher, Qi Wu, Feng Wang, Valerio Pascucci, Charles D. Hansen, and Chris R. Johnson	
<b>Spatial Data Applications</b>	
<i>Visual Analysis of Charge Flow Networks for Complex Morphologies</i>	479
Sathish Kottravel, Martin Falk, Talha Bin Masood, Mathieu Linares, and Ingrid Hotz	
<i>IGM-Vis: Analyzing Intergalactic and Circumgalactic Medium Absorption Using Quasar Sightlines in a Cosmic Web Context</i>	491
Joseph N. Burchett, David Abramov, Jasmine Tan Otto, Cassia Artanegara, Jason Xavier Prochaska, and Angus G. Forbes	
<i>Analysis of Decadal Climate Predictions with User-guided Hierarchical Ensemble Clustering</i>	505
Christopher P. Kappe, Michael Böttinger, and Heike Leitte	
<i>Evaluating Image Quality Measures to Assess the Impact of Lossy Data Compression Applied to Climate Simulation Data</i>	517
Allison H. Baker, Dorit M. Hammerling, and Terece L. Turton	

## TABLE OF CONTENTS

### Interaction Techniques for Scalability

- Kyrix: Interactive Pan/Zoom Visualizations at Scale* 529  
Wenbo Tao, Xiaoyu Liu, Yedi Wang, Leilani Battle, Çağatay Demiralp, Remco Chang, and Michael Stonebraker
- Designing Animated Transitions to Convey Aggregate Operations* 541  
Younghoon Kim, Michael Correll, and Jeffrey Heer
- Hybrid Touch/Tangible Spatial 3D Data Selection* 553  
Lonni Besançon, Mickael Sereno, Lingyun Yu, Mehdi Ammi, and Tobias Isenberg
- Focus+Context Exploration of Hierarchical Embeddings* 569  
Thomas Höllt, Anna Vilanova, Nicola Pezzotti, Boudewijn P. F. Lelieveldt, and Helwig Hauser

### Geospatial and Social Data

- Route-Aware Edge Bundling for Visualizing Origin-Destination Trails in Urban Traffic* 581  
Wei Zeng, Qiaomu Shen, Yuzhe Jiang, and Alexandru Telea
- Bird's-Eye - Large-Scale Visual Analytics of City Dynamics using Social Location Data* 595  
Robert Krueger, Qi Han, Nikolay Ivanov, Sanae Mahtal, Dennis Thom, Hanspeter Pfister, and Thomas Ertl
- Topic Tomographies (TopTom): a Visual Approach to Distill Information From Media Streams* 609  
Beatrice Gobbo, Duilio Balsamo, Michele Mauri, Paolo Bajardi, André Panisson, and Paolo Ciuccarelli
- Segmentifier: Interactive Refinement of Clickstream Data* 623  
Kimberly Dextras-Romagnino and Tamara Munzner

### Interaction Techniques

- Augmenting Tactile 3D Data Navigation With Pressure Sensing* 635  
Xiyao Wang, Lonni Besançon, Mehdi Ammi, and Tobias Isenberg
- InsideInsights: Integrating Data-Driven Reporting in Collaborative Visual Analytics* 649  
Andreas Mathisen, Tom Horak, Clemens Nylandsted Klokmose, Kaj Grønbaek, and Niklas Elmquist
- Investigating the Manual View Specification and Visualization by Demonstration Paradigms for Visualization Construction* 663  
Bahador Saket and Alex Endert
- Linking and Layout: Exploring the Integration of Text and Visualization in Storytelling* 675  
Qiyu Zhi, Alvitta Ottley, and Ronald Metoyer
- Capture & Analysis of Active Reading Behaviors for Interactive Articles on the Web* 687  
Matthew Conlen, Alex Kale, and Jeffrey Heer

### Graphs and Networks

- netflower: Dynamic Network Visualization for Data Journalists* 699  
Christina Stoiber, Alexander Rind, Florian Grassinger, Robert Gutounig, Eva Goldgruber, Michael Sedlmair, Štefan Emrich, and Wolfgang Aigner
- Efficient Optimal Overlap Removal: Algorithms and Experiments* 713  
Wouter Meulemans

## TABLE OF CONTENTS

<i>A Stable Graph Layout Algorithm for Processes</i>	725
Robin J. P. Mennens, Roeland Scheepens, and Michel A. Westenberg	
<i>A Random Sampling <math>O(n)</math> Force-calculation Algorithm for Graph Layouts</i>	739
Robert Gove	

## Author Index

Abbas, Mostafa M. ....	225	Cui, Weiwei .....	213	Harrison, Lane .....	95
Abramov, David .....	491	Damborský, Jiří .....	441	Hauser, Helwig .....	569
Agus, Marco .....	53, 427	Das, Subhajit .....	185	Heer, Jeffrey ...	67, 145, 541, 687
Aigner, Wolfgang .....	699	De, Suranjan .....	95	Hege, Hans-Christian .....	273
Al-Awami, Ali K. ....	427	Demiralp, Çağatay .....	529	Heidrich, Raimund .....	25
Al-maneea, Hayder Mahdi ...	79	Dextras-Romagnino, K. ....	623	Heimerl, Florian .....	185
Ammi, Mehdi .....	553, 635	Dortmont, Martijn van .....	387	Heinzl, Christoph .....	273
Amstutz, Jefferson .....	455	Dou, Wenwen .....	161	Hildebrandt, Klaus .....	413
Angelini, Marco .....	237	Ebert, David S. ....	131, 375	Hofmann, Lutz .....	261
Arleo, Alessio .....	107	Elberfeld, Tim .....	273	Höllt, Thomas .....	569
Artanegara, Cassia .....	491	Elmqvist, Niklas ...	249, 375, 649	Horak, Tom .....	649
Aupetit, Michaël .....	225	Elzen, Stef van den .....	387	Horváth, Zsolt .....	25
Bajardi, Paolo .....	609	Emrich, Štefan .....	699	Hotz, Ingrid .....	337, 479
Baker, Allison H. ....	517	Endert, Alex .....	185, 663	Humayoun, Shah Rukh .....	185
Ballester-Ripoll, Rafael .....	119	Ertl, Thomas .....	595	Hutter, Marco .....	401
Balsamo, Duilio .....	609	Falk, Martin .....	479	Igarashi, Takeo .....	13
Battle, Leilani .....	145, 529	Federico, Paolo .....	107	Isenberg, Tobias .....	553, 635
Beenhouwer, Jan De .....	273	Filipov, Velitchko Andreev ...	107	Ivanov, Nikolay .....	595
Bensmail, Halima .....	225	Flueckiger, Barbara .....	119	Jankowai, Jochen .....	337
Bernard, Jürgen .....	401	Forbes, Angus G. ....	491	Jiang, Yuzhe .....	581
Besançon, Lonni .....	553, 635	Frankenberg-Garcia, Ana .....	79	Johnson, Chris R. ....	467
Bors, Christian .....	401	Fröhler, Bernhard .....	273	Jun, Eunice .....	67
Böttinger, Michael .....	505	Fu, Wai-Tat .....	173	Jung, Sanghun .....	249
Brownlee, Carson .....	455	Garnett, Roman .....	41	Kakar, Tabassum .....	95
Buchmüller, Juri .....	237	Gebre, Binyam .....	1	Kale, Alex .....	687
Burchett, Joseph N. ....	491	Gerrits, Tim .....	325	Kappe, Christopher P. ....	505
Butcher, Peter W. S. ....	79	Giesen, Joachim .....	351	Karduni, Alireza .....	161
Buttinger-Kreuzhuber, A. ....	25	Gleicher, Michael .....	185	Karimzadeh, Morteza .....	375
Byška, Jan .....	441	Gobbetti, Enrico .....	53, 427	Kastner, Johann .....	273
Caballero, Humberto S. G. ....	1	Gobbo, Beatrice .....	609	Keim, Daniel A. ....	237
Calì, Corrado .....	427	Goldgruber, Eva .....	699	Kim, Byungsoo .....	285
Cashman, Dylan .....	185	Gove, Robert .....	739	Kim, Younghoon .....	541
Chang, Remco .....	185, 529	Grassinger, Florian .....	699	Klaus, Julien .....	351
Chang, Youli .....	201	Grønbaek, Kaj .....	649	Klokmoose, Clemens N. ....	649
Chen, Min .....	131	Günther, Johannes .....	455	Kohlhammer, Jörn .....	401
Cho, Isaac .....	161	Günther, Tobias .....	285	Konev, Artem .....	25
Choi, Jinho .....	249	Gutounig, Robert .....	699	Kottravel, Sathish .....	479
Choo, Jaegul .....	249	Hadwiger, Markus .....	427	Kozlíková, Barbora .....	441
Ciuccarelli, Paolo .....	609	Halter, Gaudenz .....	119	Krueger, Robert .....	595
Conlen, Matthew .....	687	Hammerling, Dorit M. ....	517	Laue, Sören .....	351
Cornel, Daniel .....	25	Han, Mengjiao .....	467	Lawonn, Kai .....	413
Correll, Michael .....	541	Han, Qi .....	595	Leitte, Heike .....	311, 505
Creem-Regehr, Sarah H. ....	363	Hansen, Charles D. ....	467	Lelieveldt, Boudewijn P. F. ...	569

## Author Index

Lew, Robert	79	Pfeifer, Hendrik	401	Telea, Alexandru	581
Li, Qisheng	67	Pfister, Hanspeter	595	Theisel, Holger	325
Linares, Mathieu	479	Preim, Bernhard	413	Thom, Dennis	595
Liu, Xiaoyu	529	Prochaska, Jason Xavier	491	Thompson, John R.	185
Liu, Yang	67	Qin, Xiao	95	Trautner, Thomas	441
L'Yi, Sehi	201	Qu, Huamin	213	Turton, Terece L.	517
Ma, Kwan-Liu	297	Quinan, P. Samuel	363	Usher, Will	455, 467
Magistretti, Pierre J.	427	Rees, Geraint Paul	79	Vilanova, Anna	569
Mahtal, Sanae	595	Reinemuth, Heiko	401	Wald, Ingo	455, 467
Marques, Sérgio M.	441	Rieck, Bastian	311	Waldner, Manuela	441
Marton, Fabio	53	Rind, Alexander	699	Wan, Ran	41
Masood, Talha Bin	479	Roberts, Jonathan C.	79	Wang, Bei	337
Mathisen, Andreas	649	Rössl, Christian	325	Wang, Feng	467
Mauri, Michele	609	Rundensteiner, Elke A.	95	Wang, Xiyao	635
Mennens, Robin J. P.	725	Sadlo, Filip	261, 311	Wang, Yedi	529
Meschenmoser, Philipp	237	Sahoo, Sanjay K.	95	Waser, Jürgen	25
Metoyer, Ronald	675	Saket, Bahador	185, 663	Weissenböck, Johannes	273
Meulemans, Wouter	713	Santhanam, Sashank	161	Wesslen, Ryan	161
Meuschke, Monique	413	Santucci, Giuseppe	237	Westenberg, Michel A.	1, 725
Meyer, Miriah	363	Sauer, Franz	297	Wickenhöfer, Ralph	413
Miksch, Silvia	107	Scheepens, Roeland	725	Wijk, Jarke J. van	1, 387
Mizuno, Kazuyo	13	Schreck, Ferdinand	351	Wimmer, Michael	25
Möller, Torsten	273	Sedlmair, Michael	225, 699	Wu, Hsiang-Yun	13
Mosca, Abigail	185	Seo, Jinwook	201	Wu, Qi	467
Munzner, Tamara	623	Sereno, Mickael	553	Wu, Yanhong	213
Neuroth, Tyson A.	297	Shaikh, Samira	161	Yau, Calvin	375
Ottley, Alvitta	41, 675	Sharma, Nirwan	79	Yen, Chi-Hsien Eric	173
Otto, Jasmine Tan	491	Shen, Qiaomu	581	Yu, Lingyun	553
Padilla, Lace M. K.	363	Shin, DongHwa	201	Zeng, Wei	581
Pajarola, Renato	119	Sijbers, Jan	273	Zhang, Haidong	213
Panisson, André	609	Stasko, John	185	Zhang,, Dongmei	213
Parameswaran, Aditya	173	Stoiber, Christina	699	Zhao, Xun	213
Park, Deok Gun	249	Stonebraker, Michael	529	Zheng, Boyan	311
Park, Kendall	185	Surakitbanharn, Chittayong	375	Zhi, Qiyu	675
Pascucci, Valerio	455, 467	Takahashi, Shigeo	13		
Pezzotti, Nicola	569	Tao, Wenbo	529		

## Invited Talk: Keynote

# Let Me Tell You a Story: Enabling Effective and Scalable Communication of Scientific Insights

*Paul A. Navrátil*

### Abstract

From time before history, humans have used imagery to shape ideas and communicate important concepts to their communities. Visualization harnesses this fundamental mode through transforming raw data into images that present actionable insights and discoveries to advance human understanding. Yet, even as techniques in scivis, infovis, and vis analytics progress, the effective application of these techniques to solve analysis problems remains very much an art plied by specialized visualization experts who understand both the tools and how to best wield them. As our data sources multiply, and the commensurate need for analysis of those data expand, relying solely on vis experts will not scale. The visualization community will need to provide simple, reliable, and expressive tools so that domain scientists can generate high-quality visualizations sooner in their discovery pipelines, challenging visualization experts to expand the state of the art in translating research to practice. This talk will present challenges to this vision and potential transformative solutions in the context of work at the Texas Advanced Computing Center and peer institutions world-wide.

### Short Biography

Dr. Paul A. Navrátil is a Research Scientist and Director of Visualization at the Texas Advanced Computing Center (TACC) at the University of Texas at Austin. He is an expert in high-performance visualization technologies, accelerator-based computing and advanced rendering techniques. His research seeks to improve analytic capacity and insight communication across scientific workflows, including efficient algorithms for large-scale parallel visualization and data analysis (VDA) and innovative design for immersive VDA systems. Dr. Navrátil's recent work includes algorithms for large-scale distributed-memory ray tracing, including the GraviT and Galaxy ray tracing frameworks, which enable photo-realistic rendering of the largest datasets produced on supercomputers today. His team provisions TACC's two visualization labs and the remote visual analytic environments on TACC's advanced computing systems, including the US NSF leadership-class systems Stampede2 and Frontera. Dr. Navrátil's work has been featured in numerous venues, both nationally and internationally, including the New York Times, Discover, and PBS News Hour. He holds BS, MS and Ph.D. degrees in Computer Science and a BA degree in Plan II Interdisciplinary Honors from the University of Texas at Austin.

## Invited Talk: Capstone

### Visualization is Not Enough

*Jeffrey Heer*

#### Abstract

We are witnessing both increased application and public skepticism of data-driven methods for decision making and automation. Within this regime, data visualization — as a technology — seems well-poised to provide valuable insight and oversight. Though arguably a *\*necessary\** component in the appropriate use of data, visualization by itself is far from *\*sufficient\**. Data visualization — as a community of practice — sits at the confluence of many “source” disciplines, including cartography, computer science, graphic design, psychology, and statistics. The practice of principled interdisciplinary thinking is perhaps our greatest asset, suggesting avenues for our community to have outsized, beneficial impact in the world. In this talk I will consider the obvious yet potentially contrarian view that *\*visualization is not enough\** — and why this realization is liberating for both research and practice. I will point to vanguards and future prospects in “visualization” research that I believe exemplify real-world relevance and require rich intellectual integration: accessibility, interactive visualization systems, reasoning under uncertainty, and interactions with machine learning models. One guiding heuristic we might consider is the degree to which we not only benefit from, but successfully contribute back to, the adjacent disciplines that fuel our endeavors. Our community is uniquely positioned to contribute to issues of critical importance to society. Let’s consider how we should rise to the challenge!

#### Short Biography

Jeffrey Heer is a Professor of Computer Science & Engineering at the University of Washington, where he directs the Interactive Data Lab and conducts research on data visualization, human-computer interaction and social computing. The visualization tools developed by Jeff and his collaborators (Vega, D3.js, Protovis, Prefuse) are used by researchers, companies, and data enthusiasts around the world. Jeff’s research papers have received awards at the premier venues in Human-Computer Interaction and Visualization (ACM CHI, UIST, CSCW, IEEE InfoVis, VAST, EuroVis). Honors include MIT Technology Review’s TR35 (2009), a Sloan Fellowship (2012), an Allen Distinguished Investigator Award (2014), a Moore Foundation Data-Driven Discovery Investigator Award (2014), the ACM Grace Murray Hopper Award (2016), and the IEEE Visualization Technical Achievement Award (2017). Jeff received B.S., M.S., and Ph.D. degrees in Computer Science from UC Berkeley, whom he then “betrayed” to join the Stanford faculty (2009–2013). He is also a co-founder of Trifacta, a provider of interactive tools for scalable data transformation.