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Petra Isenberg, Florian Heimerl, Steffen Koch, Tobias Isenberg, Panpan Xu,
Charles D. Stolper, Michael Sedlmair, Jian Chen, Torsten Möller, John Stasko

petra.isenberg@inria.fr

A BRIEF HISTORY OF IEEE VIS

1990

IEEE CONFERENCE ON VISUALIZATION (VIS)

1991

1992

1993

1994

1995

Proceedings

Information Visualization

Edited by

Nahum Gershon
Steve Eick

(published as part of the IEEE Visualization proceedings)

1996

Proceedings

IEEE Symposium on Information Visualization'96

October 28 — 29, 1996
San Francisco, California

Sponsored by

IEEE Computer Society Technical Committee on Computer Graphics

Edited by

Stuart Card

Stephen G. Eick

Nahum Gershon

1997

1998

1999

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2001

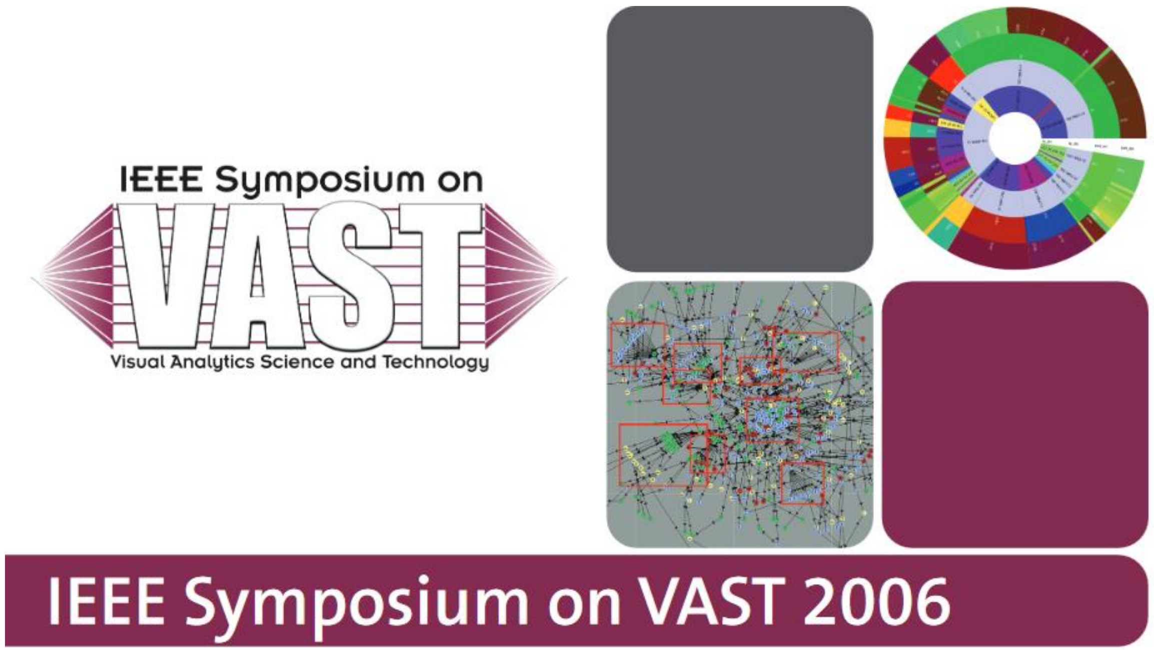
2002

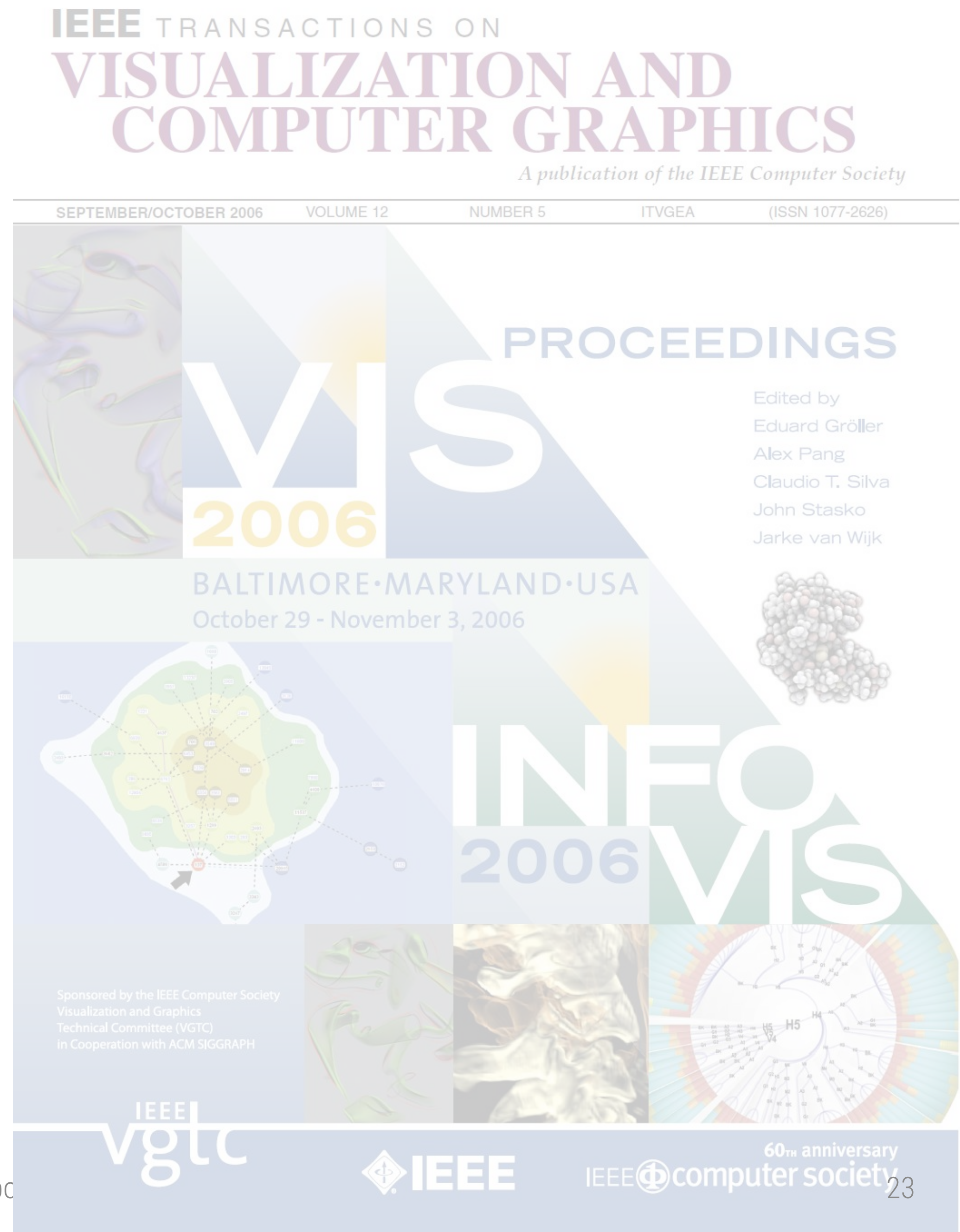
2003

2004

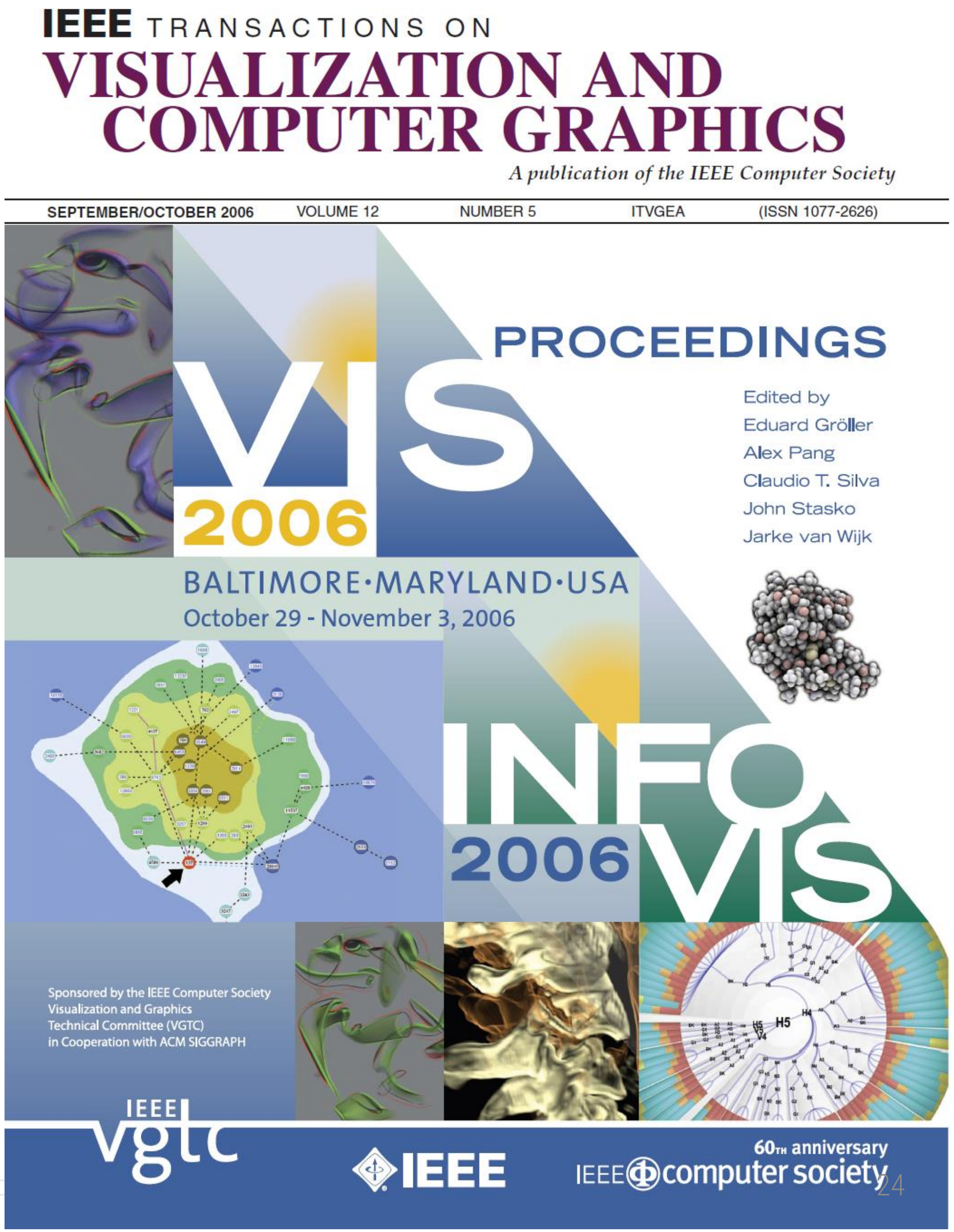
2005

2006


IEEE Symposium on
VAST
Visual Analytics Science and Technology
IEEE Symposium on VAST 2006


IEEE TRANSACTIONS ON
VISUALIZATION AND COMPUTER GRAPHICS
A publication of the IEEE Computer Society
SEPTEMBER/OCTOBER 2006 VOLUME 12 NUMBER 5 ITVGEA (ISSN 1077-2626)
PROCEEDINGS
VIS 2006
Edited by
Eduard Gröller
Alex Pang
Claudio T. Silva
John Stasko
Jarke van Wijk
BALTIMORE·MARYLAND·USA
October 29 - November 3, 2006
INFOVIS 2006
Sponsored by the IEEE Computer Society
Visualization and Graphics
Technical Committee (VGTC)
in Cooperation with ACM SIGGRAPH
IEEE vgtc
IEEE
60th anniversary
IEEE computer society

IEEE Symposium on
VAST
Visual Analytics Science and Technology
IEEE Symposium on VAST 2006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in Cooperation with ACM SIGGRAPH
IEEE
vgtc
IEEE
60th anniversary
IEEE computer society

2007

IEEE Transactions on Visualization and Computer Graphics

IEEE VISUALIZATION CONFERENCE AND

IEEE INFORMATION VISUALIZATION CONFERENCE

PROCEEDINGS 2007

2008


VisWeek 08
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Welcome
Vis • InfoVis • VAST
Week-at-a-Glance
VisWeek Sessions
Exhibition
Registration
Student Volunteers
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VisWeek 2008 is the premier forum for data
academia, government, and industry. This ev
with a shared interest in tools, techniques, an
include an exciting and informative collection
demonstrations, posters, and exhibitions. We
Visualization Conference (IEEE Vis), the
(IEEE InfoVis) and the IEEE Symposium

2009

2010

VAST 10

IEEE Conference on Visual Analytics Science and Technology 2010

Salt Lake City, Utah, USA

24 - 29 October, 2010

2011

2012

IEEE Transactions on Visualization and Computer Graphics

IEEE Scientific Visualization Conference,

IEEE Information Visualization Conference, and

IEEE Visual Analytics Science & Technology Conference

Proceedings 2012

SOME BUT NOT ALL VAST PAPERS

Seattle, Washington, USA
14 - 19 October 2012

2013

ALL PAPERS

IEEE *Transactions on Visualization and Computer Graphics*

IEEE Visual Analytics Science & Technology Conference,
IEEE Information Visualization Conference, and
IEEE Scientific Visualization Conference,
Proceedings 2013

Atlanta, Georgia, USA
13 - 18 October 2013


VIS 2013
VAST · INFOVIS · SCIVIS
13-18 OCTOBER 2013
ATLANTA, GEORGIA, USA

2014

VAST INTRODUCES CONFERENCE PAPERS

NOW HAS: CONFERENCE + JOURNAL PAPERS

2015

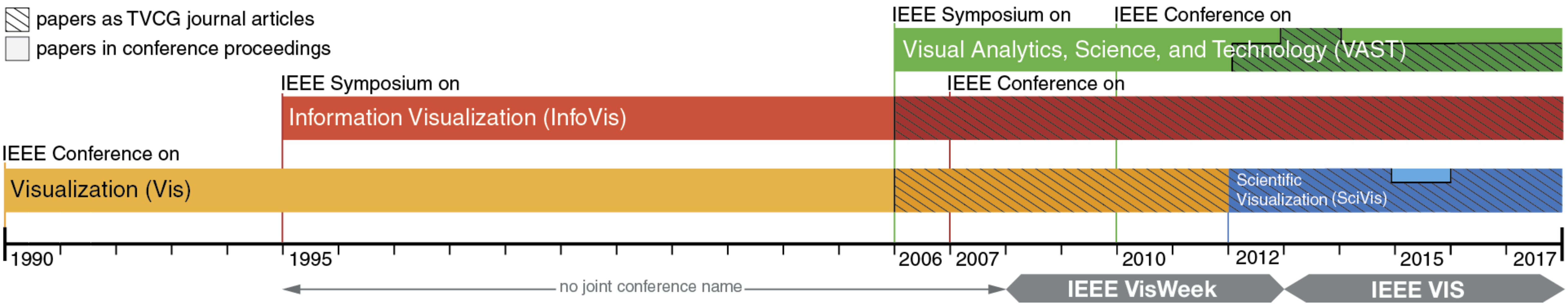
SCIVIS INTRODUCES CONFERENCE PAPERS

NOW HAS CONFERENCE + JOURNAL PAPERS

2016

SCIVIS PUBLISHES ONLY JOURNAL PAPERS

40 SLIDES IN ONE GRAPHIC



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IEEEXPLORE VIEW ON VAST

Visual Analytics Science and Technology (VAST), IEEE Symposium on
Publisher: IEEE

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2012 2012 IEEE Conference on Visual Analytics Science and Technology (VAST)
2011 2011 IEEE Conference on Visual Analytics Science and Technology (VAST)
2010 2010 IEEE Symposium on Visual Analytics Science and Technology
2009 2009 IEEE Symposium on Visual Analytics Science and Technology
2008 2008 IEEE Symposium on Visual Analytics Science and Technology
2007 2007 IEEE Symposium on Visual Analytics Science and Technology
2006 2006 IEEE Symposium On Visual Analytics Science And Technology

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Visual Analytics Science and Technology, IEEE Conference on
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2016 2016 IEEE Conference on Visual Analytics Science and Technology (VAST)
2015 2015 IEEE Conference on Visual Analytics Science and Technology (VAST)
2014 2014 IEEE Conference on Visual Analytics Science and Technology (VAST)

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Visual Analytics Science and Technology, IEEE Conference on
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- 2016 2016 IEEE Conference on Visual Analytics Science and Technology (VAST)
- 2015 2015 IEEE Conference on Visual Analytics Science and Technology (VAST)
- 2014 2014 IEEE Conference on Visual Analytics Science and Technology (VAST)

10

2013 IS PART OF TVCG

HERE: CONFERENCE PAPERS ONLY

Visual Analytics Science and Technology (VAST), IEEE Symposium on
Publisher: IEEE

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2012 2012 IEEE Conference on Visual Analytics Science and Technology (VAST)
2011 2011 IEEE Conference on Visual Analytics Science and Technology (VAST)
2010 2010 IEEE Symposium on Visual Analytics Science and Technology
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2016 2016 IEEE Conference on Visual Analytics Science and Technology (VAST)
2015 2015 IEEE Conference on Visual Analytics Science and Technology (VAST)
2014 2014 IEEE Conference on Visual Analytics Science and Technology (VAST)

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- Metadata on all IEEEVis papers from 1990 – 2016
- Google spreadsheet – can be commented, edited, & easily converted
- Cleaned titles, authors, DOIs

Vis	1990	Surface representations of two- and three-dimensional fluid	10.1109/VISUAL.1990.146359	http://dx.doi.org/10.1109/VISUAL.1990.146359	6	13, 460	C	The use of critical po	James Helman;Lambertus Hesseli	Stanford Univ., CA, USA|c|;	
Vis	1990	FAST: a multi-processed environment for visualization of co	10.1109/VISUAL.1990.146360	http://dx.doi.org/10.1109/VISUAL.1990.146360	14	27, 461	C	The authors discuss	Gordon V. Bancroft;Fergus Merrit	Sterling Federal Syst. Inc., Palo Alto, CA, USA|c|;;;;;	
Vis	1990	The VIS-5D system for easy interactive visualization	10.1109/VISUAL.1990.146361	http://dx.doi.org/10.1109/VISUAL.1990.146361	28	35, 462	C	The VIS-5D system p	William L. Hibbard;David A. Sante	Space Sci. & Eng. Center, Wisconsin Univ., Madison, WI, USA|c|;	
Vis	1990	A procedural interface for volume rendering	10.1109/VISUAL.1990.146362	http://dx.doi.org/10.1109/VISUAL.1990.146362	36	44, 462	C	The author presents	James L. Montine	Alliant Comput. Syst., Littleton, MA, USA|c|	
Vis	1990	Techniques for the interactive visualization of volumetric da	10.1109/VISUAL.1990.146363	http://dx.doi.org/10.1109/VISUAL.1990.146363	45	50, 462	C	Some ideas and tech	Gregory M. Nielson;Bernd Hamar	Dept. of Comput. Sci., A	10.1109/VISUAL.1990.146388
Vis	1990	Displaying voxel-based objects according to their qualitativ	10.1109/VISUAL.1990.146364	http://dx.doi.org/10.1109/VISUAL.1990.146364	51	58, 463	C	The use of qualitative	Yaser Yacoob	Dept. of Comput. Sci., Maryland Univ., College Park, MD, USA|c|	
Vis	1990	Interpreting a 3D object from a rough 2D line drawing	10.1109/VISUAL.1990.146365	http://dx.doi.org/10.1109/VISUAL.1990.146365	59	66	C	Visualizing the third	Del Lamb;Amit Bandopadhay	Dept. of Comput. Sci., State Univ. of New York, Stony Brook, NY, USA|c|;	
Vis	1990	Animation techniques for chain-coded objects	10.1109/VISUAL.1990.146366	http://dx.doi.org/10.1109/VISUAL.1990.146366	67	73	C	The animation of two	Anthony J. Maeder	Dept. of Comput. Sci., Monash Univ., Clayton, Vic., Australia|c|	
Vis	1990	Extracting geometric models through constraint minimizati	10.1109/VISUAL.1990.146367	http://dx.doi.org/10.1109/VISUAL.1990.146367	74	82, 464	C	The authors propose	James V. Miller;David E. Breen;Mi	Rensselaer Design. Res. Center, Rensselaer Polytech Inst., Troy, NY, USA|c|;;	
Vis	1990	Wide-band relativistic Doppler effect visualization	10.1109/VISUAL.1990.146368	http://dx.doi.org/10.1109/VISUAL.1990.146368	83	92, 465	C	The authors present	Ping-Kang Hsiung;Robert H. Thiba	Carnegie Mellon Univ., Pittsburgh, PA, USA|c|;;;;;	
Vis	1990	Dynamic graphics for network visualization	10.1109/VISUAL.1990.146369	http://dx.doi.org/10.1109/VISUAL.1990.146369	93	96, 467	C	The authors describe	Richard A. Becker;Stephen G. Eick	AT&T Bell Lab., Murray Hill, NJ, USA|c|;;;	
Vis	1990	Techniques for visualizing Fermat's last theorem: a ca	10.1109/VISUAL.1990.146370	http://dx.doi.org/10.1109/VISUAL.1990.146370	97	106, 46	C	The authors describe	Andrew J. Hanson;Pheng-Ann Hei	Indiana Univ., Bloomington, IN, USA|c|;;	
Vis	1990	Visualizing computer memory architectures	10.1109/VISUAL.1990.146371	http://dx.doi.org/10.1109/VISUAL.1990.146371	107	113	C	The authors describe	Bowen Alpern;Larry Carter;Ted Se	IBM Thomas J. Watson Res. Center, Yorktown Heights, NY, USA|c|;;	
Vis	1990	A methodology for scientific data visualisation: choosing re	10.1109/VISUAL.1990.146372	http://dx.doi.org/10.1109/VISUAL.1990.146372	114	123	C	A methodology for gu	Philip K. Robertson	CSIRO, Canberra, ACT, Australia|c|	
Vis	1990	Moving iconic objects in scientific visualization	10.1109/VISUAL.1990.146373	http://dx.doi.org/10.1109/VISUAL.1990.146373	124	130, 46	C	The idea of independ	G. David Kerlick	Tektronix Labs., Beaverton, OR, USA|c|	
Vis	1990	Classifying visual knowledge representations: a foundation	10.1109/VISUAL.1990.146374	http://dx.doi.org/10.1109/VISUAL.1990.146374	131	138	C	An exploratory effort	Gerald L. Lohse;Henry H. Rueter;K	Cognitive Sci. & Machine Intelligence Lab., Michigan Univ., Ann Arbor, MI, USA|c|;;;	
Vis	1990	A problem-oriented classification of visualization technique	10.1109/VISUAL.1990.146375	http://dx.doi.org/10.1109/VISUAL.1990.146375	139	143, 46	C	Progress in scientific	Stephen Wehrend;Clayton Lewis	Colorado Univ., Boulder, CO, USA|c|;	
Vis	1990	Visualization and three-dimensional image processing of p	10.1109/VISUAL.1990.146376	http://dx.doi.org/10.1109/VISUAL.1990.146376	144	149, 46	C	The author applied in	Nahum D. Gershon	MITRE Corp., McLean, VA, USA|c|	
Vis	1990	Applying space subdivision techniques to volume rendering	10.1109/VISUAL.1990.146377	http://dx.doi.org/10.1109/VISUAL.1990.146377	150	159, 47	C	We present a new ra	Kalpathi R. Subramanian;Donald S	;	
Vis	1990	Volume visualization in cell biology	10.1109/VISUAL.1990.146378	http://dx.doi.org/10.1109/VISUAL.1990.146378	160	168, 47	C	The authors discuss	Arie E. Kaufman;Roni Yagel;Reuve	Dept. of Comput. Sci., State Univ. of New York, Stony Brook, NY, USA|c|;;;	
Vis	1990	Hierarchical triangulation using terrain features	10.1109/VISUAL.1990.146379	http://dx.doi.org/10.1109/VISUAL.1990.146379	168	175	C	A hierarchical triangu	Lori L. Scarlatos;Theodosios Pavlid	Grumman Data Syst., Woodbury, NY, USA|c|;	
Vis	1990	Rendering and managing spherical data with sphere quadtr	10.1109/VISUAL.1990.146380	http://dx.doi.org/10.1109/VISUAL.1990.146380	176	186	C	The sphere quadtree	Gyorgy Fekete	NASA, Goddard Space Flight Center, Greenbelt, MD|c|	
Vis	1990	Methods for surface interrogation	10.1109/VISUAL.1990.146381	http://dx.doi.org/10.1109/VISUAL.1990.146381	187	193, 47	C	The authors discuss	Hans Hagen;Thomas Schreiber;Er	Kaiserslautern Univ., Germany|c|;;	
Vis	1990	A three-dimensional/stereoscopic display and model contr	10.1109/VISUAL.1990.146382	http://dx.doi.org/10.1109/VISUAL.1990.146382	194	201, 47	C	A forecasting system	Chieh-Cheng Yen;Keith W. Bedfor	Dept. of Civil Eng., Ohio State Univ., OH, USA|c|;;;	
Vis	1990	Spline-based color sequences for univariate, bivariate and t	10.1109/VISUAL.1990.146383	http://dx.doi.org/10.1109/VISUAL.1990.146383	202	208, 47	C	Alternative models th	Binh Pham	Dept. of Comput. Sci., Monash Univ., Melbourne, Vic., Australia|c|	
Vis	1990	Interactive visualization of quaternion Julia sets	10.1109/VISUAL.1990.146384	http://dx.doi.org/10.1109/VISUAL.1990.146384	209	218, 47	C	The first half of a two	John C. Hart;Louis H. Kauffman;D	Electron. Visualization Lab., Illinois Univ., Chicago, IL, USA|c|;;	
Vis	1990	A journey into the fourth dimension	10.1109/VISUAL.1990.146385	http://dx.doi.org/10.1109/VISUAL.1990.146385	219	229, 47	C	It is shown that by a	Yan Ke;E. S. Panduranga	Dept. of Comput. Sci., Saskatchewan Univ., Saskatoon, Sask., Canada|c|;	
Vis	1990	Exploring N-dimensional databases	10.1109/VISUAL.1990.146386	http://dx.doi.org/10.1109/VISUAL.1990.146386	230	237	C	The ability of researc	Jeffrey LeBlanc;Matthew O. Ward	Worcester Polytech. Inst., MA, USA|c|;;	

TYPES OF ERRORS CORRECTED

MISSING PAPERS (47 ENTRIES MISSING FROM IEEEXPLORE)

INCORRECT DATA IN IEEEXPLORE (Titles, DOIs, …)

THE DATASET

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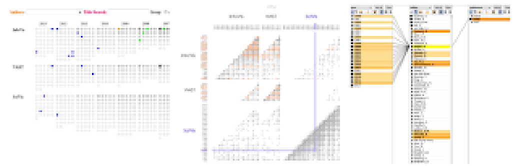
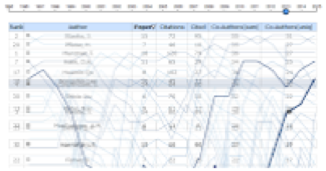
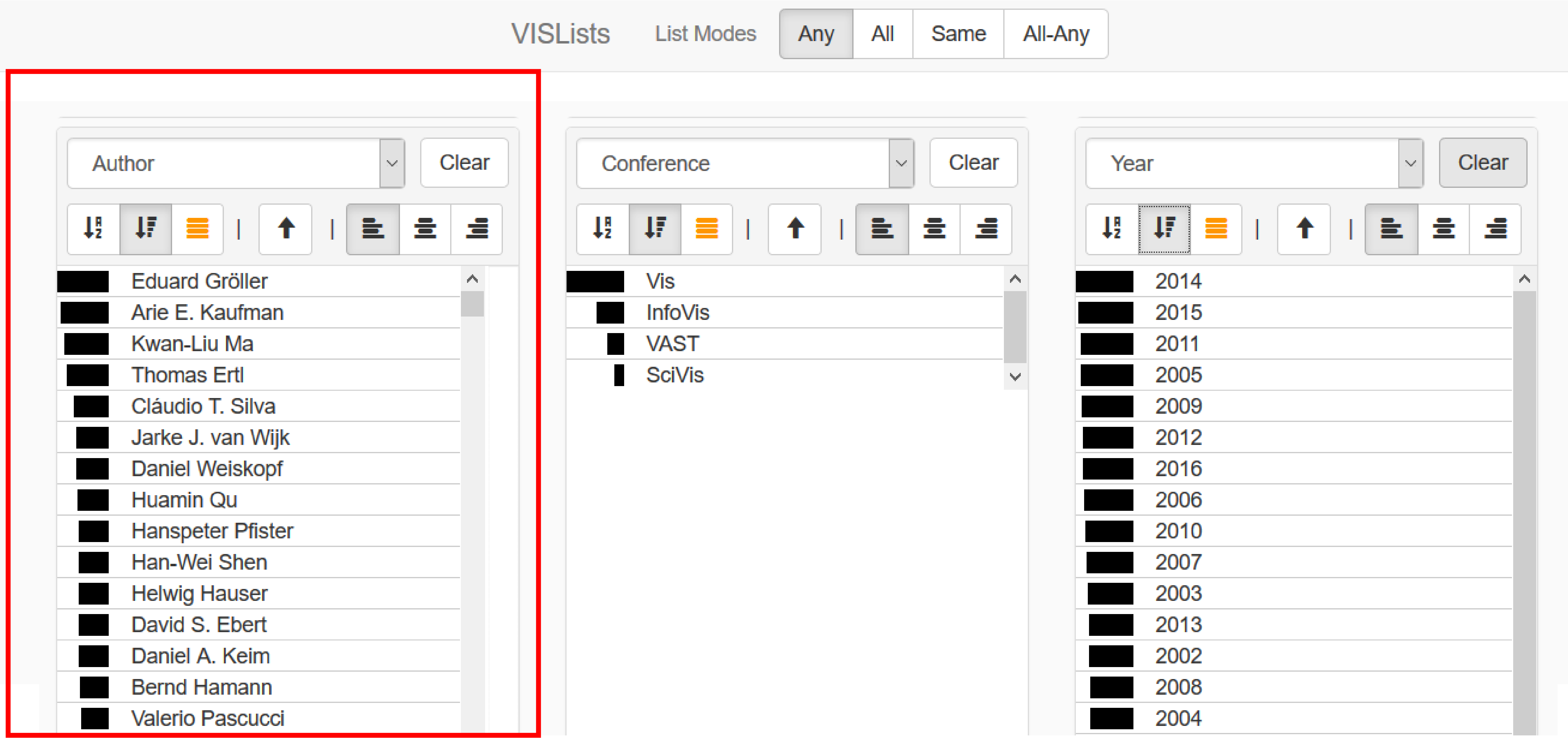
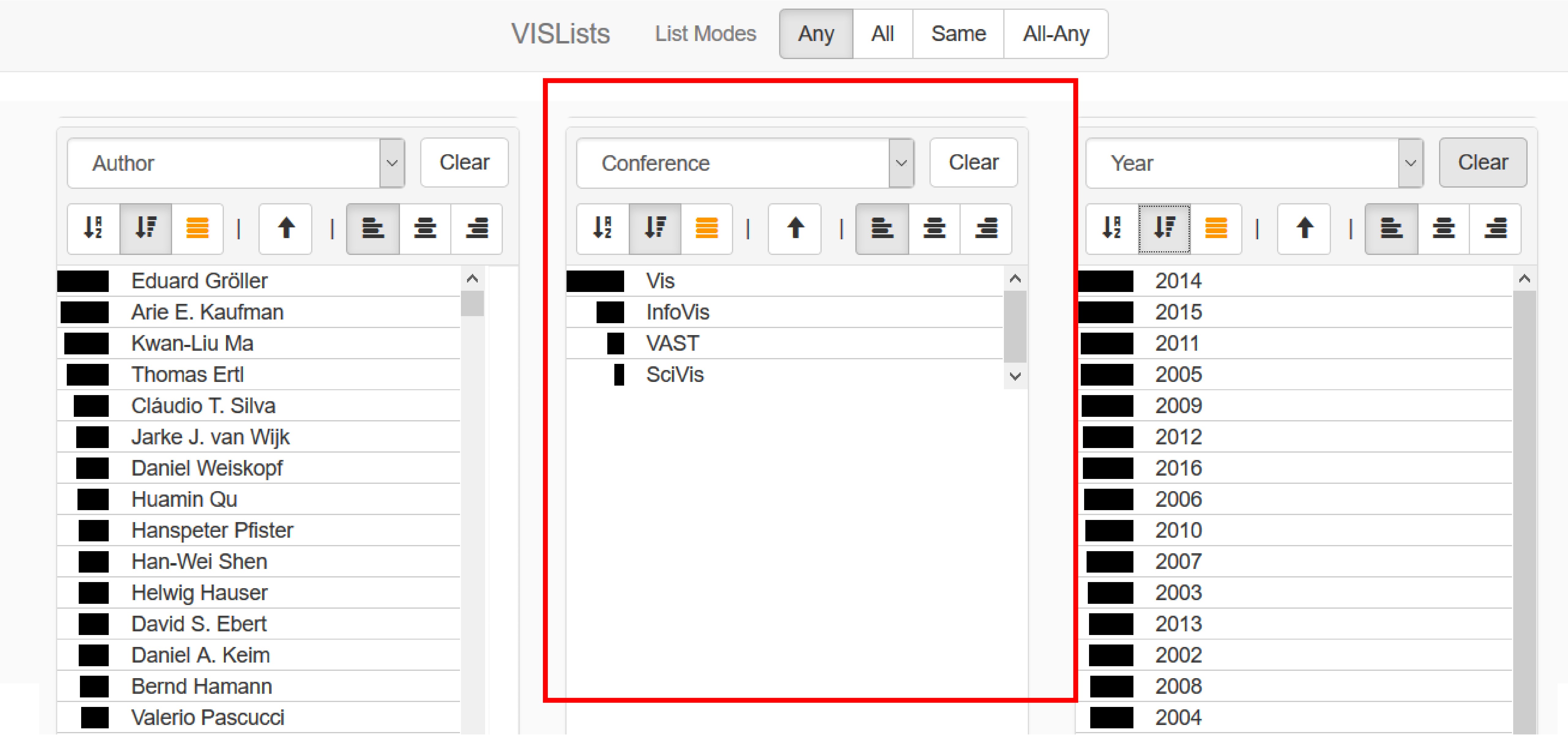
	CiteVis2 , CiteMatrix, VisLists (up to 2015) VisLists (incl. 2016)	Panpan Xu, Chad Stolper, Anand Sainath, John Stasko
	Keshif	M. Adil Yalçın
	A table	Chales Perin
	Paper quest	Ponsard et al. (link to paper pdf)

VISLISTS http://iilabgt.org/vislists/



Panpan Xu, Chad Stolper, Anand Sainath, John Stasko

VISLISTS http://iilabgt.org/vislists/



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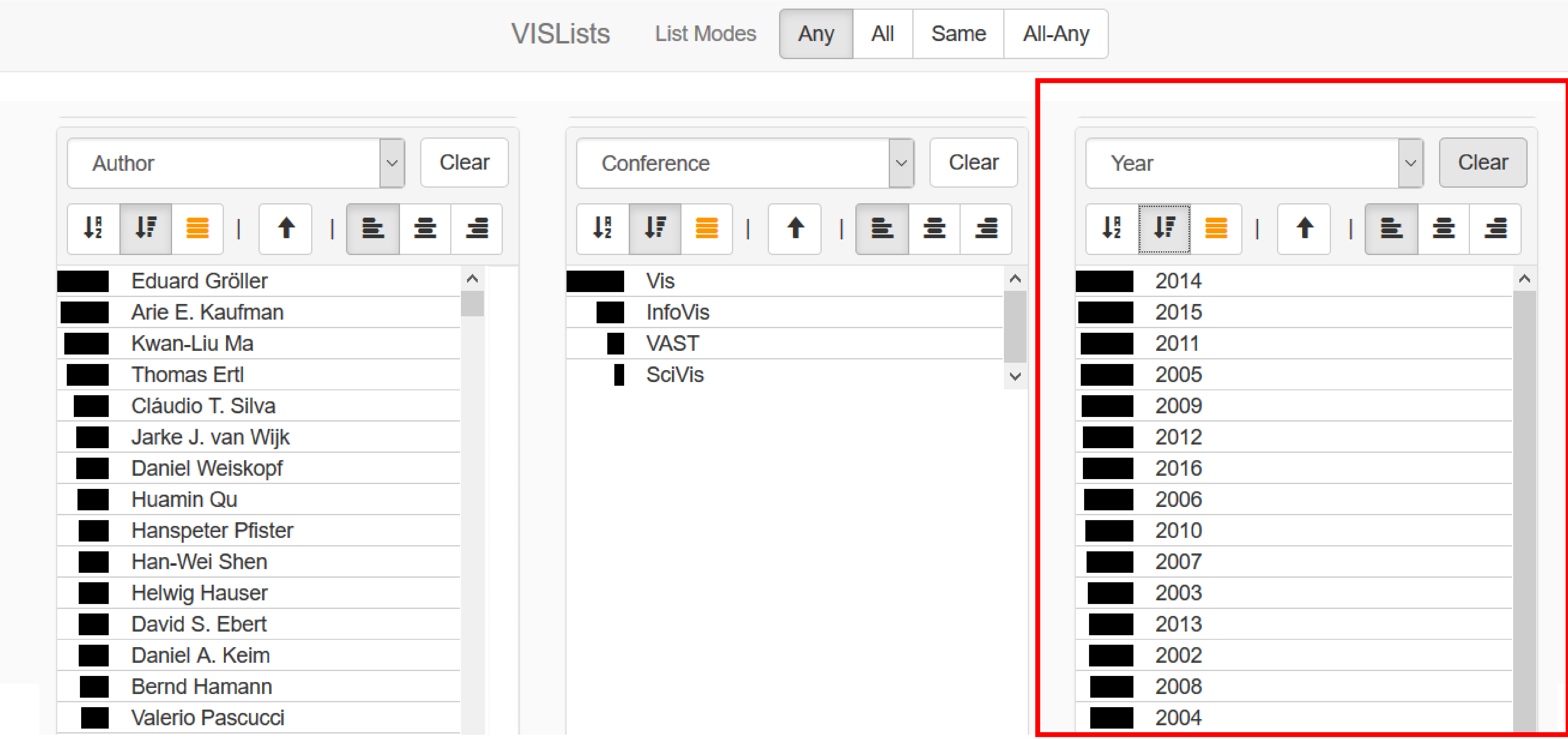

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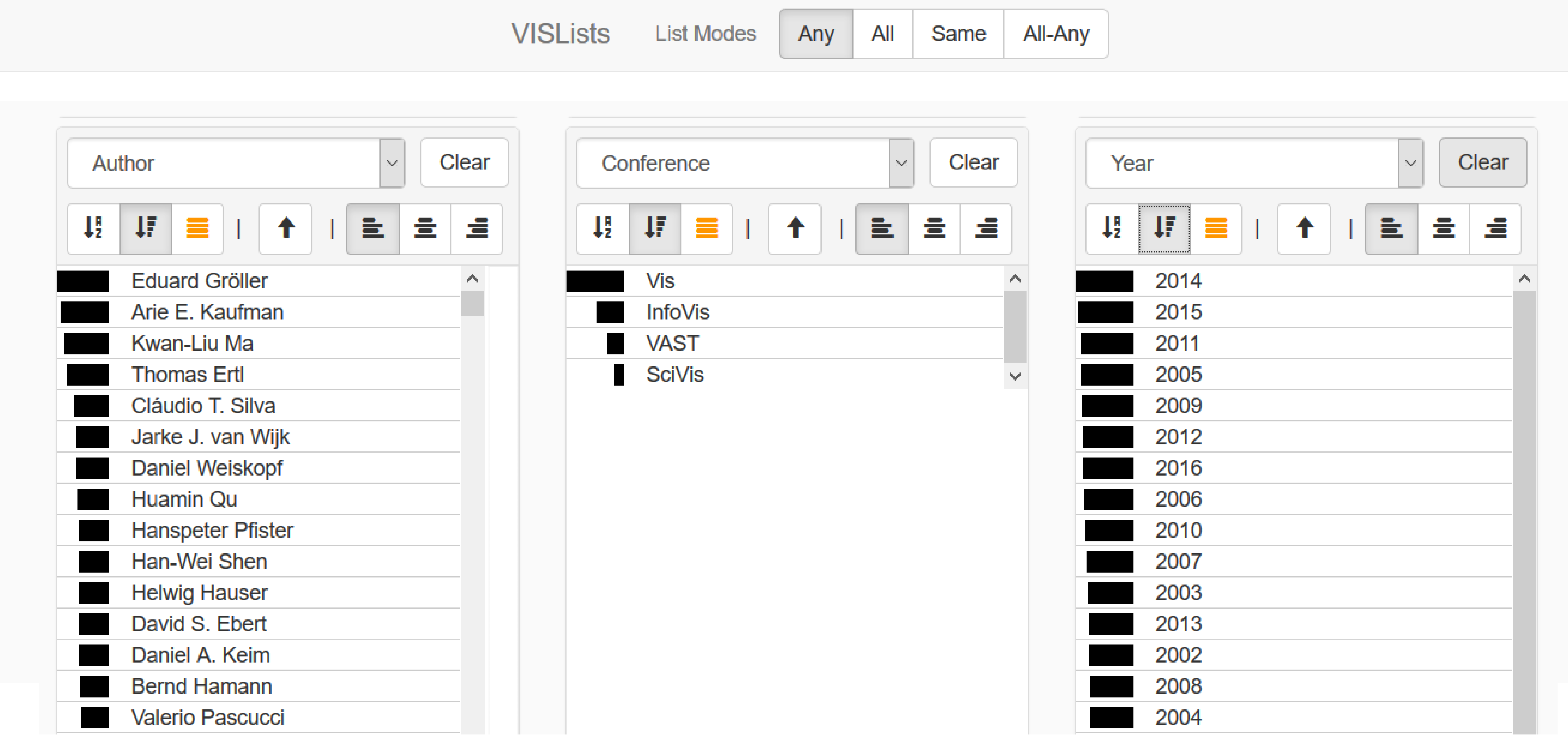

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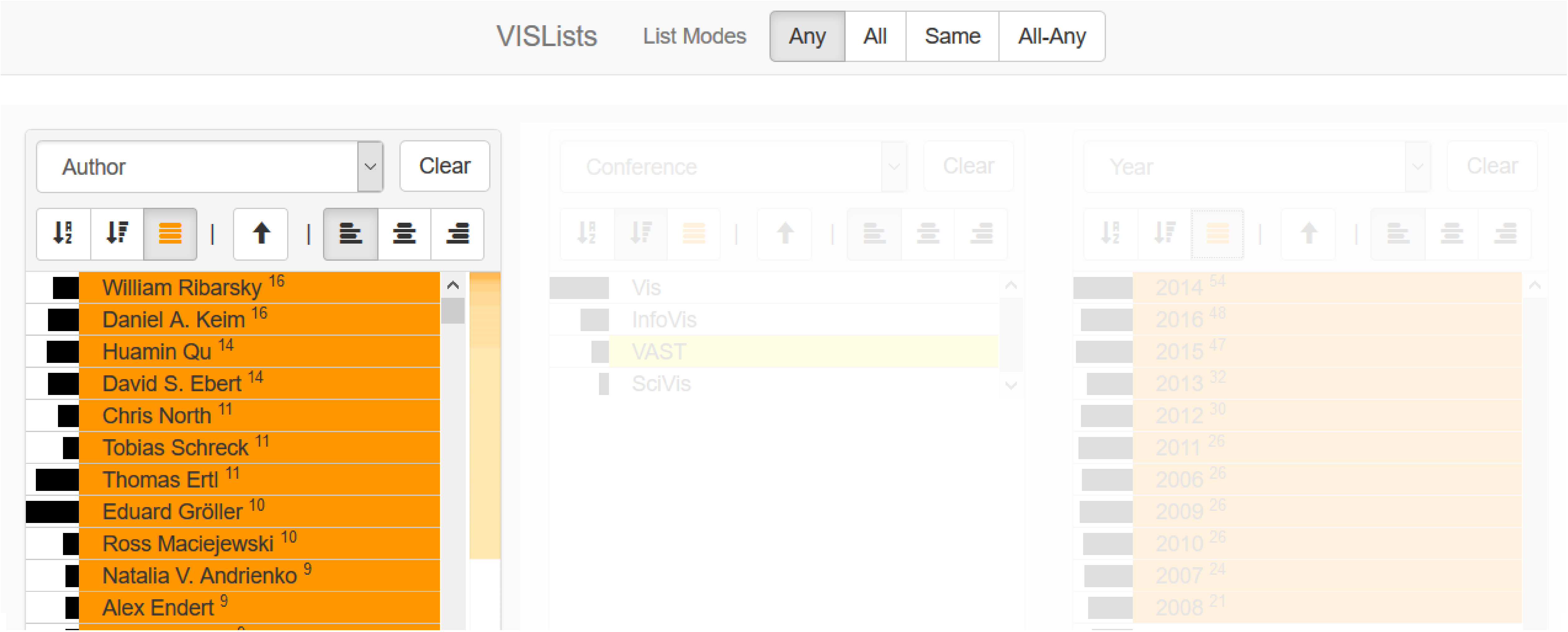

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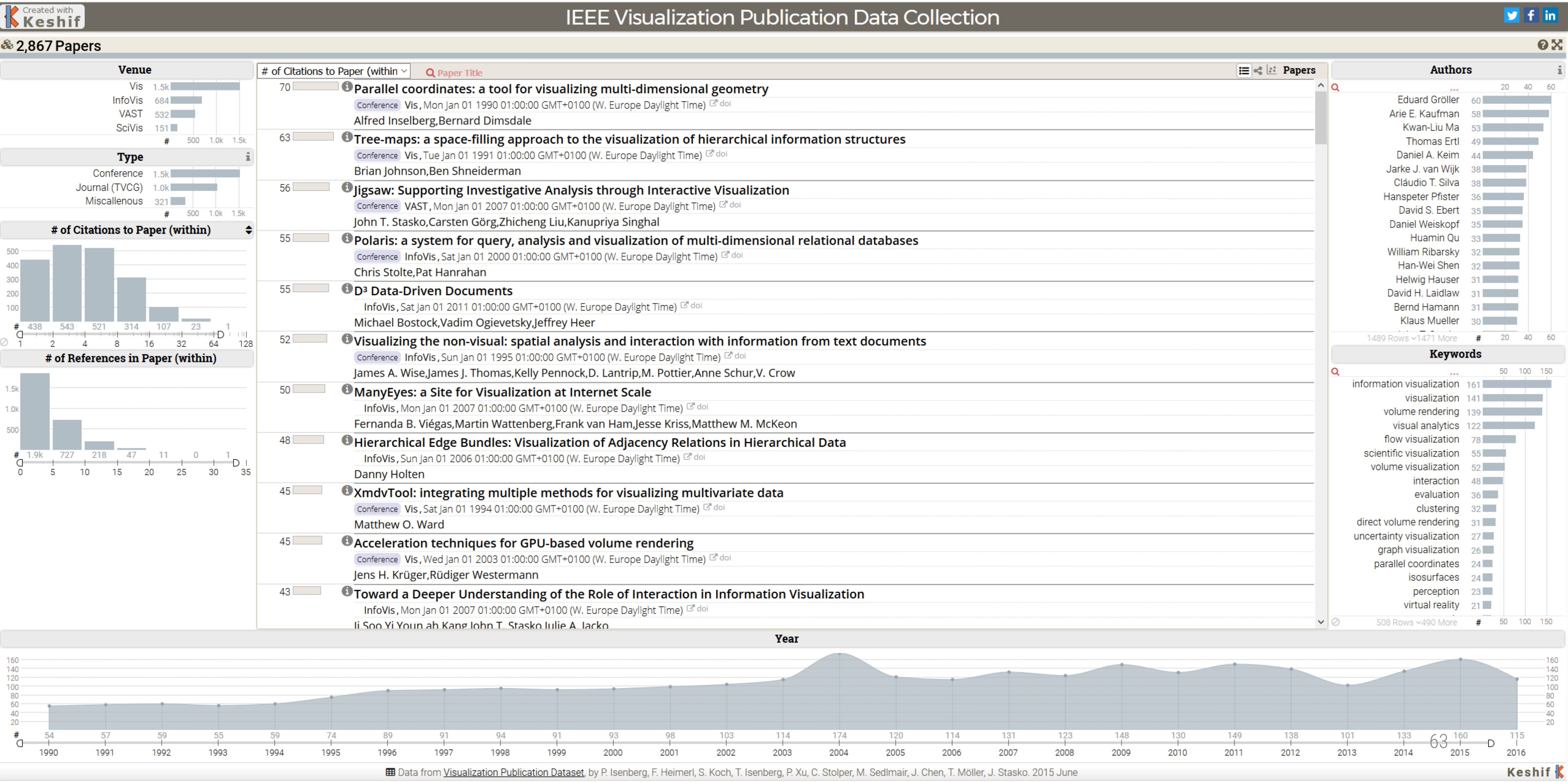

https://keshif.me/demo/vispubdata

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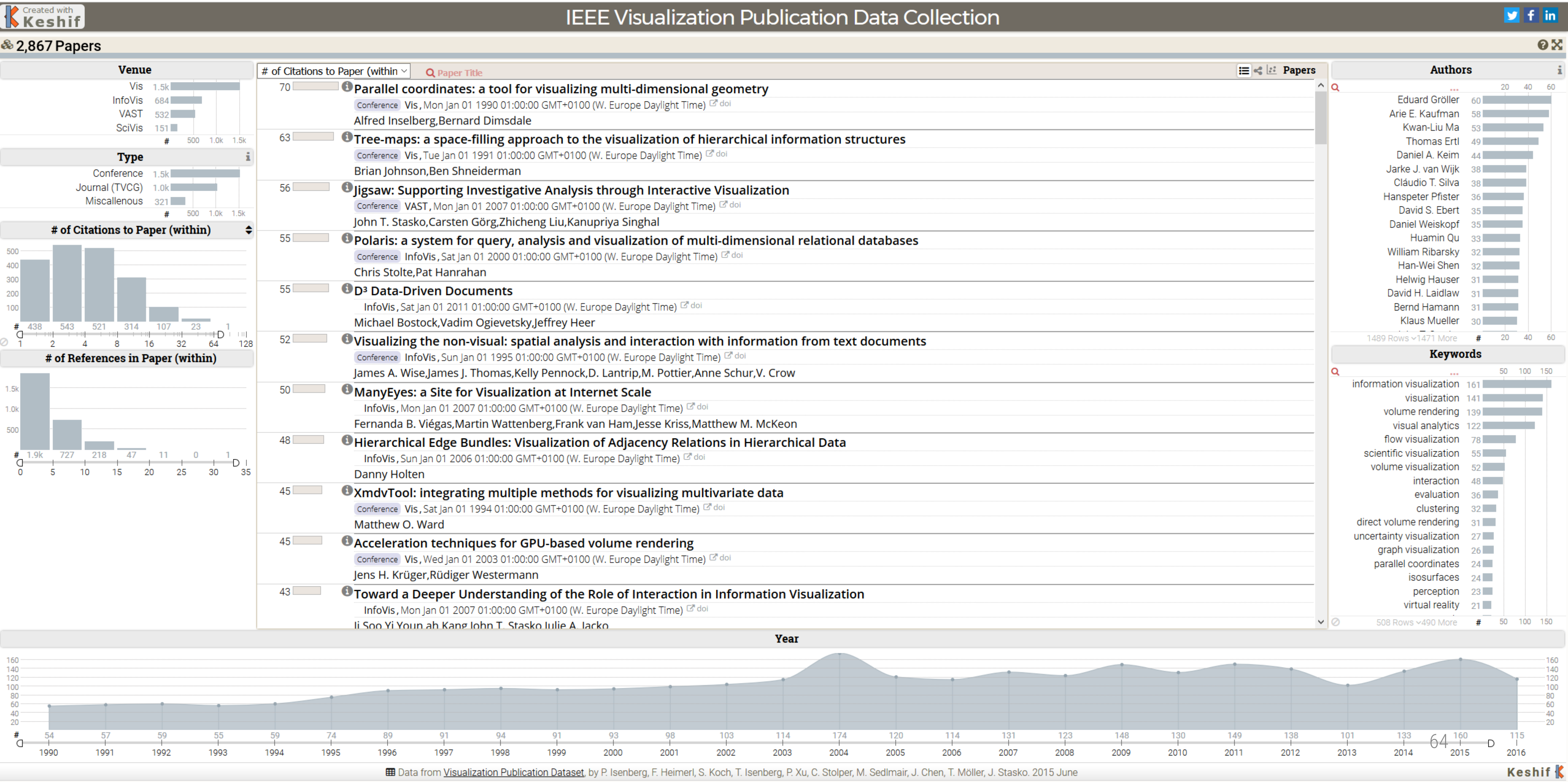

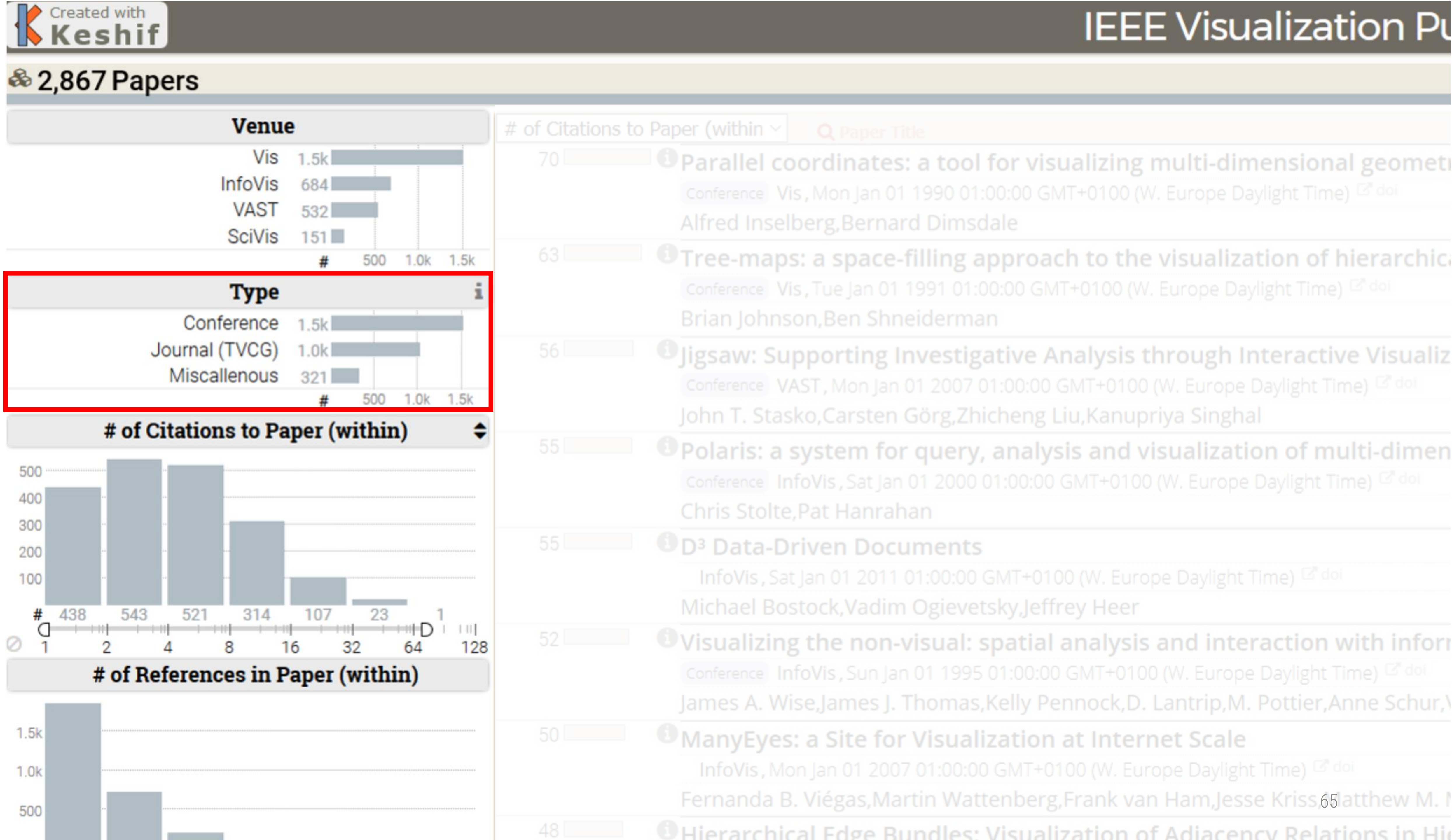
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70 Parallel coordinates: a tool for visualizing multi-dimensional geomet
Conference Vis, Mon Jan 01 1990 01:00:00 GMT+0100 (W. Europe Daylight Time)
Alfred Inselberg,Bernard Dimsdale
63 Tree-maps: a space-filling approach to the visualization of hierarchic
Conference Vis, Tue Jan 01 1991 01:00:00 GMT+0100 (W. Europe Daylight Time)
Brian Johnson,Ben Shneiderman
56 Jigsaw: Supporting Investigative Analysis through Interactive Visualiz
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John T. Stasko,Carsten Görg,Zhicheng Liu,Kanupriya Singhal
55 Polaris: a system for query, analysis and visualization of multi-dimen
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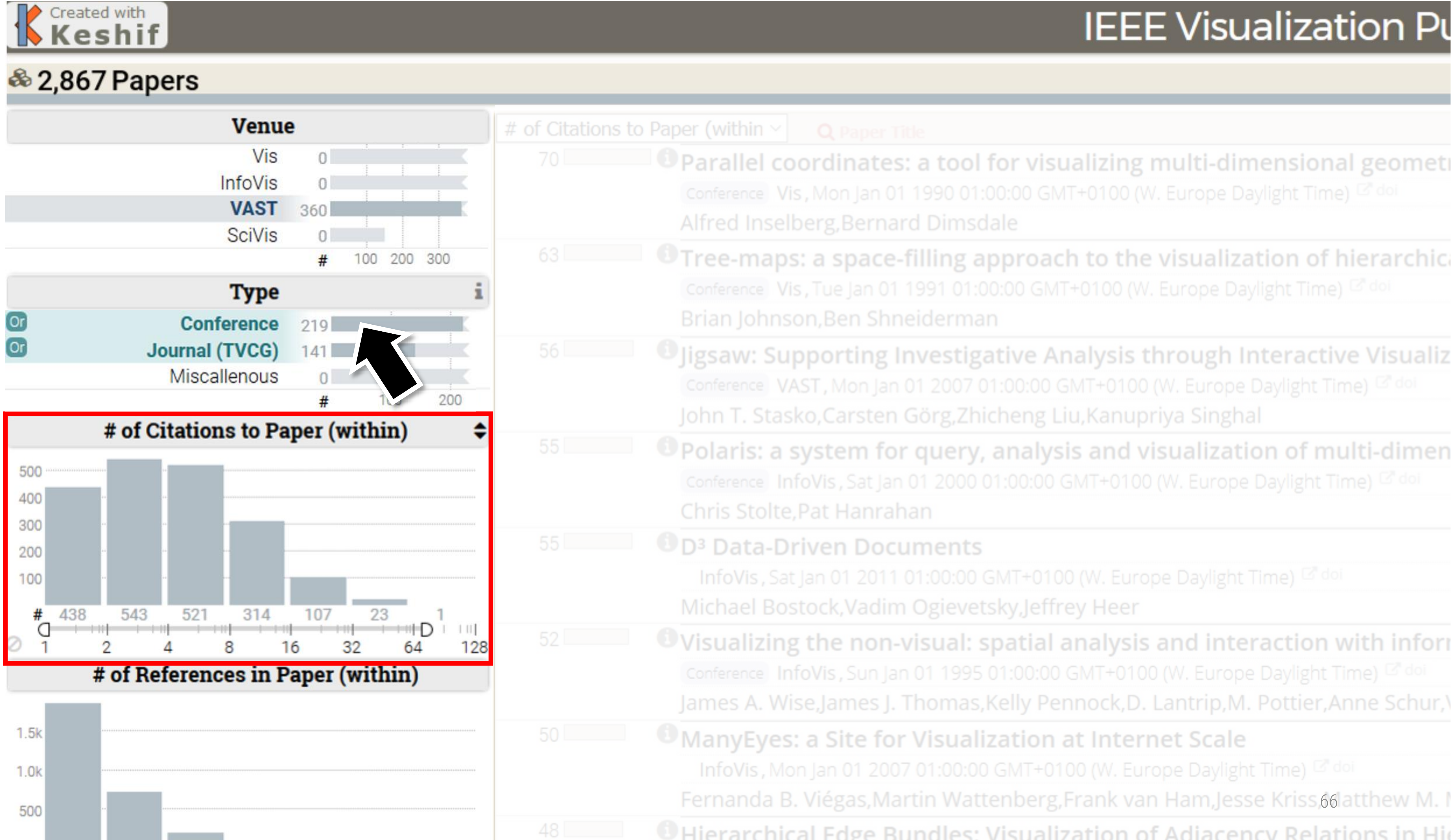
Chris Stolte,Pat Hanrahan
55 D³ Data-Driven Documents
InfoVis, Sat Jan 01 2011 01:00:00 GMT+0100 (W. Europe Daylight Time)
Michael Bostock,Vadim Ogievetsky,Jeffrey Heer
52 Visualizing the non-visual: spatial analysis and interaction with infor
Conference InfoVis, Sun Jan 01 1995 01:00:00 GMT+0100 (W. Europe Daylight Time)
James A. Wise,James J. Thomas,Kelly Pennock,D. Lantrip,M. Pottier,Anne Schur,
50 ManyEyes: a Site for Visualization at Internet Scale
InfoVis, Mon Jan 01 2007 01:00:00 GMT+0100 (W. Europe Daylight Time)
Fernanda B. Viégas,Martin Wattenberg,Frank van Ham,Jesse Kriss,Matthew M.
48 Hierarchical Edge Bundles: Visualization of Adjacency Relations in Hi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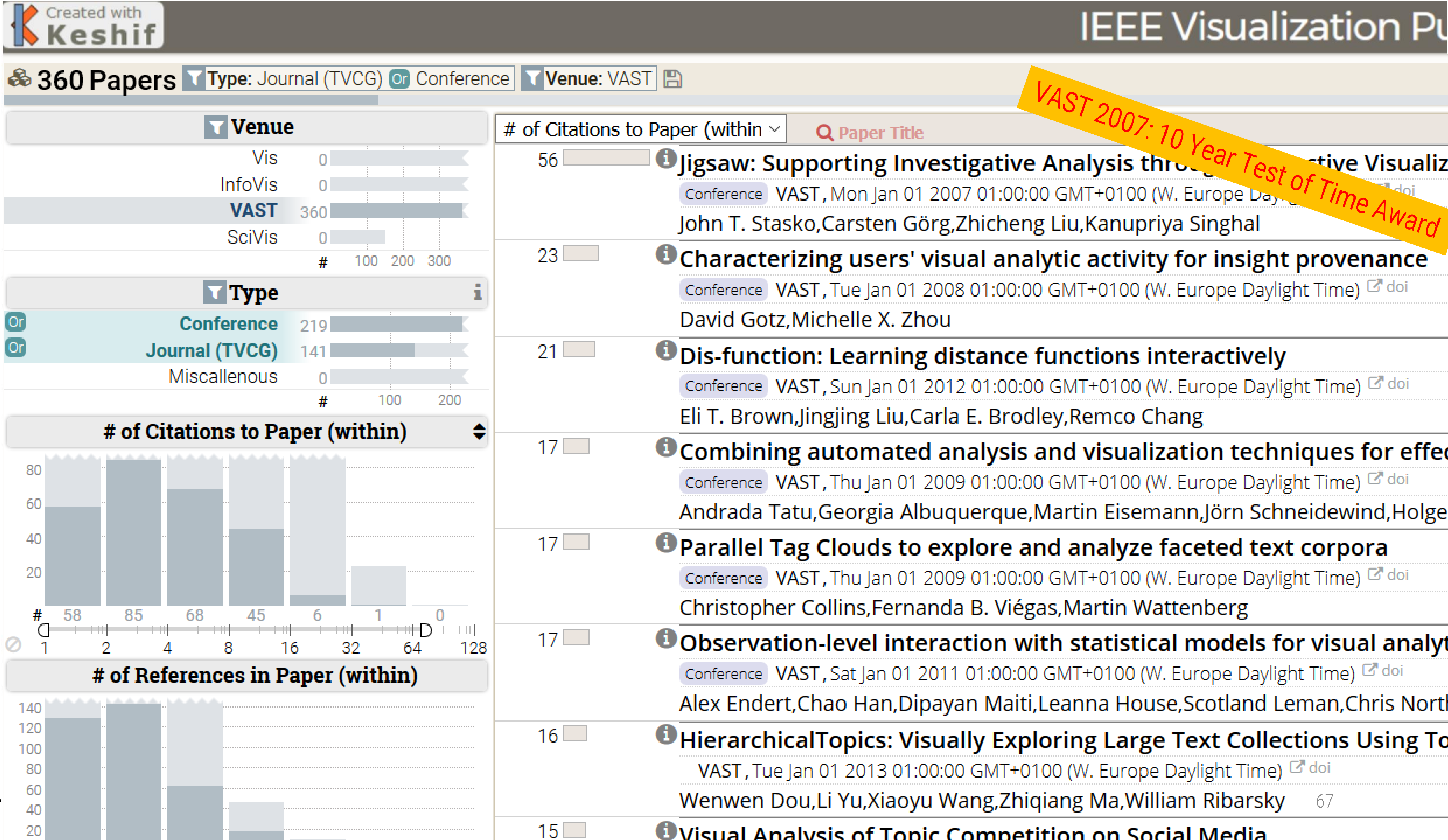
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Paper Title
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David Gotz,Michelle X. Zhou
21 Dis-function: Learning distance functions interactively
Conference VAST, Sun Jan 01 2012 01:00:00 GMT+0100 (W. Europe Daylight Time) doi
Eli T. Brown,Jingjing Liu,Carla E. Brodley,Remco Chang
17 Combining automated analysis and visualization techniques for effe
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Andrada Tatu,Georgia Albuquerque,Martin Eisemann,Jörn Schneidewind,Holge
17 Parallel Tag Clouds to explore and analyze faceted text corpora
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Christopher Collins,Fernanda B. Viégas,Martin Wattenberg
17 Observation-level interaction with statistical models for visual analyt
Conference VAST, Sat Jan 01 2011 01:00:00 GMT+0100 (W. Europe Daylight Time) doi
Alex Endert,Chao Han,Dipayan Maiti,Leanna House,Scotland Leman,Chris Nort
16 HierarchicalTopics: Visually Exploring Large Text Collections Using To
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Wenwen Dou,Li Yu,Xiaoyu Wang,Zhiqiang Ma,William Ribarsky 67
15 Visual Analysis of Topic Competition on Social Media

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Panpan Xu, Chad Stolper, Anand Sainath, John Stasko

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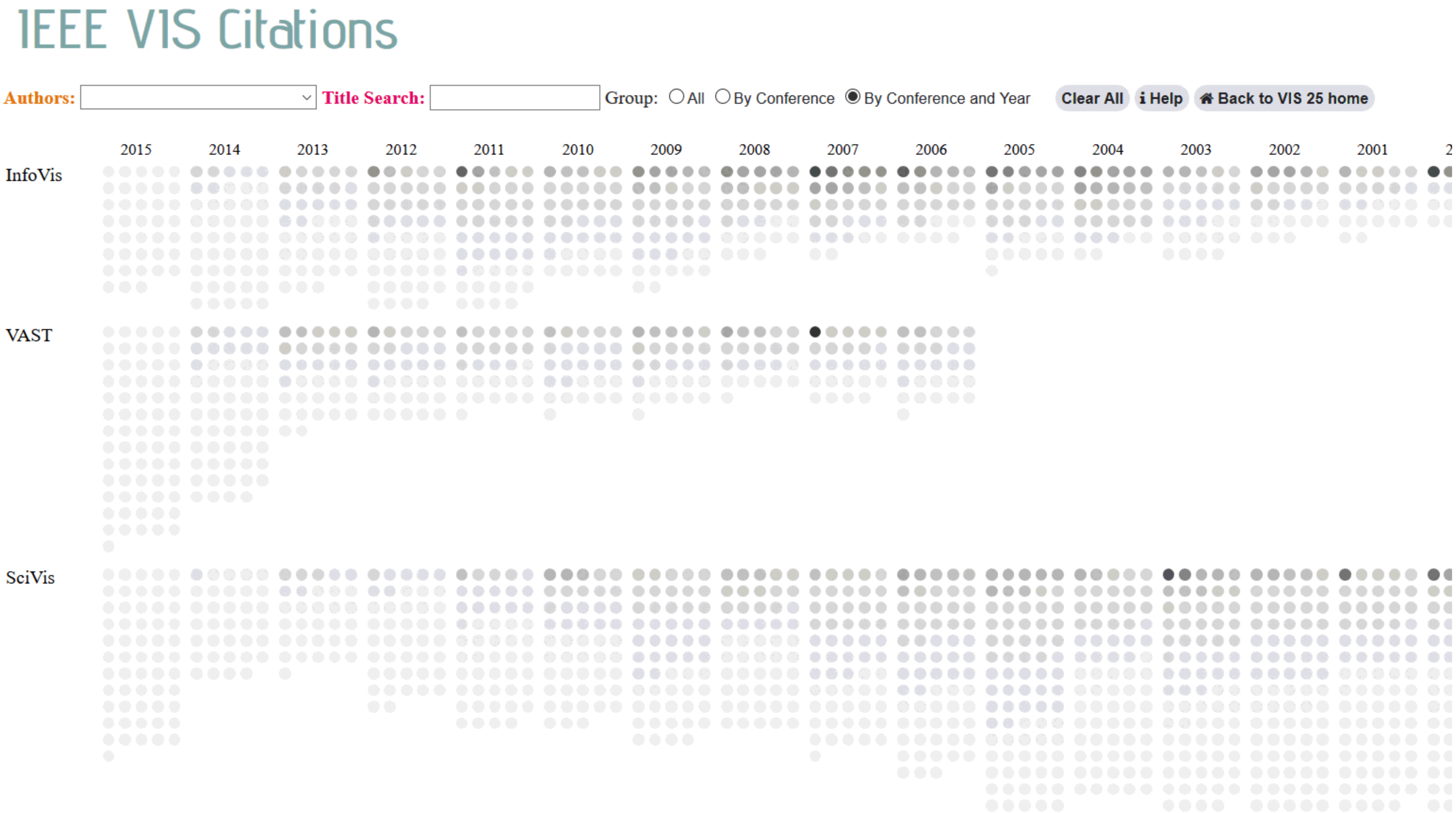

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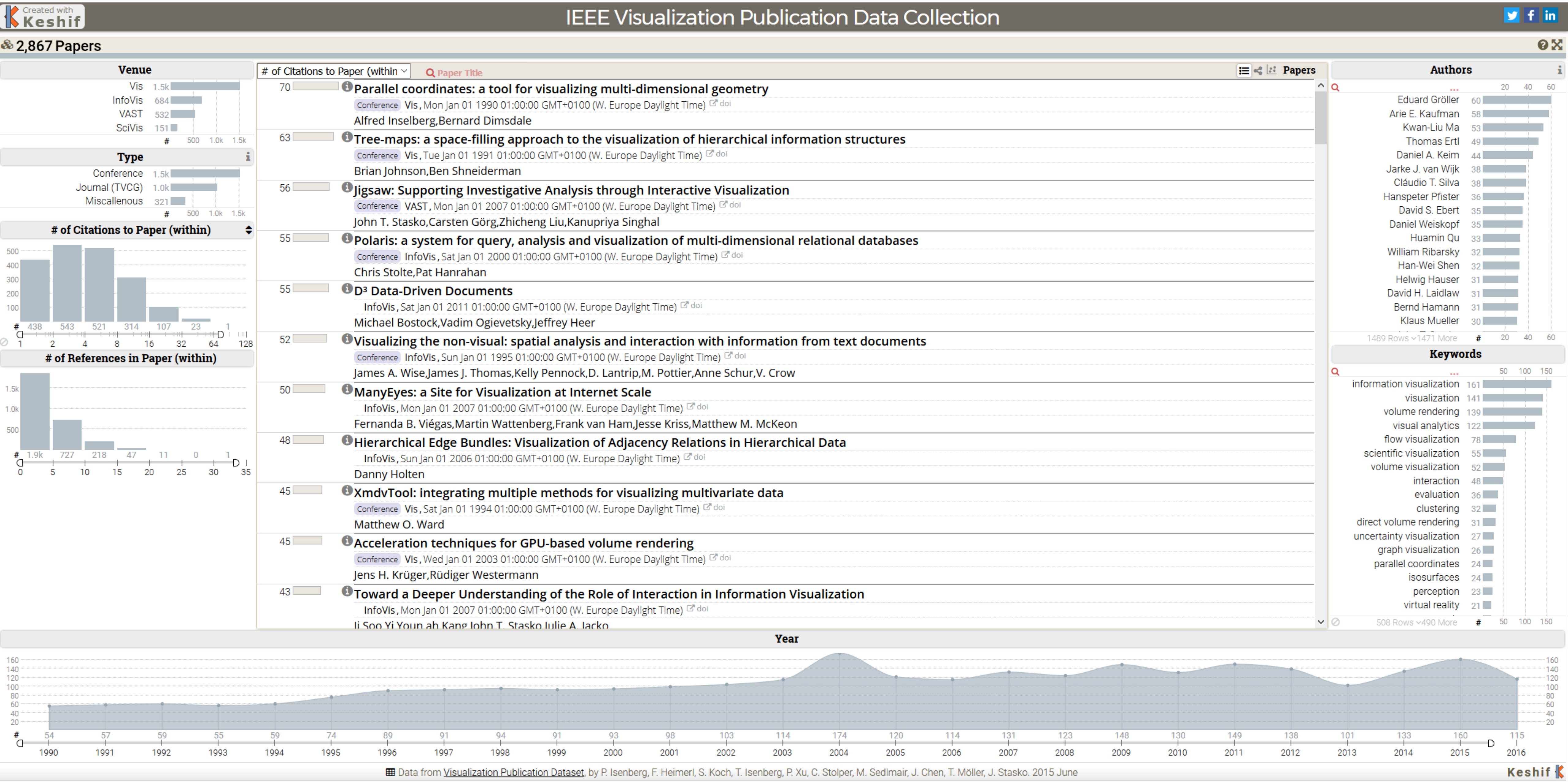
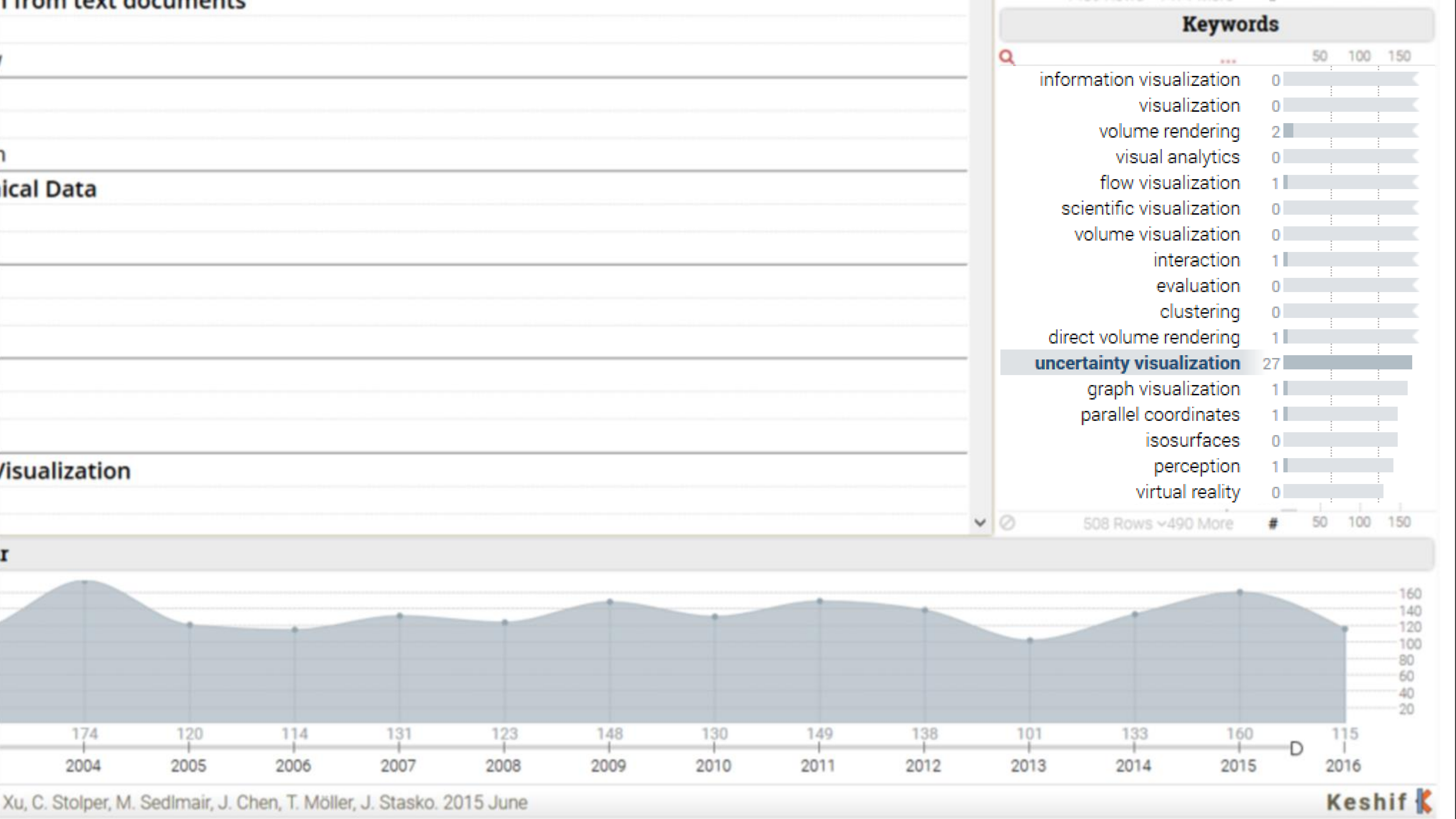
Adil Yalcin <adil@keshif.me>

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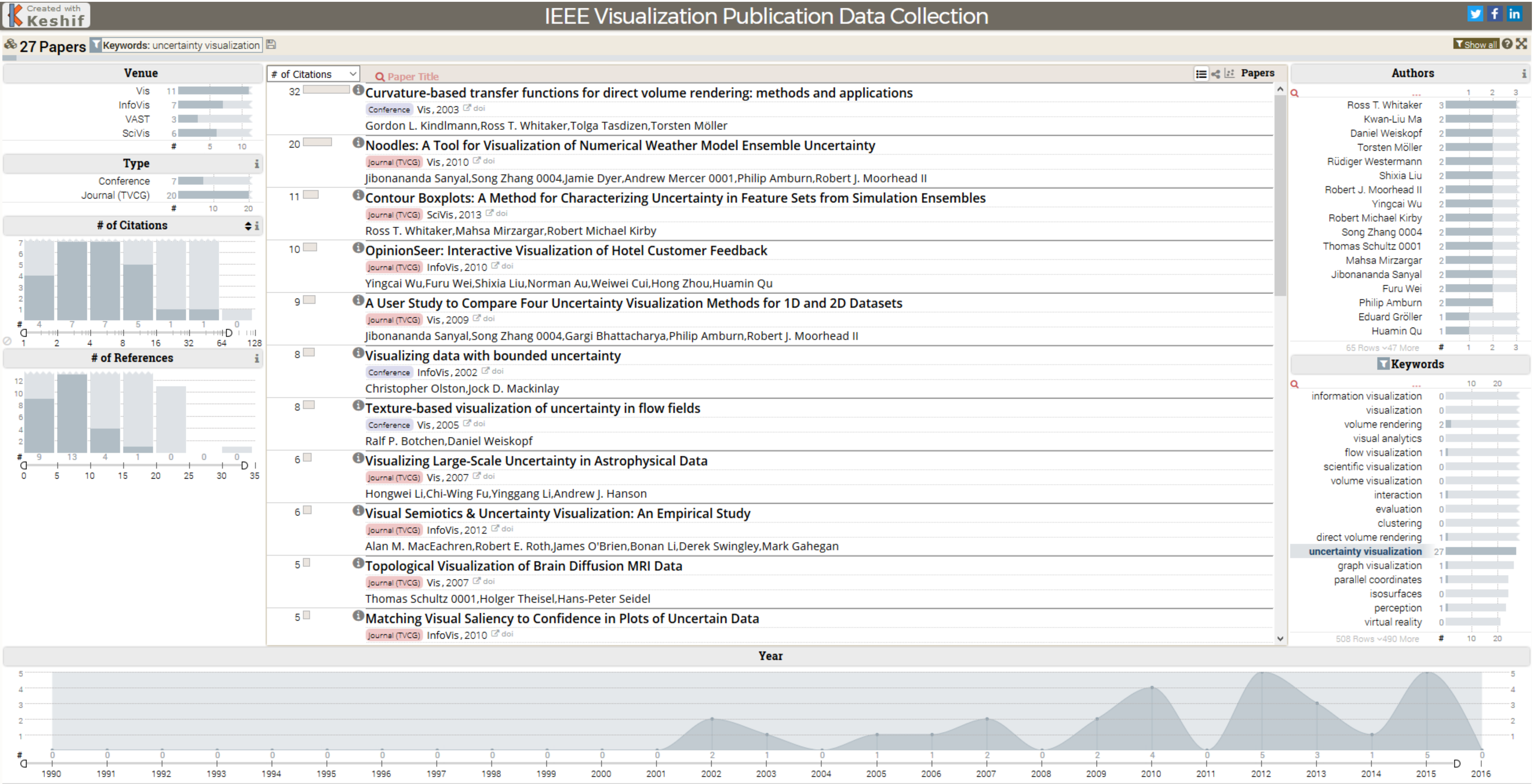

ADDITIONAL FIELDS

ABSTRACTS

PAGE NUMBERS
FIRST AUTHOR AFFILIATION


IEEE TRANSACTIONS ON VISUALIZATION AND COMPUTER GRAPHICS, VOL. 20, NO. 12, DECEMBER 2014 1633

Supporting Communication and Coordination in Collaborative Sensemaking

Narges Mahyar and Melanie Tory

Abstract—When people work together to analyze a data set, they need to organize their findings, hypotheses, and evidence, share that information with their collaborators, and coordinate activities amongst team members. Sharing externalizations (recorded information such as notes) could increase awareness and assist with team communication and coordination. However, we currently know little about how to provide tool support for this sort of sharing. We explore how linked common work (LCW) can be employed within a 'collaborative thinking space', to facilitate synchronous collaborative sensemaking activities in Visual Analytics (VA). Collaborative thinking spaces provide an environment for analysts to record, organize, share and connect externalizations. Our tool, CLIP, extends earlier thinking spaces by integrating LCW features that reveal relationships between collaborators' findings. We conducted a user study comparing CLIP to a baseline version without LCW. Results demonstrated that LCW significantly improved analytic outcomes at a collaborative intelligence task. Groups using CLIP were also able to more effectively coordinate their work, and held more discussion of their findings and hypotheses. LCW enabled them to maintain awareness of each other's activities and findings and link those findings to their own work, preventing disruptive oral awareness notifications.

Index Terms—Sensemaking; Collaboration; Externalization; Linked common work; Collaborative thinking space

1 INTRODUCTION

Supporting collaborative sensemaking has been identified as an important challenge in collaborative visualization [20]. Sensemaking in collaborative VA is a very time consuming and demanding process, requiring the analysts to iteratively exchange and discuss results to form and evaluate hypotheses, derive conclusions, and publish findings. Team members also need to maintain *awareness* of each other's work, including both activities that people are working on and results and evidence that they have found. Tools that provide *externalization* support (i.e., ability to record insights, questions, and findings, e.g., as text notes) can help teams to organize and share their results [6, 18, 22, 41], and those that provide awareness channels should enhance collaboration, communication and coordination [12]. However, to date, we have a very limited understanding of how to provide externalization and awareness support for collocated collaborative teams. How should such tool support look and behave within VA tools?

We investigate the use of *Linked Common Work* (LCW) to facilitate synchronous collaborative sensemaking. With LCW, common work elements such as similar findings are automatically discovered, linked, and visually shared among the group. We built this technique within a 'collaborative thinking space' that enables analysts to record, organize and schematize their externalizations. Linked common work reveals similarities in people's externalizations, enabling analysts to acquire awareness of each other's findings, hypotheses, and evidence. Moreover, each individual analyst can review and merge others' work from within his/her workspace. Our results demonstrate that applying LCW to externalizations, and providing the ability to integrate collaborators' findings together within one view, noticeably improve team awareness, coordination, communication, and analytic outcomes.

Our work focuses on supporting teams of investigative analysts, for example in the domain of intelligence analysis. Intelligence analysts need to sift through large document collections, determine which pieces of data are relevant, and gradually build up an explanation supported by evidence. Field studies have revealed that professional analysts need to share sources and data, view each other's work, and combine findings together in order to build common ground, resolve conflicts, and validate each other's findings and hypotheses [8, 25].

The *sensemaking* process of intelligence analysts has been studied in some depth, and has been described as involving two iterative loops: the information foraging loop and the sensemaking loop [34]. The information foraging loop involves searching for relevant data and reading, filtering, and extracting information, whereas the sensemaking loop involves iteratively developing a mental model, forming and evaluating hypotheses, and publishing the results. We focus primarily on supporting later stages of the sensemaking process (i.e., the sensemaking loop), when teams are more likely to work together in a synchronous, collocated fashion [25]. This synthesis phase is reported to be the most difficult and time-consuming phase of analysis [25].

We are exploring the design of visual thinking spaces that support the sensemaking loop in collaborative VA. A collaborative thinking space should enable analysts to record and organize findings, evidence, and hypotheses; moreover, it should facilitate the process of sharing findings amongst collaborators, to minimize redundant work and help investigators identify relationships and build a shared understanding. In this paper, we examine the value of employing LCW to relate and integrate team members' visual thinking spaces. The notion of LCW closely resembles *collaborative brushing and linking* [21] in which certain actions of each investigator are visible to collaborators through their own views. However, collaborative brushing and linking was only applied to search queries and retrieved documents and did not cover externalizations. It also focused on supporting only information foraging activities. In contrast, our work facilitates later stages of the collaborative sensemaking process (i.e., the sensemaking loop), by applying the linking concept to people's externalizations (i.e., recorded findings and notes). We anticipate that enabling analysts to see how their findings relate to each other should make it easier to maintain awareness of each others' work, build common ground, and solve analytic problems. We address the following research questions (RQs):

- RQ1: Does linking collaborators' externalizations lead to better analytic outcomes?
- RQ2: Does linking collaborators' externalizations improve communication?
- RQ3: Does linking collaborators' externalizations help collaborators to coordinate their work more effectively?
- RQ4: Does linking collaborators' externalizations increase collaborators' awareness of each others' findings and activities?

To answer these questions, we designed and implemented CLIP, a visual thinking space to support collaborative sensemaking. CLIP allows analysts to record their findings in the form of a node-link graph and

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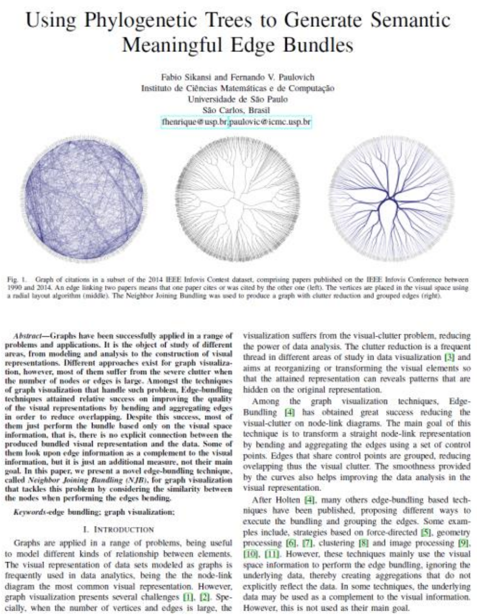
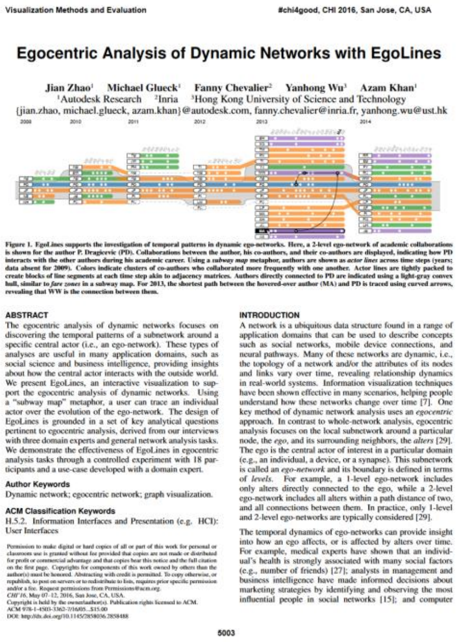
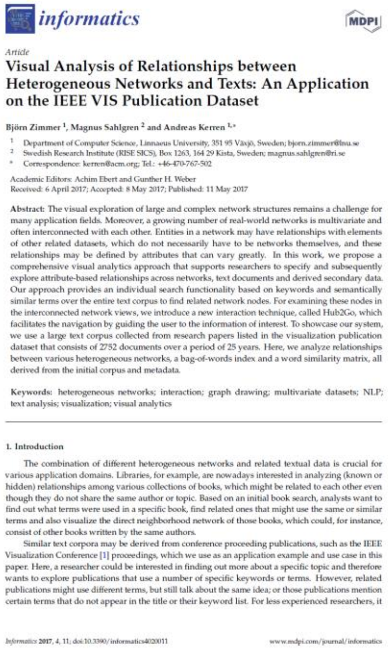
USE CASES

RESEARCH

DATASET AS A USE CASE







RESEARCH

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The final version of record is available at http://dx.doi.org/10.1109/TVCG.2016.2598827

Visualization as Seen Through its Research Paper Keywords

Petra Isenberg, *Member, IEEE*, Tobias Isenberg, *Senior Member, IEEE*, Michael Sedlmair, *Member, IEEE*,
Jian Chen, *Member, IEEE*, and Torsten Möller, *Senior Member, IEEE*

Abstract—We present the results of a comprehensive multi-pass analysis of visualization paper keywords supplied by authors for their papers published in the IEEE Visualization conference series (now called IEEE VIS) between 1990–2015. From this analysis we derived a set of visualization topics that we discuss in the context of the current taxonomy that is used to categorize papers and assign reviewers in the IEEE VIS reviewing process. We point out missing and overemphasized topics in the current taxonomy and start a discussion on the importance of establishing common visualization terminology. Our analysis of research topics in visualization can, thus, serve as a starting point to (a) help create a common vocabulary to improve communication among different visualization sub-groups, (b) facilitate the process of understanding differences and commonalities of the various research sub-fields in visualization, (c) provide an understanding of emerging new research trends, (d) facilitate the crucial step of finding the right reviewers for research submissions, and (e) it can eventually lead to a comprehensive taxonomy of visualization research. One additional tangible outcome of our work is an online query tool (http://keyvis.org/) that allows visualization researchers to easily browse the 3 952 keywords used for IEEE VIS papers since 1990 to find related work or make informed keyword choices.

Index Terms—Keywords, data analysis, research themes, research topics, taxonomy, visualization history, theory.

1 Motivation

One of the main reasons why visualization is such a fascinating field of research is its diversity. There is not only a diversity of applications but also a diversity of research methods being employed, a diversity of research contributions being made, as well as the diversity of its roots.

Diversity of roots: The term ***visualization*** can be understood very broadly, expressing a long history of its use in common language. Therefore, it is not surprising that concepts of visual thinking have penetrated many areas of science, engineering, and philosophy. The field of modern (computer-based) visualization has been greatly influenced by research methods from the fields of numerics and computer graphics, which have given it its birth in 1990. The impact of human-computer interaction affected the birth of the InfoVis community in 1995 and the influence of applied statistics (such as data mining) and cognition has led to the establishment of VAST in 2006.

Diversity of research methods: Given its diverse roots, visualizations remains a highly inter-disciplinary field that borrows and extends research methods from other fields. Methods come from fields as diverse as the broader computer science, mathematics, statistics, machine learning, psychology, cognitive science, semiotics, design, or art.

Diversity of contributions and applications: Based on these diverse influences, the results of visualization research can be manifold: from engineering solutions to dealing with large data sources (such as real-time rendering solutions, distributed and parallel computing technologies, novel display devices, and visualization toolkits) to understanding design processes (as in perceptual guidelines for proper visual encodings and interaction or facilitating collaboration between different users through visual tools) to scientific inquiries (such as improved understanding of perceptual and cognitive processes).

While all these diverse influences make the field of visualization research an exciting field to be part of, they also create enormous challenges. There are different levels of appreciation for all aspects of visualization research, communication challenges between visualization researchers, and the challenge of communicating visualization as an independent field of research to the outside. These issues lead, in particular, to the frequently asked question "what is visualization?"—among funding agencies or even between colleagues. Given our field's broad nature, we need to ask how we can comprehensively describe and summarize all on-going visualization research. These are not just theoretical and philosophical questions, but the answer to these questions has many real-world (e. g., career-deciding) impacts—from finding the right reviewers during peer-review to administrative strategic decisions on conference and journal structures and foci.

So while "what is visualization?" is a fundamental question, it has not been discussed to a large extent within our community. In fact, thus far the approaches have mostly focused on understanding some sub-field of visualization (e. g., [17, 38, 42]) but the question for the broader community has rarely been tackled beyond general textbook definitions (e. g., [6, 34, 46]). Those who have approached the problem, did so in a top-down approach based on the opinion and experiences of the authors. For example, several taxonomies were suggested by experts based on tasks, techniques, or data models (e. g., [7, 38, 43]). Another way of splitting visualization into more focused areas has been through specific application foci (e. g., VisSec, BioVis, SoftVis, etc.).

What is missing in this picture is a bottom-up analysis: What types of visualization research are actually happening as expressed by single research contributions in the visualization conferences and journals. Our paper is one of the first steps in this direction. We analyze one type of data that can shed light on the diversity of visualization research: author-assigned keywords as well as author-selected taxonomy entries in the submission system for the three IEEE VisWeek/VIS conferences. Based on this analysis, we make the following contributions:

Mapping visualization research: In Sect. 4, through the vehicle of keyword analysis, we build a conceptual map of all visualization work as indexed by individual authors. Our main assumption here is that, while each single keyword might be understood in a slightly different way by different researchers, their co-occurrence with other keywords clarifies their meaning, especially when aggregated over many different usages (i. e., many research papers in a major publication venue). This co-occurrence analysis is the basis for deriving clusters and, therefore, research sub-fields. The use of keywords seen over the past years also allows us to understand historical trends and we report on the most prominent declining and rising keywords within all of visualization.

Taxonomy and Terminology Discussion: Visualization research is influenced by a diverse set of application domains. The vocabulary of

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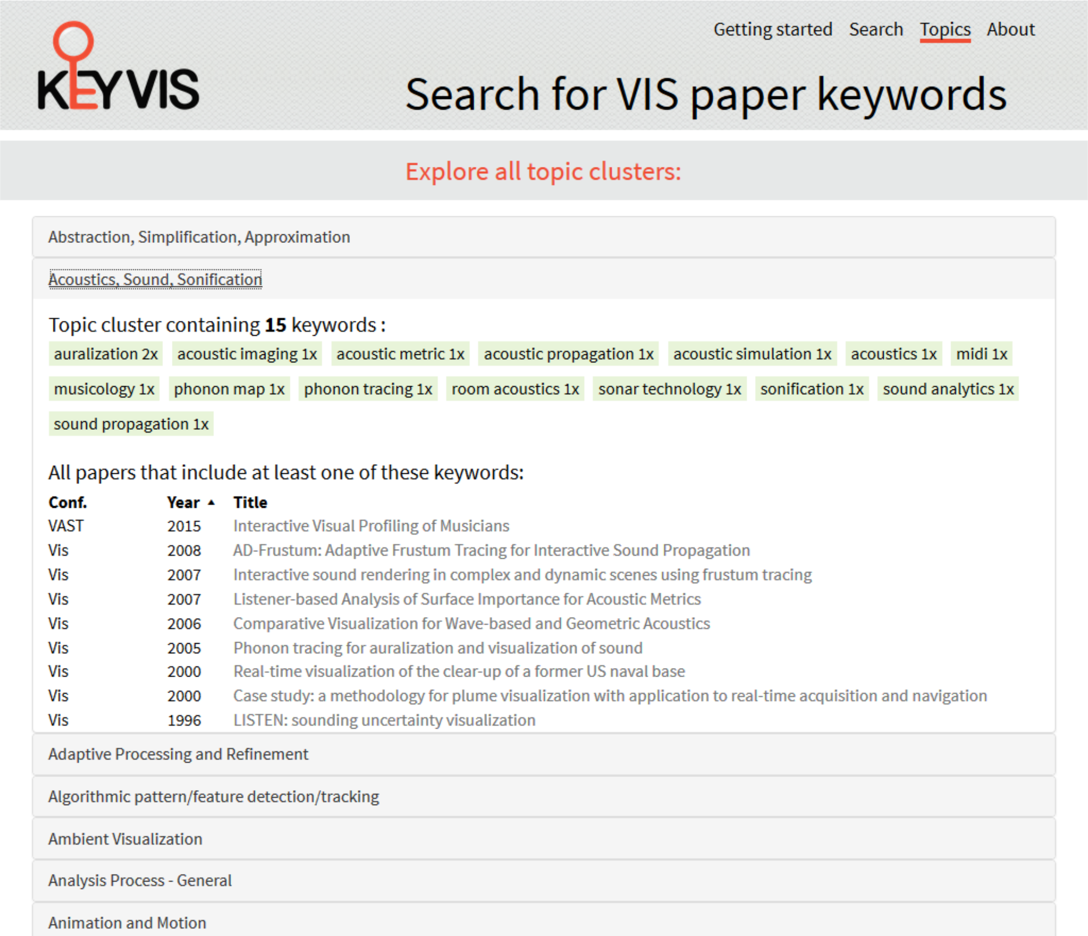

http://keyvis.org

keywords, papers, topics

TEACHING

TEACHING

- CLEANING
- TRANSFORMING
- JOINING

- DEVELOPING OF RESEARCH QUESTION

- DEVELOPING APPS

MEMBER HUNTER --- FIND THE NEXT COMMITTEE BOARD

by ranking past experience and publications

Vis	VAST	InfoVis	SciVis

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Maciejewski, R.
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Xiaoyu Wang
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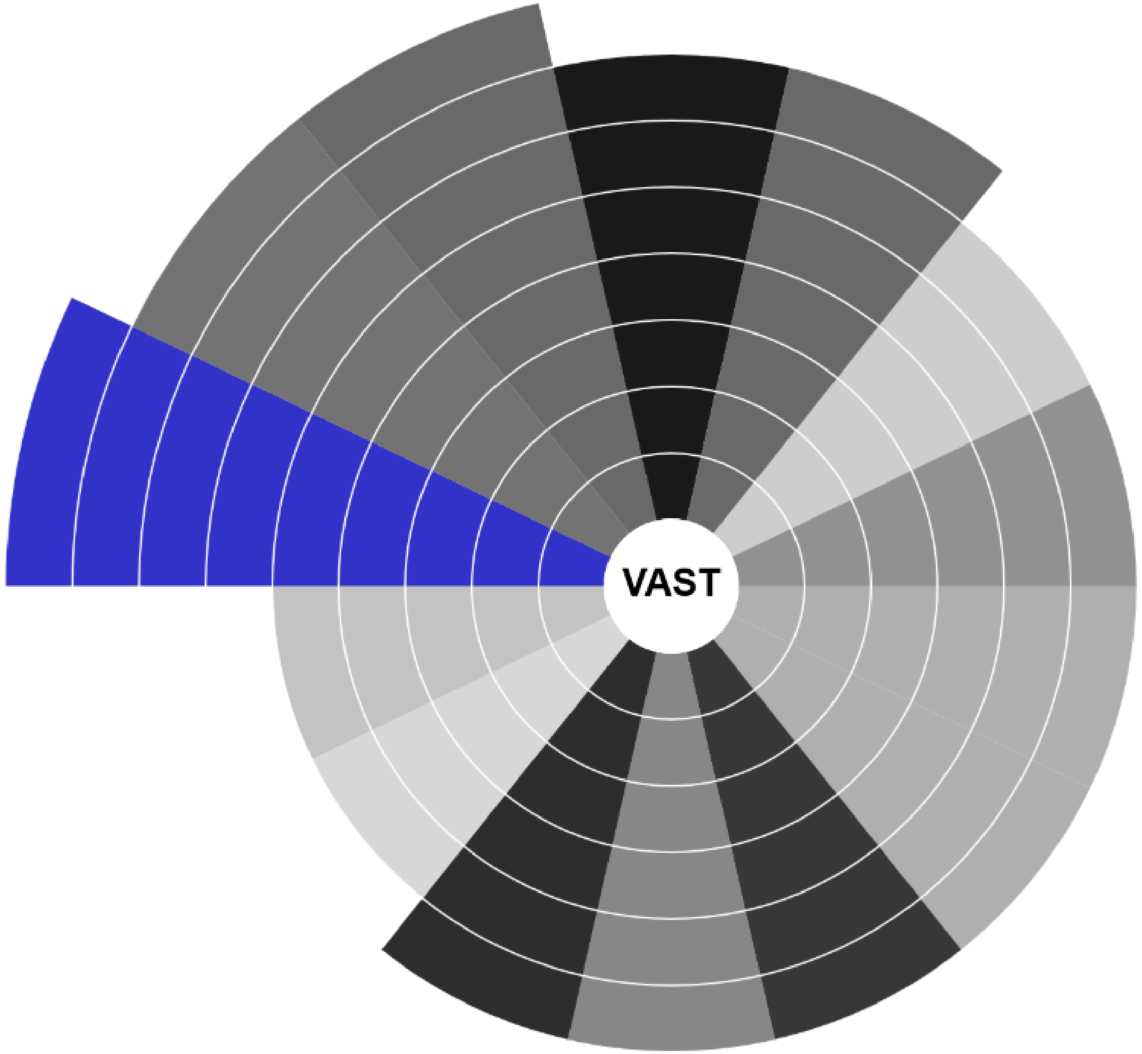

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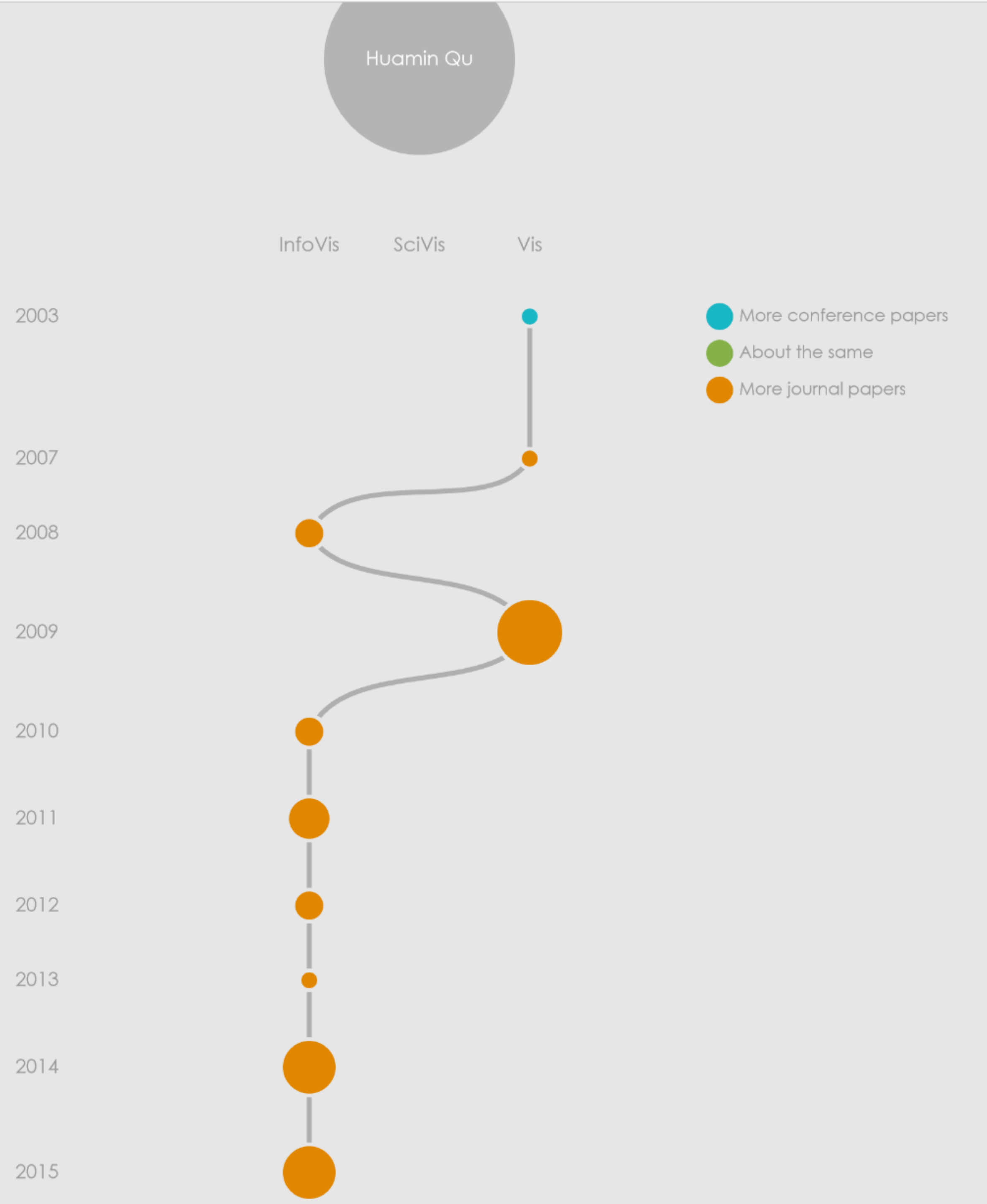

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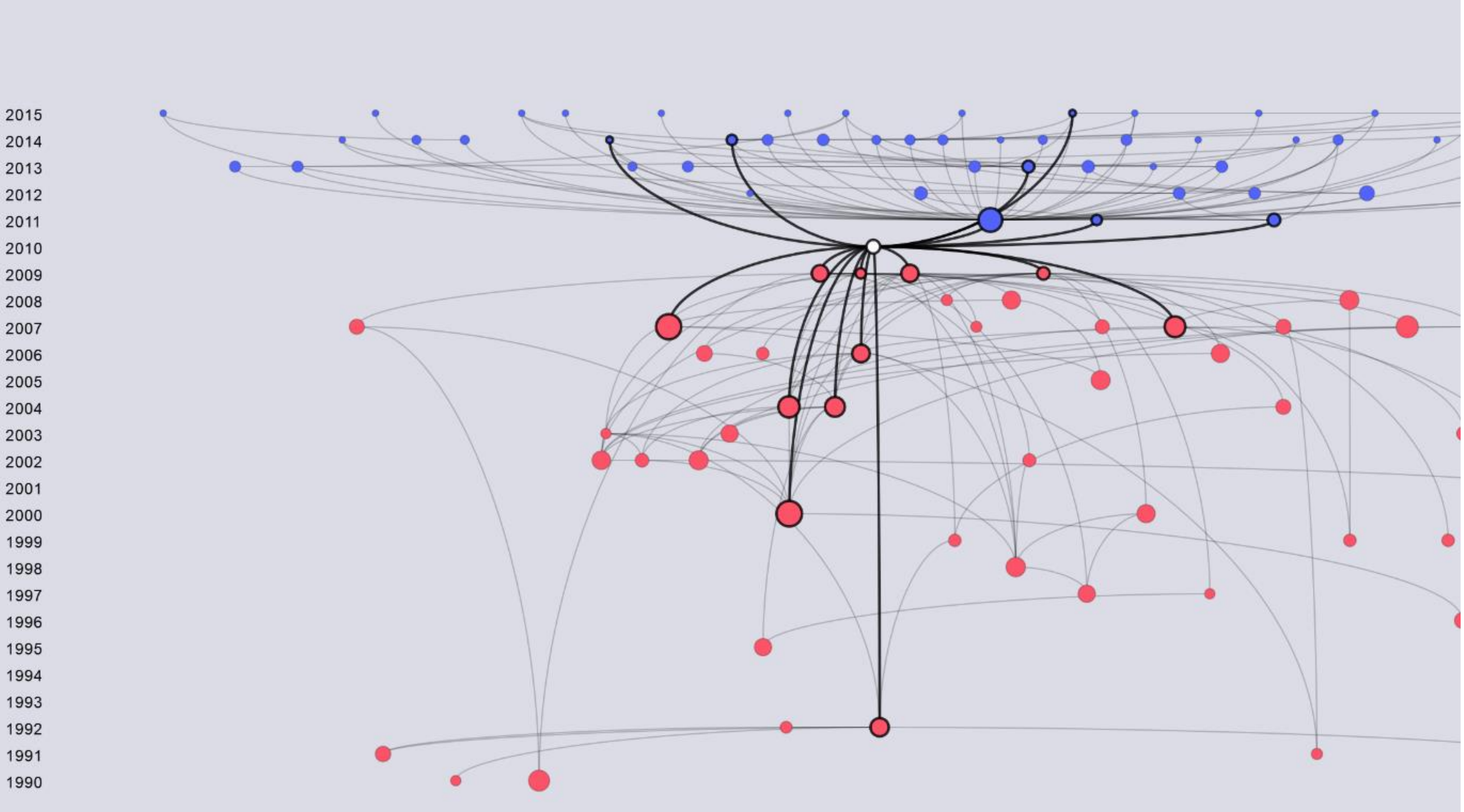
How can we support paper writing with citation information?

RefTree - A tool to help finding and exploring related articles



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CONFERENCE ORGANIZATION

Conference Organisation

- Finding PC members
- Finding reviewers
- Proposing / updating keyword taxonomy
- …

SUMMARY

vispubdata.org

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Visualization Publication Data Collection

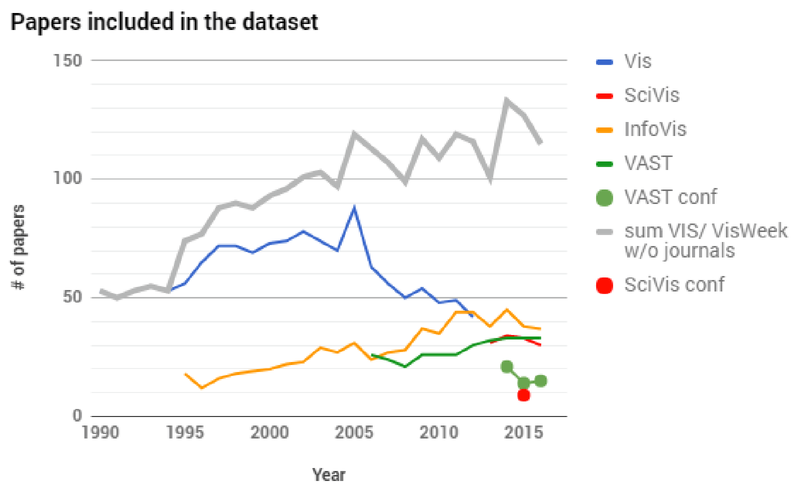
Search this site

VISUALIZATION PUBLICATIONS DATASET
RECENTDATACHANGES
SITEMAP

Visualization publications dataset

We are making available a dataset that contains information on IEEE Visualization (IEEE VIS) publications from 1990-2015. The dataset includes a variety of information about each paper including title, authors, DOI, etc., as well as a list of the citations to other previous VIS papers. To download the dataset open the Google spreadsheet through the link below and choose File->Download as. If you spot errors in the dataset feel free to leave a comment in the respective cells. We will try to maintain and fix the spreadsheet.

Look at and download complete dataset here
Current version: 7.00



GET MORE DATA

Visualization Paper Submission and Keyword Dataset

Description:

This is a dataset of the submission information for VGTC-sponsored, visualization-related conferences. Included are the regular *full-paper* submissions for IEEE Vis, IEEE InfoVis, IEEE SciVis, IEEE VAST, IEEE PacificVis, and EuroVis roughly from 2008. For each full paper submission, the dataset contains the title, conference information, potential publication data (in form of a DOI link), and all keywords marked in the submission system by the submitting authors based on the "PCS taxonomy" that has largely stayed stable since 2008/2009. For full details see the dataset's readme file.

Data download: (0.2 MB)

Cross-References:

See other work that uses or relates to this data or that reports on the use of keywords in visualization:

- vispubdata.org: A Metadata Collection about IEEE Visualization (VIS) Publications
- Visualization as Seen Through its Research Paper Keywords

References:

This work was done at the AVIZ project group of Inria, France, with the help of numerous people who are acknowledged in the readme file.

(temporary location)

https://tinyurl.com/pcskeywords

FUTURE WORK

- EuroVis (STAR papers, short papers?)
- PacificVis
- (TVCG, CG&A) journal papers presented at EuroVis / PacificVis / VIS (?)

- Affiliations
- Going back to Lastname, Firstname (?)

vispubdata.org

A METADATA COLLECTION ABOUT IEEE VIS PUBLICATIONS

Petra Isenberg, Florian Heimerl, Steffen Koch, Tobias Isenberg, Panpan Xu,
Charles D. Stolper, Michael Sedlmair, Jian Chen, Torsten Möller, John Stasko

petra.isenberg@inria.fr

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