Additional Material for Visualization as Seen Through its Research Paper Keywords

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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.

Note that all the graphs on page 1 and pages 3–16 are also available in an interactive html form as part of the additional material package (zip file). These html versions support the interactive data read-out via mouse-over.

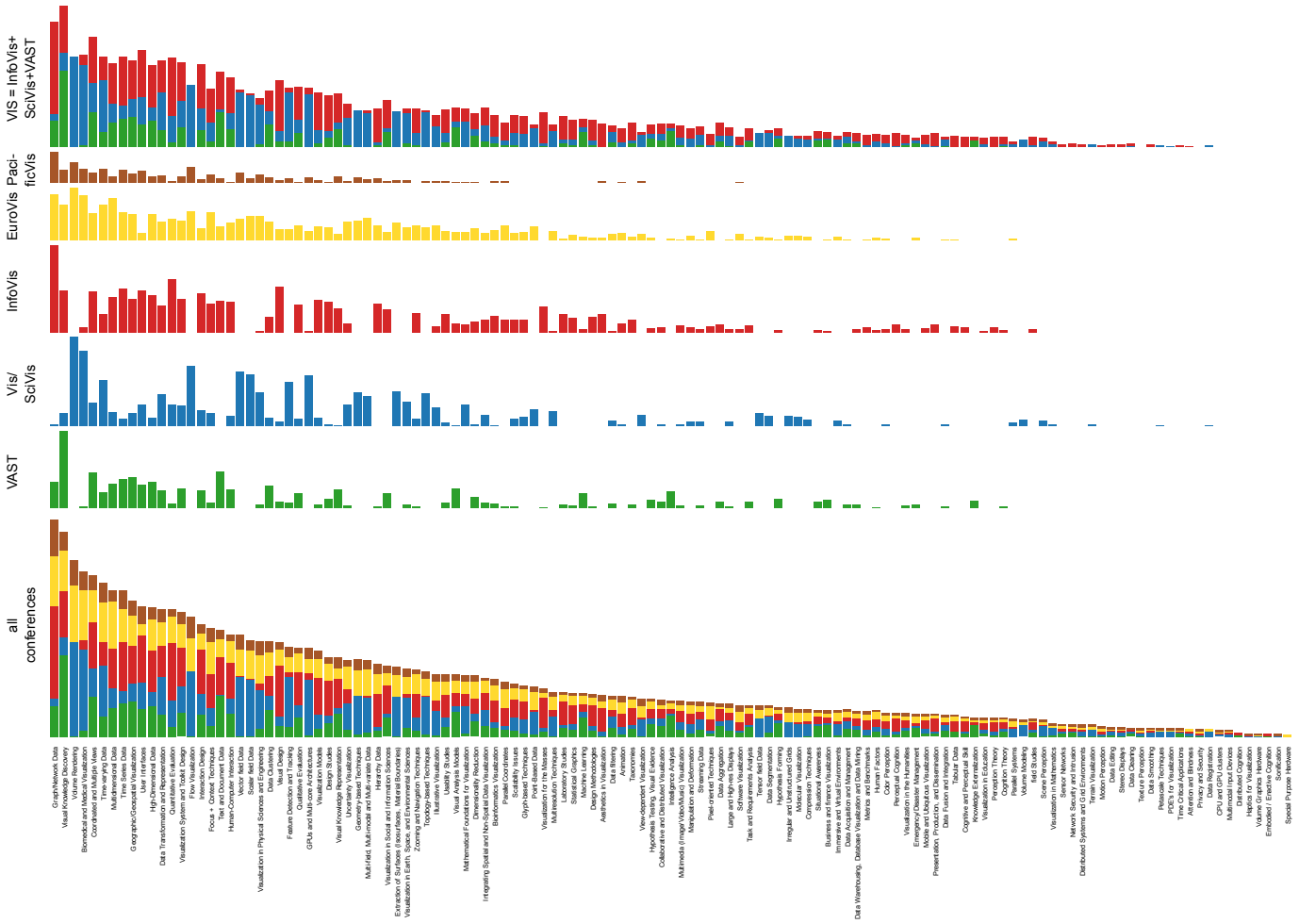


Fig. 1. Comparison of use of PCS taxonomy keywords for all papers submitted to PacificVis, EuroVis, InfoVis, Vis/SciVis, and VAST in 2008–2015 (PacificVis from 2009), sorted by their global frequency. Notice that PacificVis and EuroVis, just like the VIS conference series overall but unlike the conferences InfoVis, SciVis, and VAST individually, roughly follow the global distribution.

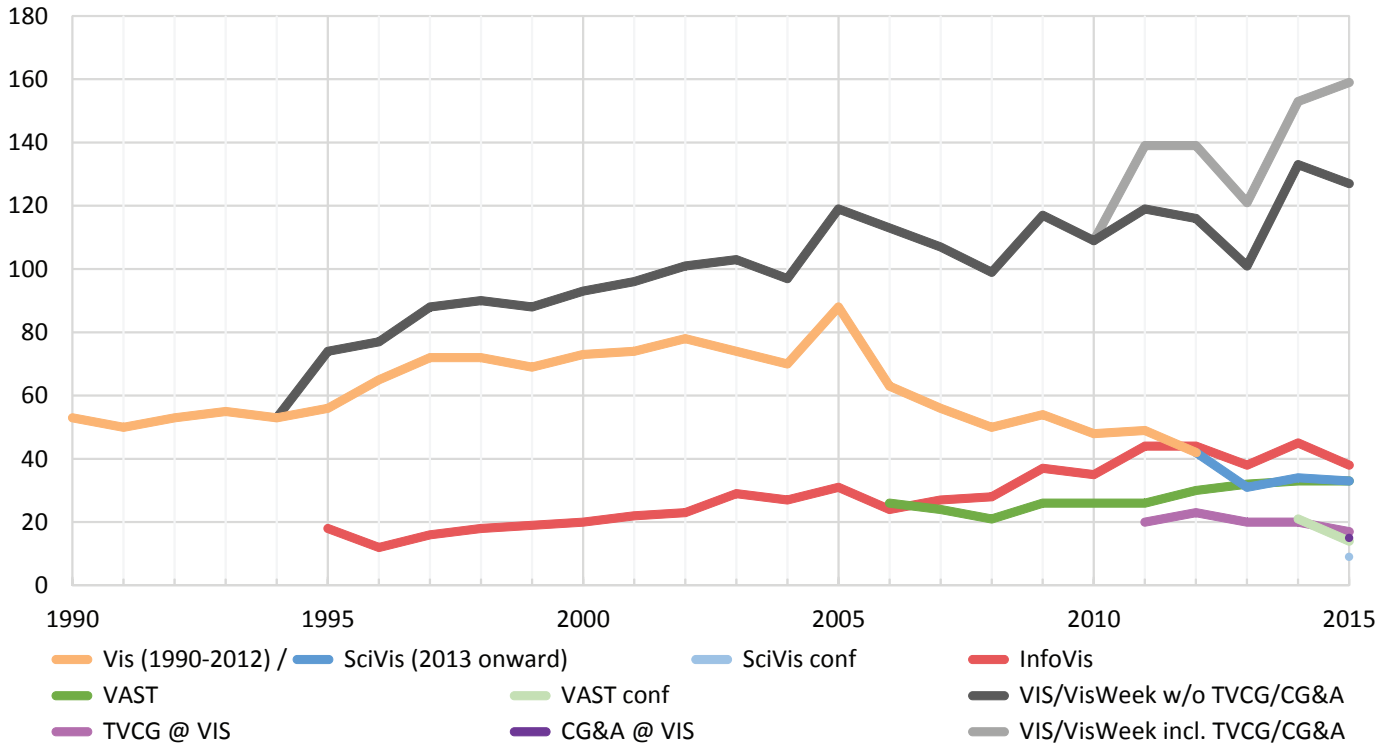


Fig. 2. Paper counts of published/presented papers per year and publication category/conference for IEEE Vis/VisWeek/VIS (i. e., InfoVis, Vis/SciVis, and VAST). *Image from [1]. Image is in the public domain.*

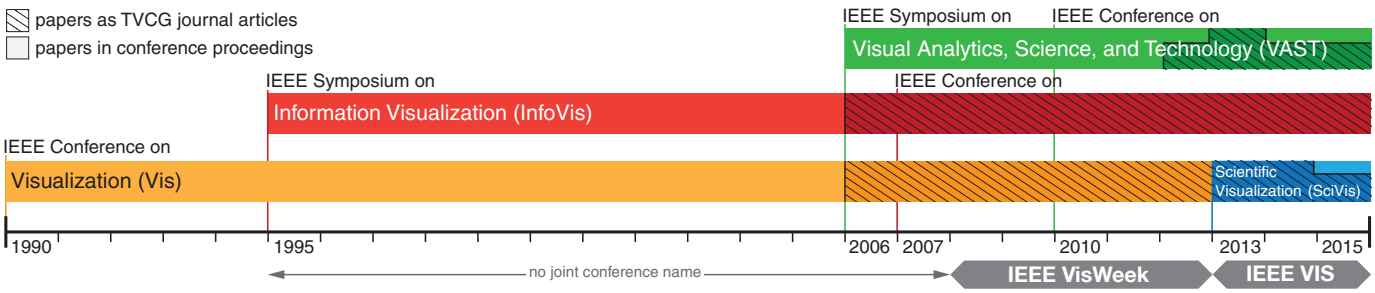


Fig. 3. History of conference/symposia names as well as publication types for IEEE Vis, SciVis, InfoVis, and VAST. *Image from [1]. Image is in the public domain.*

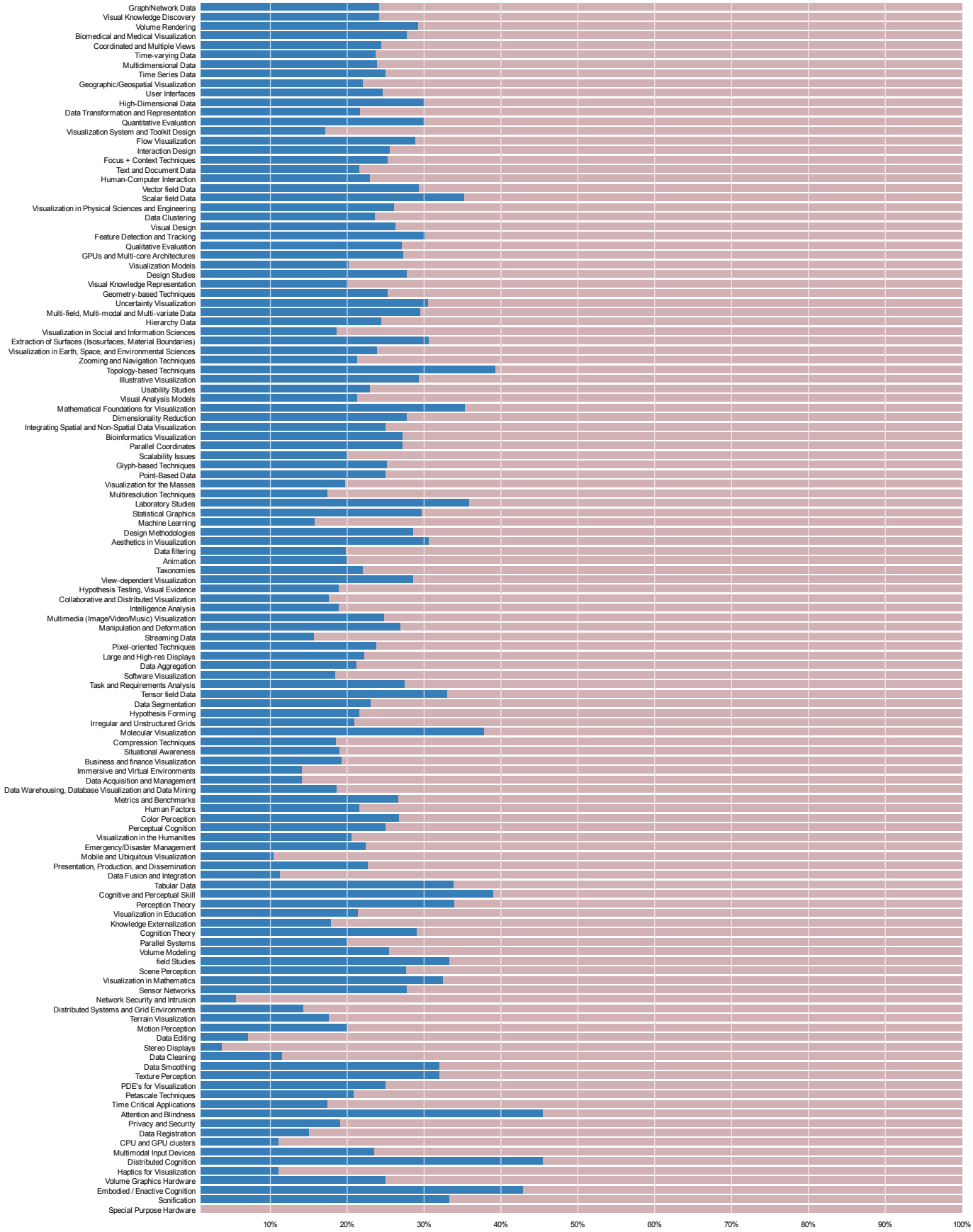


Fig. 4. Acceptance percentages (blue–accepted, red–rejected) for the lower-level **PCSs keywords** for all papers submitted to **PacificVis, EuroVis, InfoVis, Vis/SciVis, and VAST** in **2008–2015** (PacificVis from 2009). Notice that the keywords are sorted by their frequency, with the most frequent at the top (same as in Fig. 1); thus the keywords at the bottom only occur very infrequently, so an extreme acceptance or rejection rate for those keywords is not statistically stable.

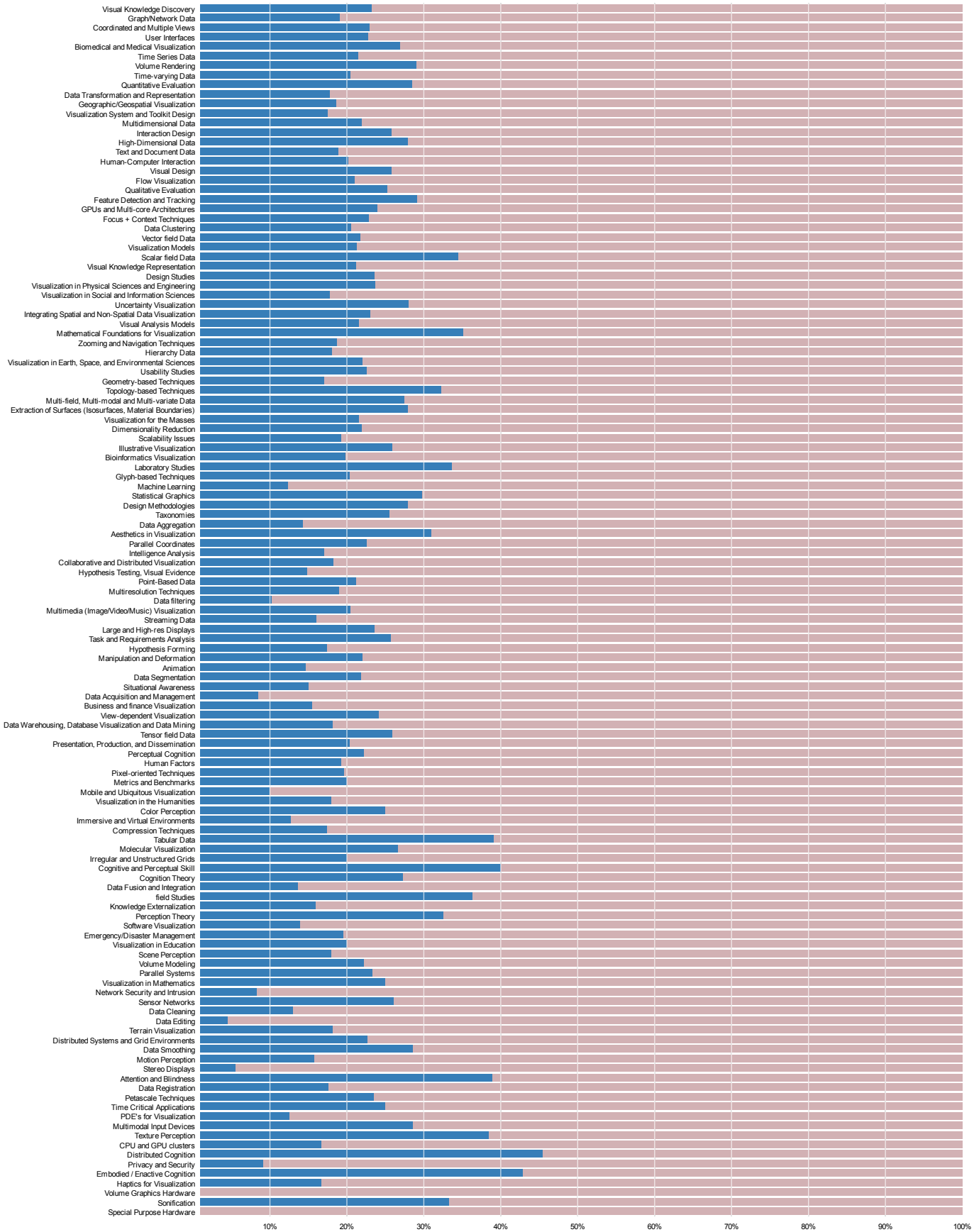


Fig. 5. Acceptance percentages (blue–accepted, red–rejected) for the lower-level **PCSs keywords** for all papers submitted to **InfoVis, Vis/SciVis, and VAST** in **2008–2015**. Notice that the keywords are sorted by their frequency, with the most frequent at the top; thus the keywords at the bottom only occur very infrequently, so an extreme acceptance or rejection rate for those keywords is not statistically stable.

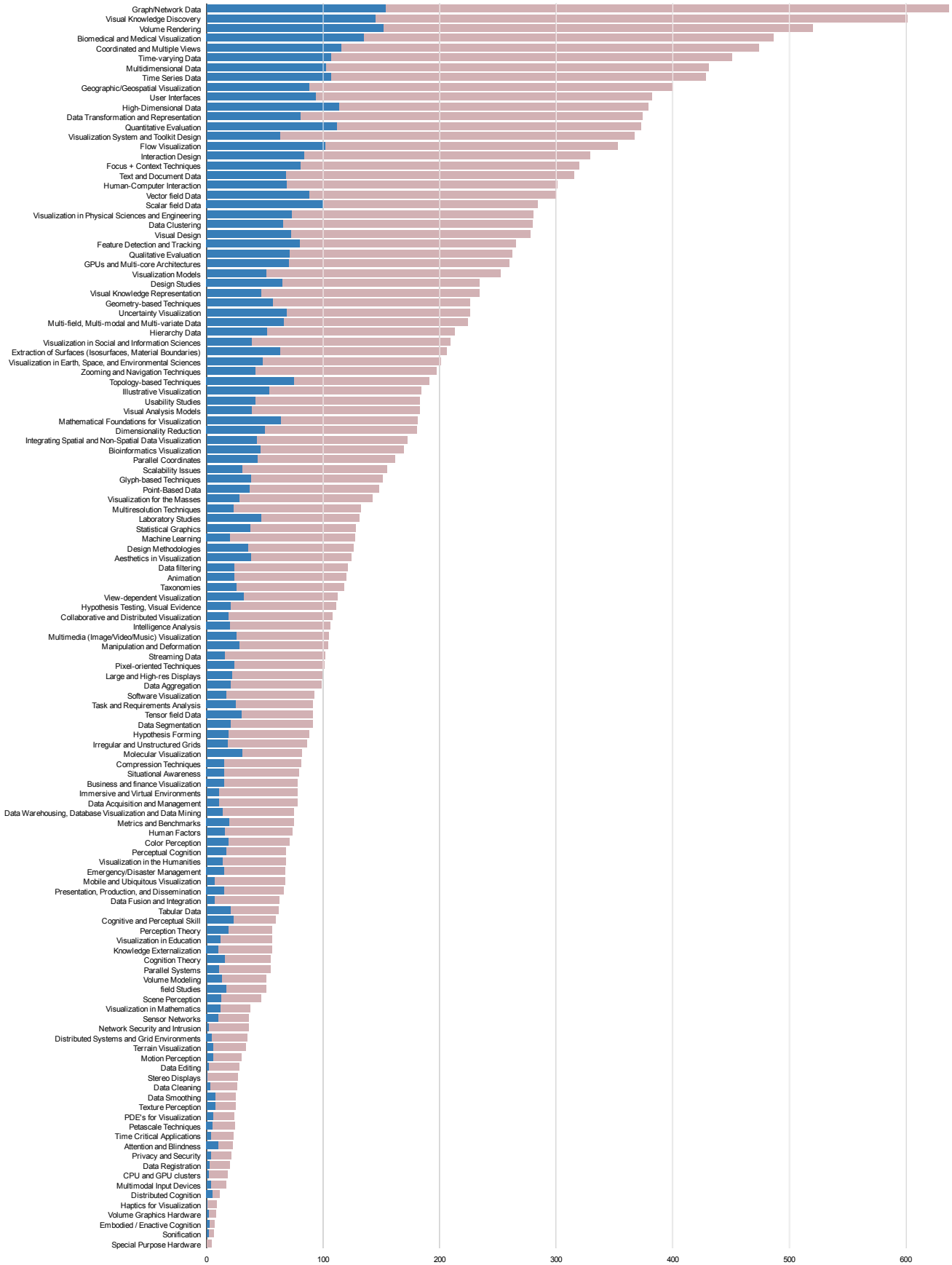


Fig. 6. Absolute number of submitted papers with acceptance percentages (blue–accepted, red–rejected) for the lower-level **PCSs keywords** for all papers submitted to **PacificVis, EuroVis, InfoVis, Vis/SciVis, and VAST** in **2008–2015** (PacificVis from 2009; same data as in Fig. 4). Notice that the keywords are sorted by their frequency, with the most frequent at the top; thus the keywords at the bottom only occur very infrequently, so an extreme acceptance or rejection rate for those keywords is not statistically stable.

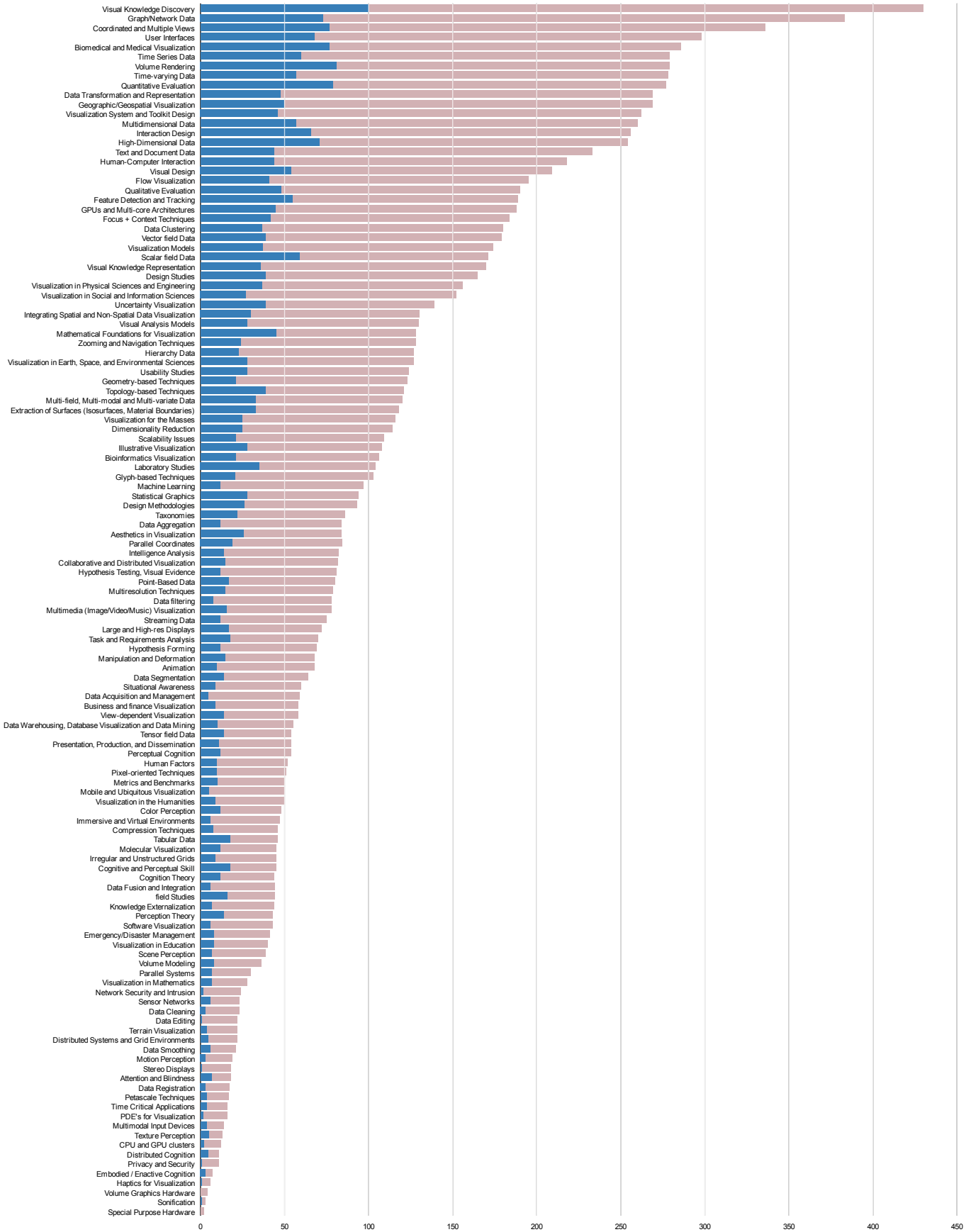


Fig. 7. Absolute number of submitted papers with acceptance percentages (blue–accepted, red–rejected) for the lower-level **PCSs keywords** for all papers submitted to **InfoVis, Vis/SciVis, and VAST** in **2008–2015** (same data as in Fig. 5). Notice that the keywords are sorted by their frequency, with the most frequent at the top; thus the keywords at the bottom only occur very infrequently, so an extreme acceptance or rejection rate for those keywords is not statistically stable.

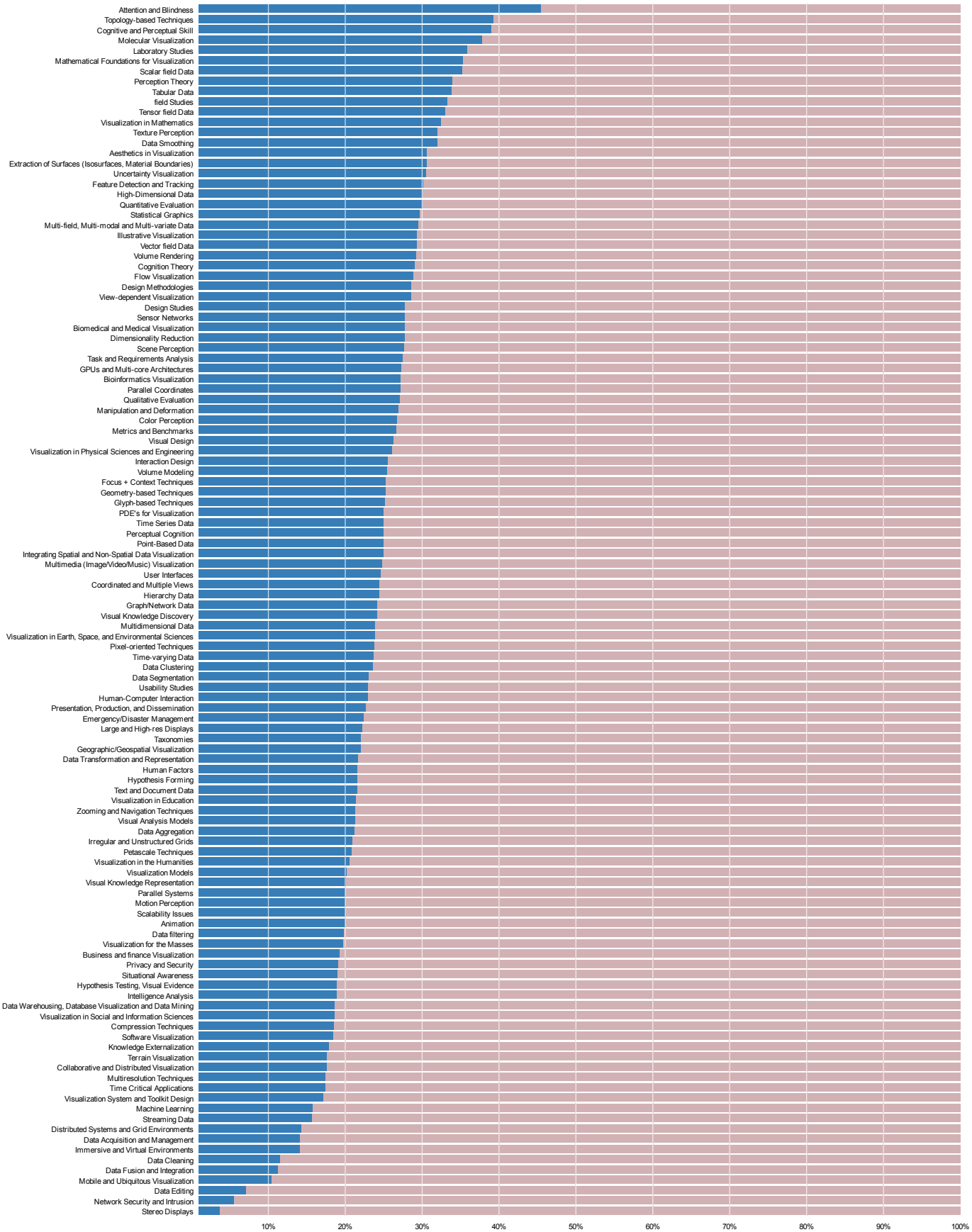


Fig. 8. Acceptance percentages (blue–accepted, red–rejected) for the lower-level **PCSs keywords** for all papers submitted to **PacificVis, EuroVis, InfoVis, Vis/SciVis, and VAST** in **2008–2015** (PacificVis from 2009; same data as in Fig. 4) with at least 21 occurrences, sorted by acceptance rate.

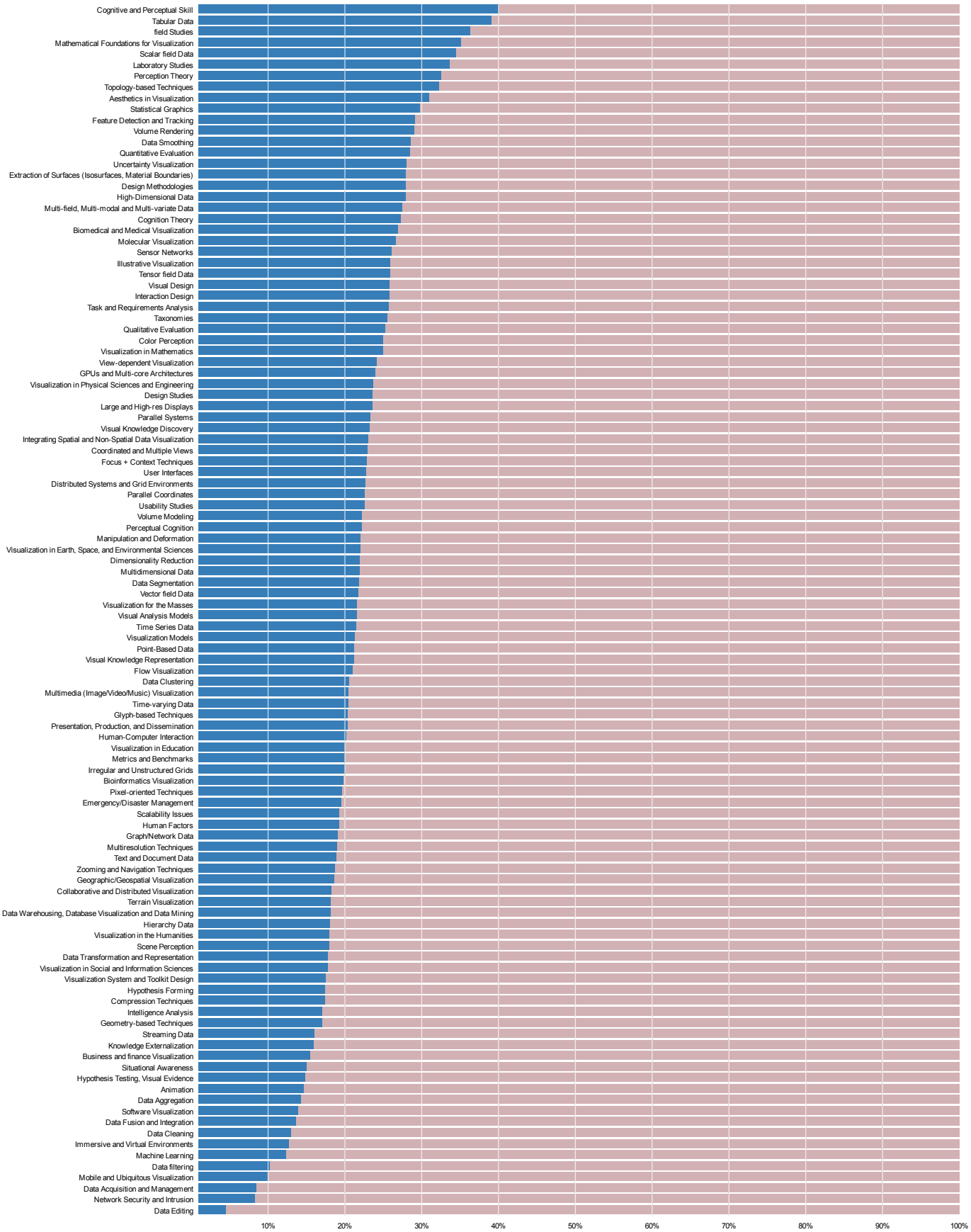


Fig. 9. Acceptance percentages (blue–accepted, red–rejected) for the lower-level **PCSs keywords** for all papers submitted to **InfoVis, Vis/SciVis, and VAST** in **2008–2015** with at least 21 occurrences, sorted by acceptance rate.

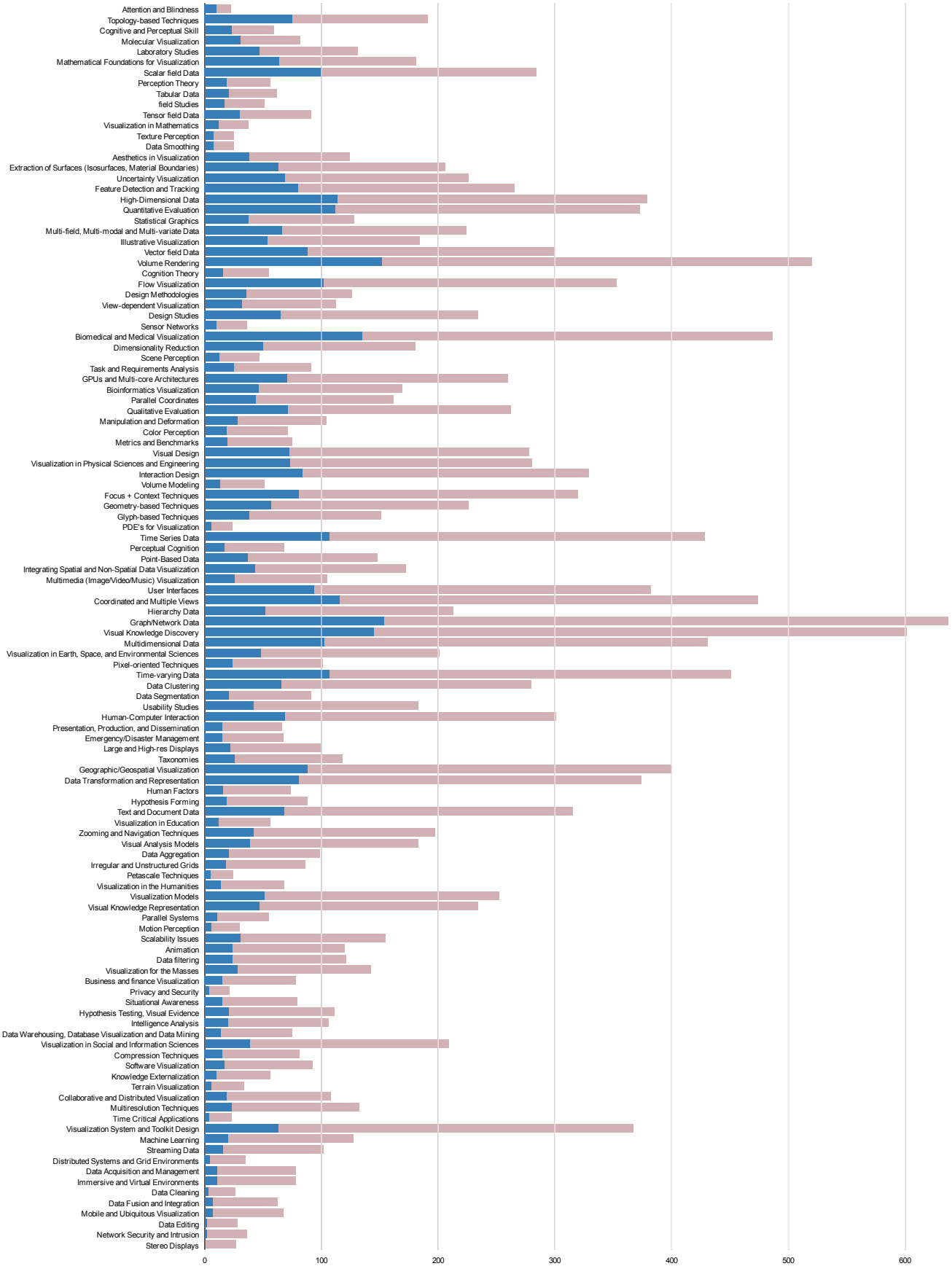


Fig. 10. Absolute number of submitted papers with acceptance percentages (blue–accepted, red–rejected) for the lower-level **PCSs keywords** for all papers submitted to **PacificVis, EuroVis, InfoVis, Vis/SciVis, and VAST** in **2008–2015** (PacificVis from 2009; same data as in Fig. 8) with at least 21 occurrences, sorted by acceptance rate.

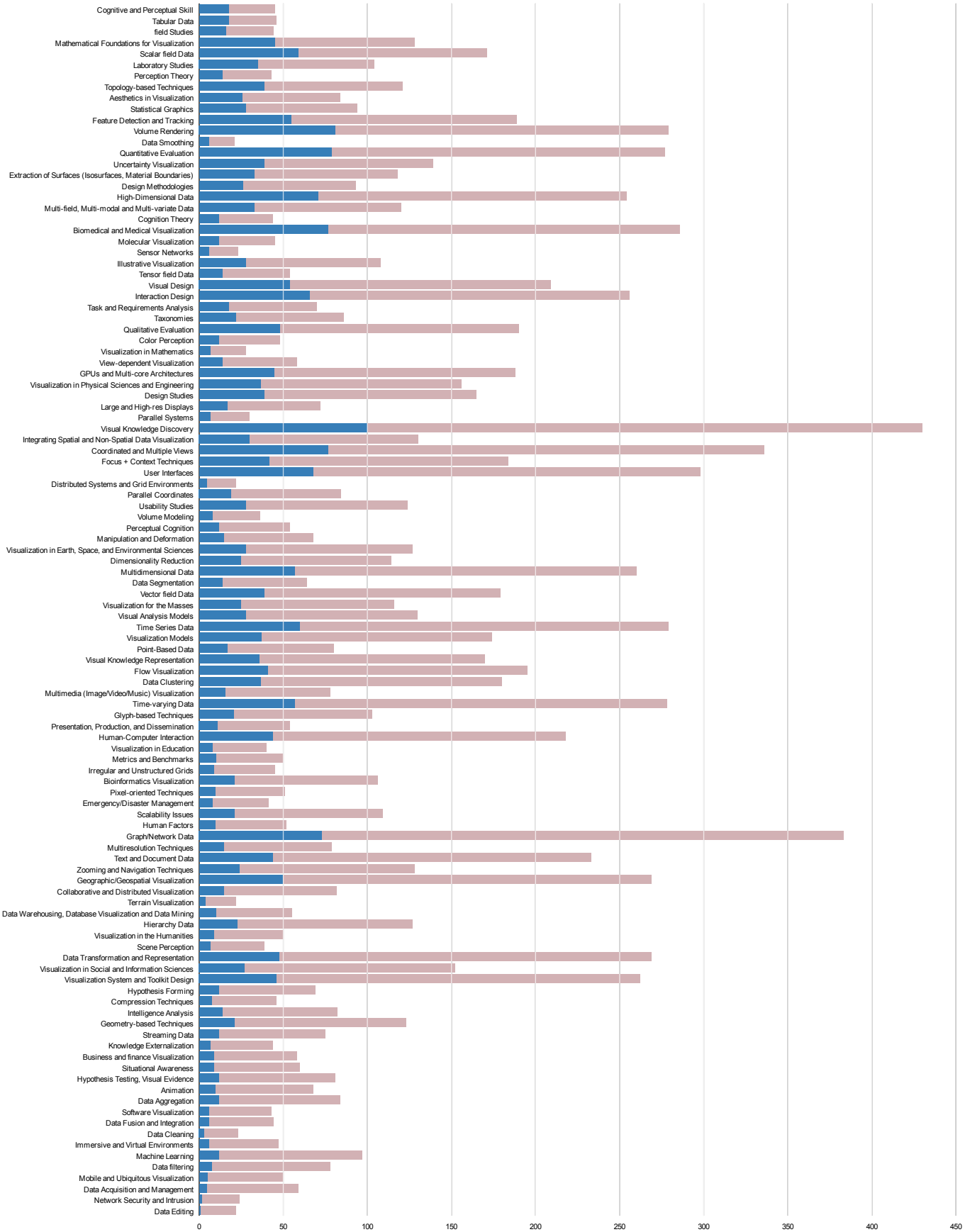


Fig. 11. Absolute number of submitted papers with acceptance percentages (blue–accepted, red–rejected) for the lower-level **PCSs keywords** for all papers submitted to **InfoVis, Vis/SciVis, and VAST** in **2008–2015** (same data as in Fig. 9) with at least 21 occurrences, sorted by acceptance rate.

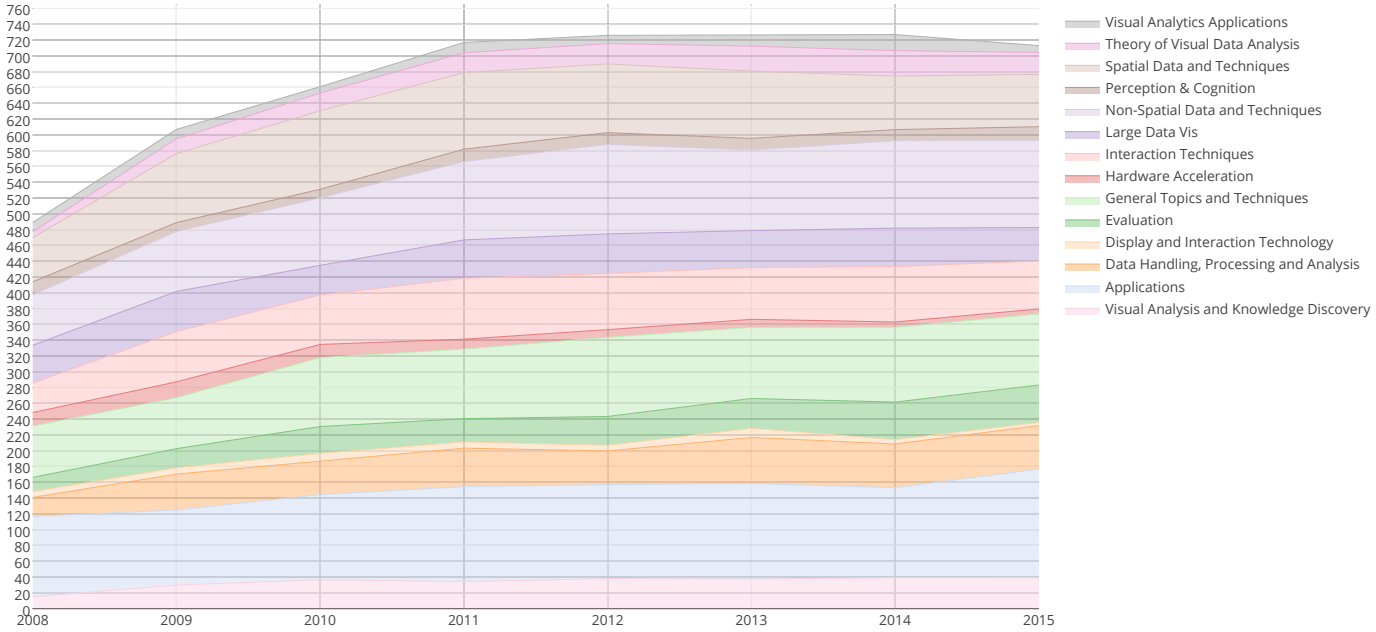


Fig. 12. History of the use of higher-level **PCS taxonomy categories** for all papers submitted to **PacificVis, EuroVis, InfoVis, SciVis, and VAST** in **2008–2015** (PacificVis from 2009), total values. Each primary keyword is weighted twice as much as secondary ones per paper, but the total weight of all keywords of a paper is 1. Thus each vertical sum in this figure reflects the overall submission numbers (except for 2008 because the PacificVis data was missing for that year).

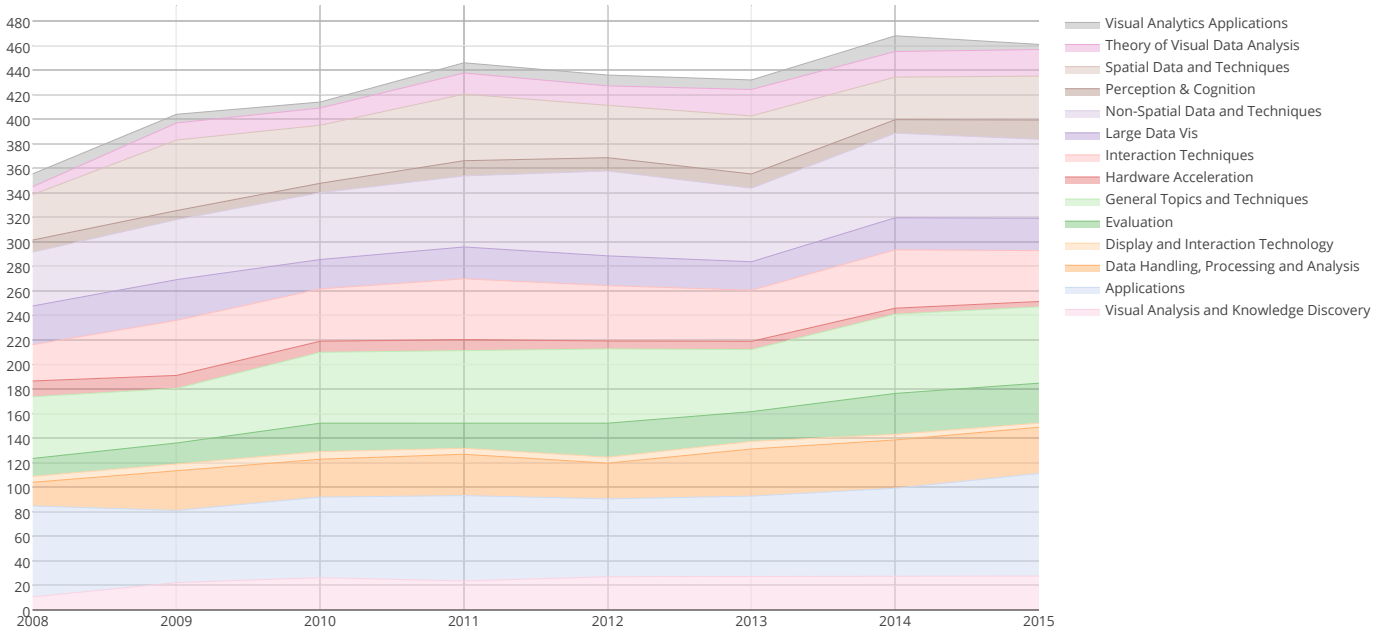


Fig. 13. History of the use of higher-level **PCS taxonomy categories** for all papers submitted to **InfoVis, Vis/SciVis, and VAST** in **2008–2015**, total values. Each primary keyword is weighted twice as much as secondary ones per paper, but the total weight of all keywords of a paper is 1. Thus each vertical sum in this figure reflects the overall submission numbers.

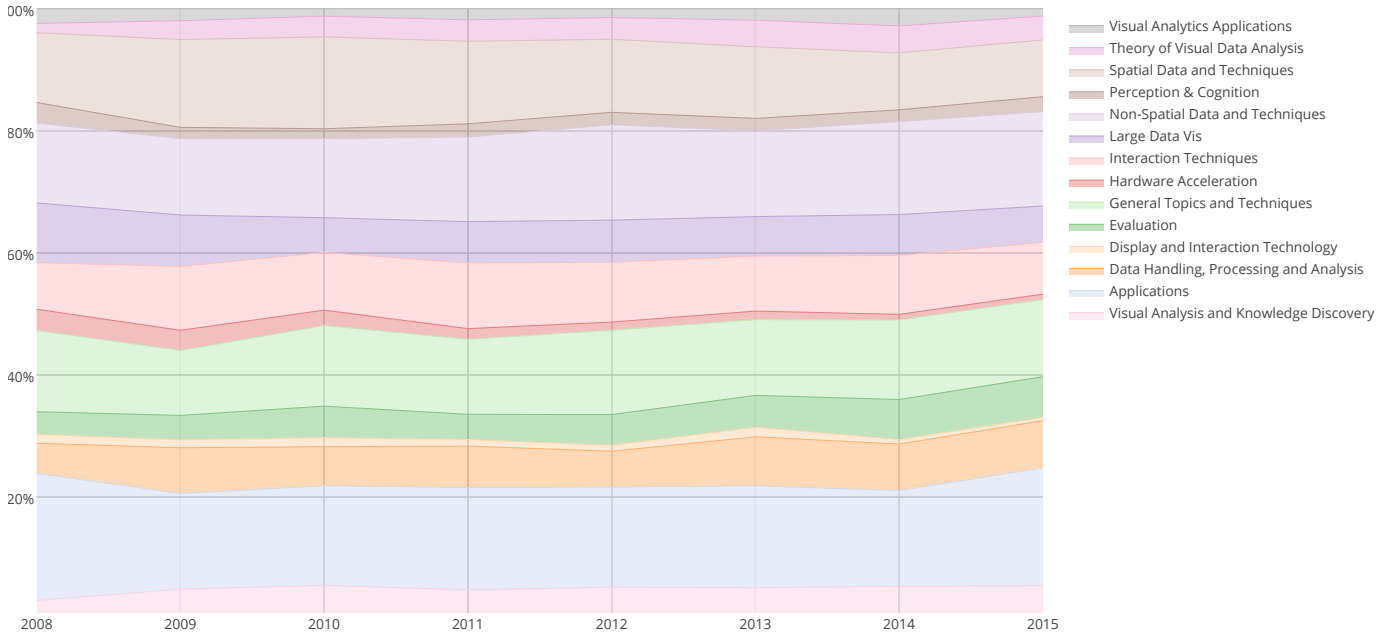


Fig. 14. History of the use of higher-level **PCS taxonomy categories** for all papers submitted to **PacificVis, EuroVis, InfoVis, SciVis, and VAST** in **2008–2015** (PacificVis from 2009), percentages (same data as in Fig. 12). Each primary keyword is weighted twice as much as secondary ones per paper, but the total weight of all keywords of a paper is 1.

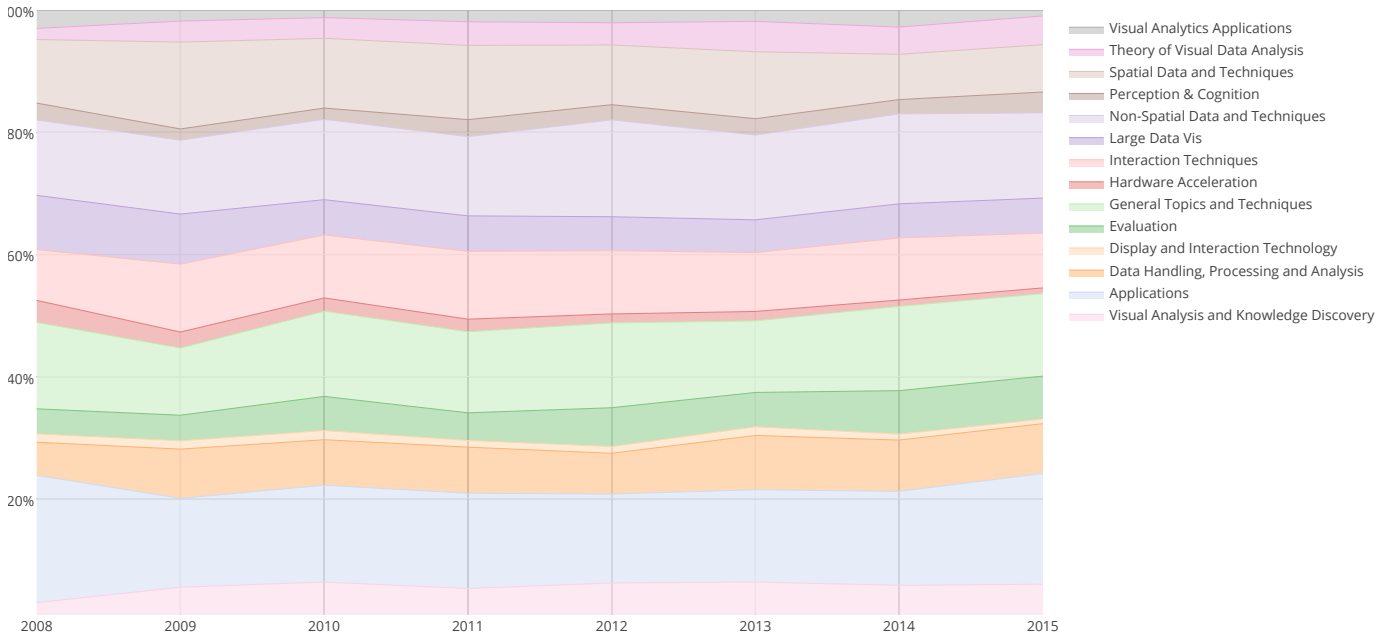


Fig. 15. History of the use of higher-level **PCS taxonomy** categories for all papers submitted to **InfoVis, Vis/SciVis, and VAST** in **2008–2015**, percentages (same data as in Fig. 13). Each primary keyword is weighted twice as much as secondary ones per paper, but the total weight of all keywords of a paper is 1.

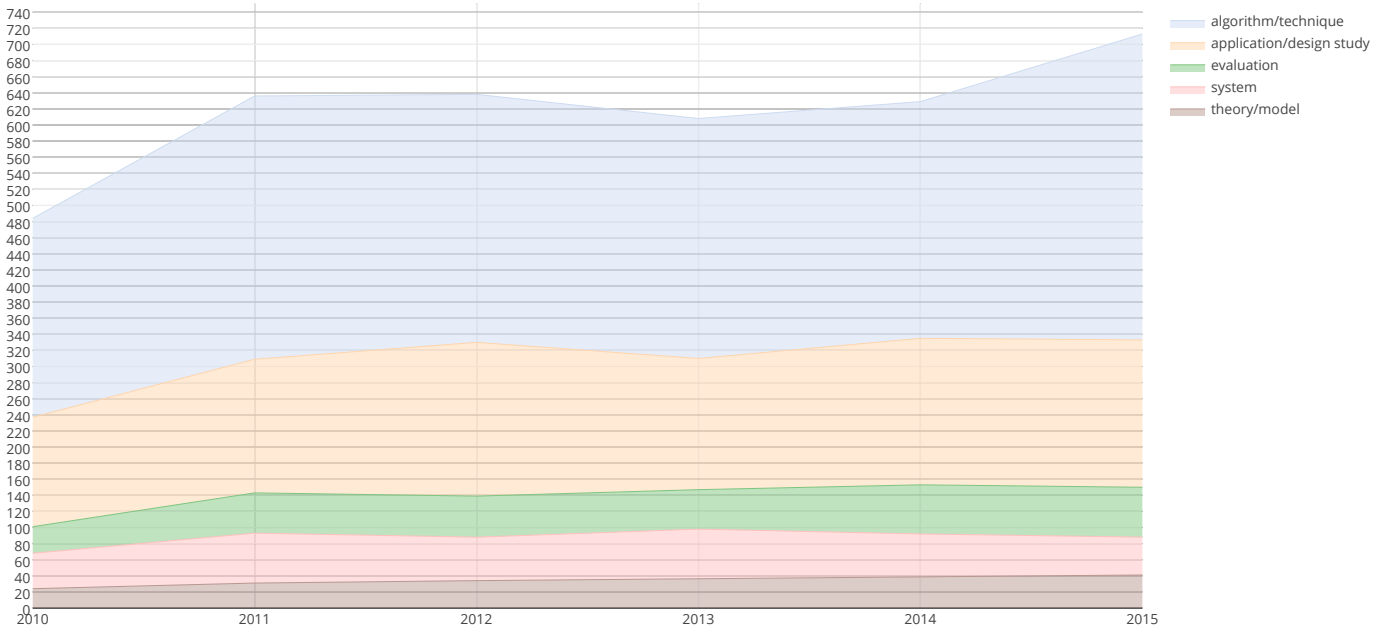


Fig. 16. History of the use of **paper types** in PCS for all papers submitted to **PacificVis, EuroVis, InfoVis, Vis/SciVis, and VAST** in **2010–2015** (VAST from 2011, PacificVis from 2015), total values. Due to the missing VAST and PacificVis data, the top line does not reflect the overall submission numbers.

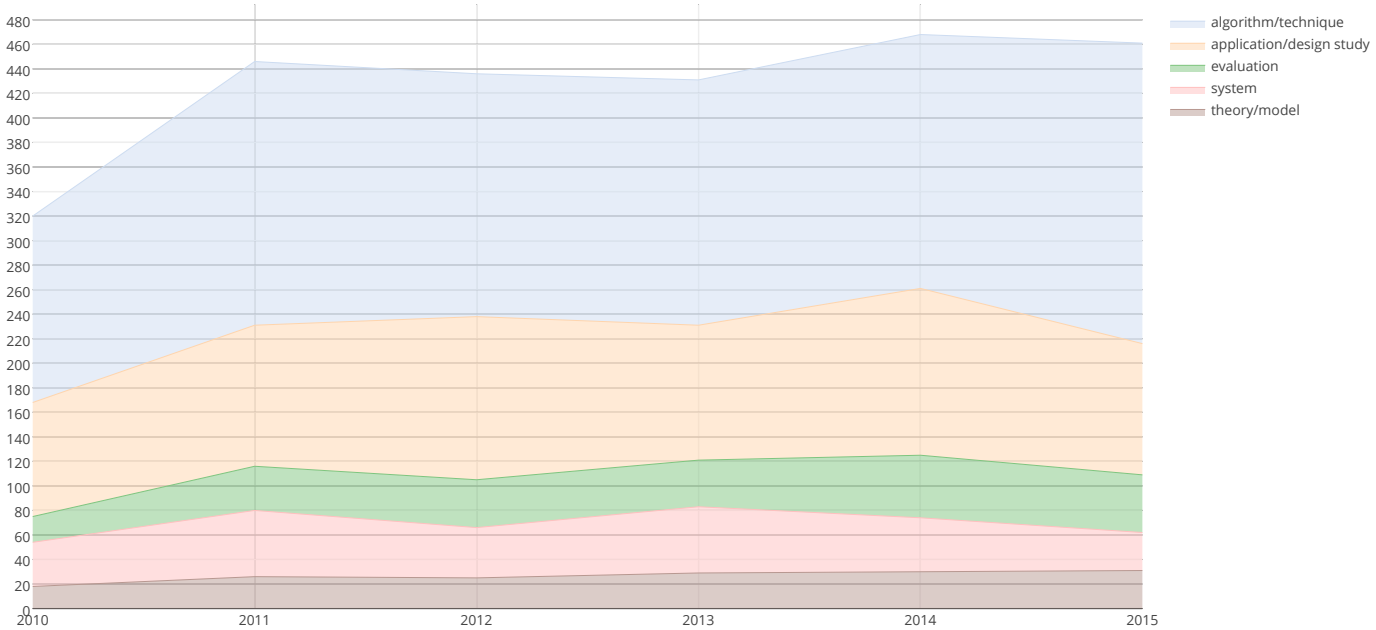


Fig. 17. History of the use of **paper types** in PCS for all papers submitted to **InfoVis, Vis/SciVis, and VAST** in **2010–2015** (VAST from 2011), total values. Thus each vertical sum in this figure reflects the overall submission numbers (except for 2010 because the VAST data was missing for that year).

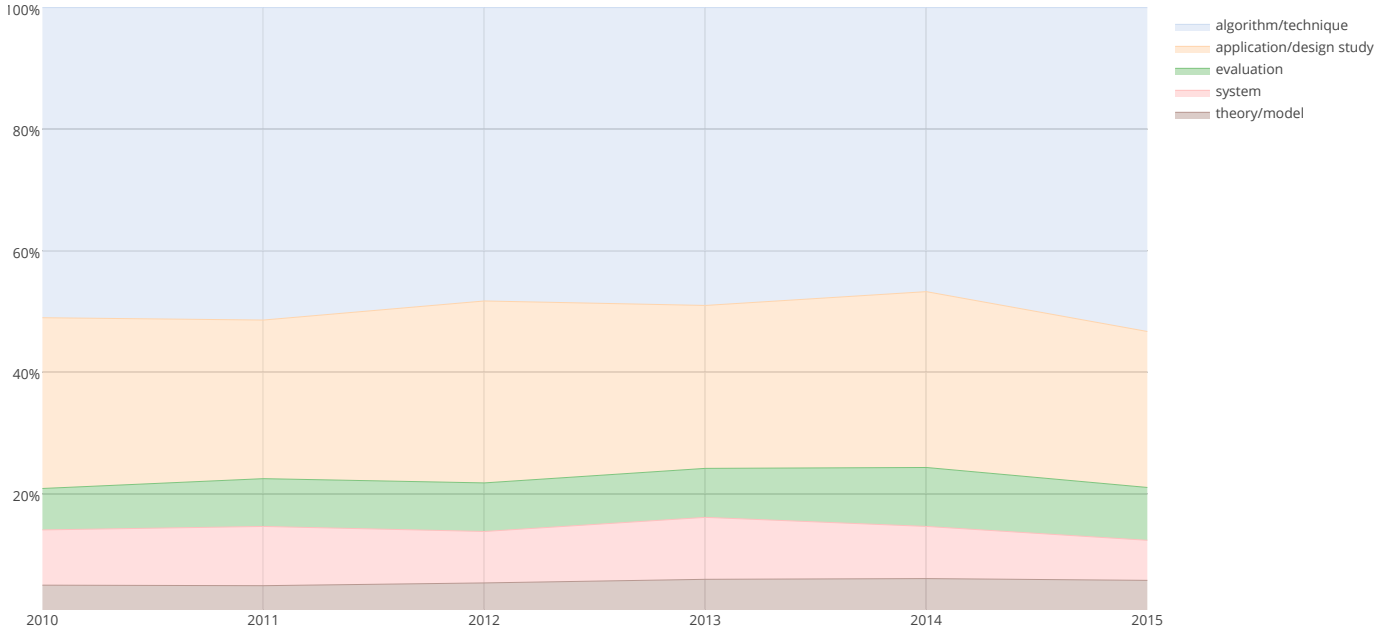


Fig. 18. History of the use of **paper types** in PCS for all papers submitted to **PacificVis, EuroVis, InfoVis, Vis/SciVis, and VAST** in **2010–2015** (VAST from 2011, PacificVis from 2015), percentages (same data as in Fig. 16).

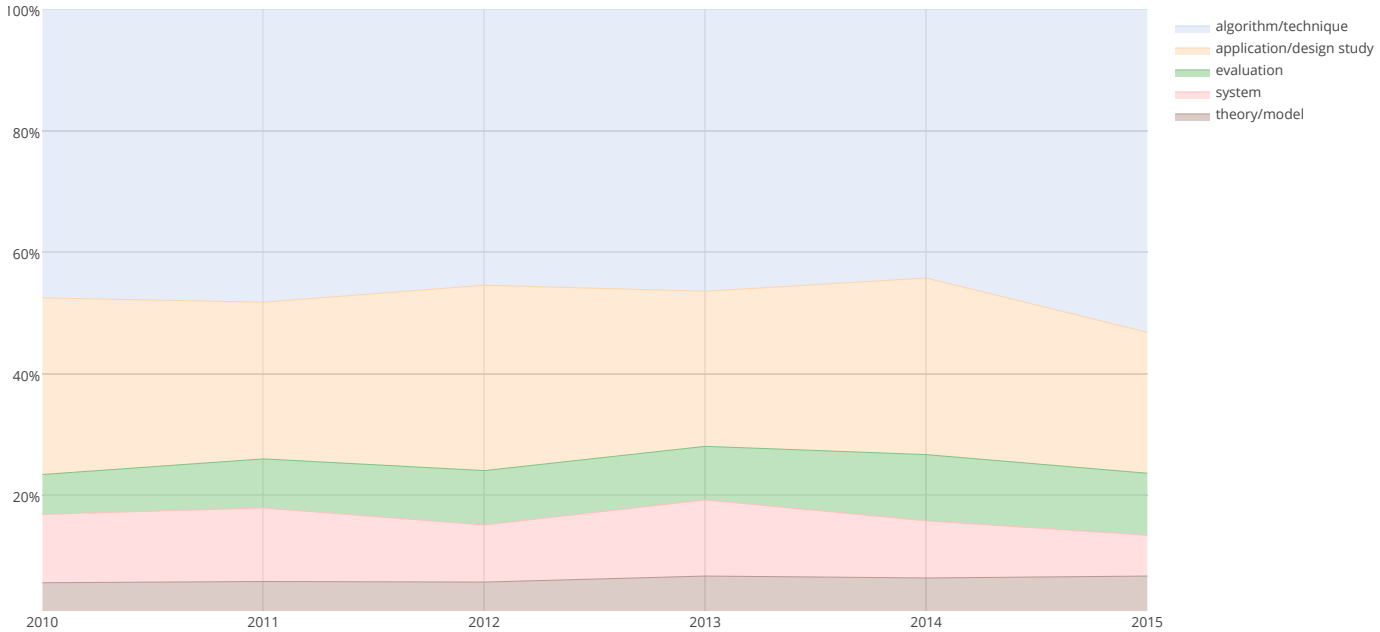


Fig. 19. History of the use of **paper types** in PCS for all papers submitted to **InfoVis, Vis/SciVis, and VAST** in **2010–2015** (VAST from 2011), percentages (same data as in Fig. 17).

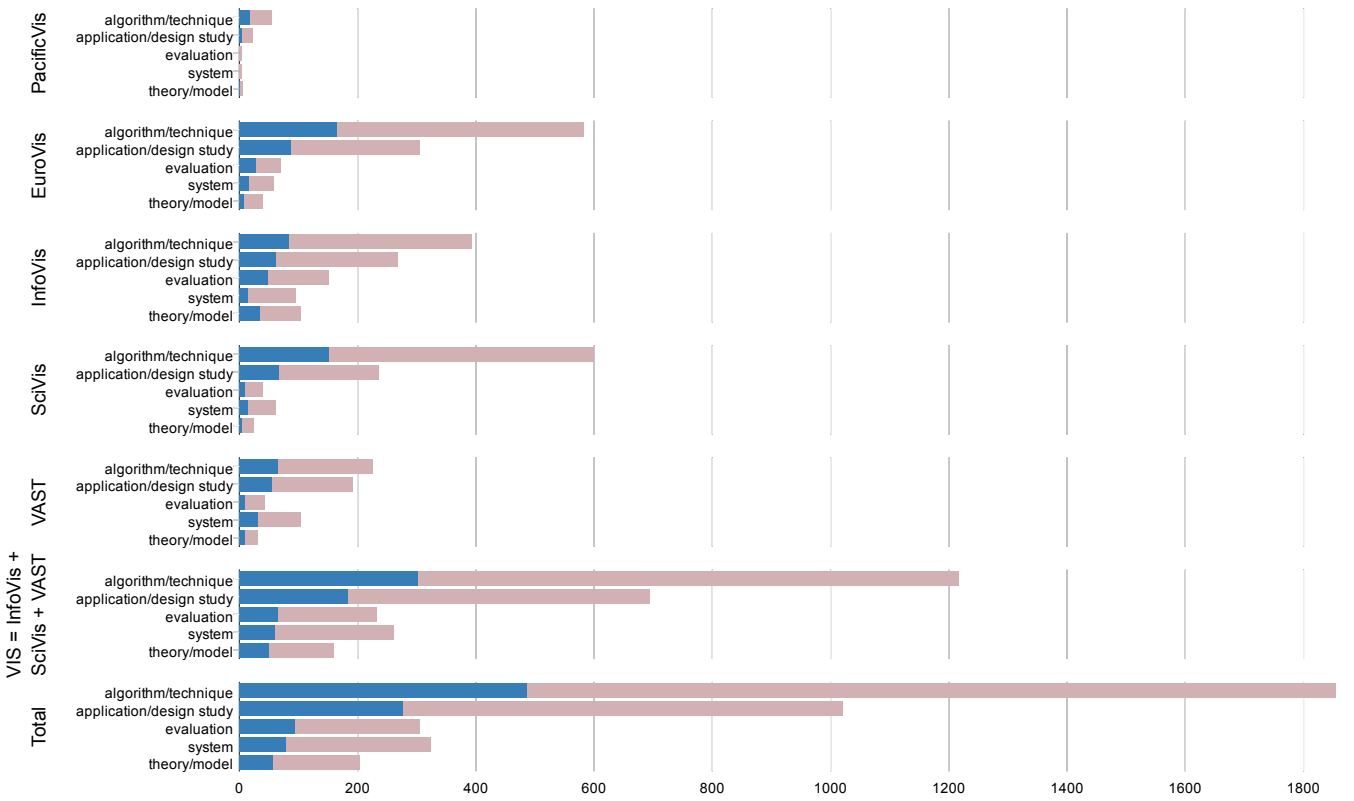


Fig. 20. Total **paper numbers** for the five different **paper types** with the **acceptance rate** (blue–accepted, red–rejected) for all papers submitted to **PacificVis, EuroVis, InfoVis, SciVis, and VAST** in **2010–2015** (VAST from 2011, PacificVis from 2015).

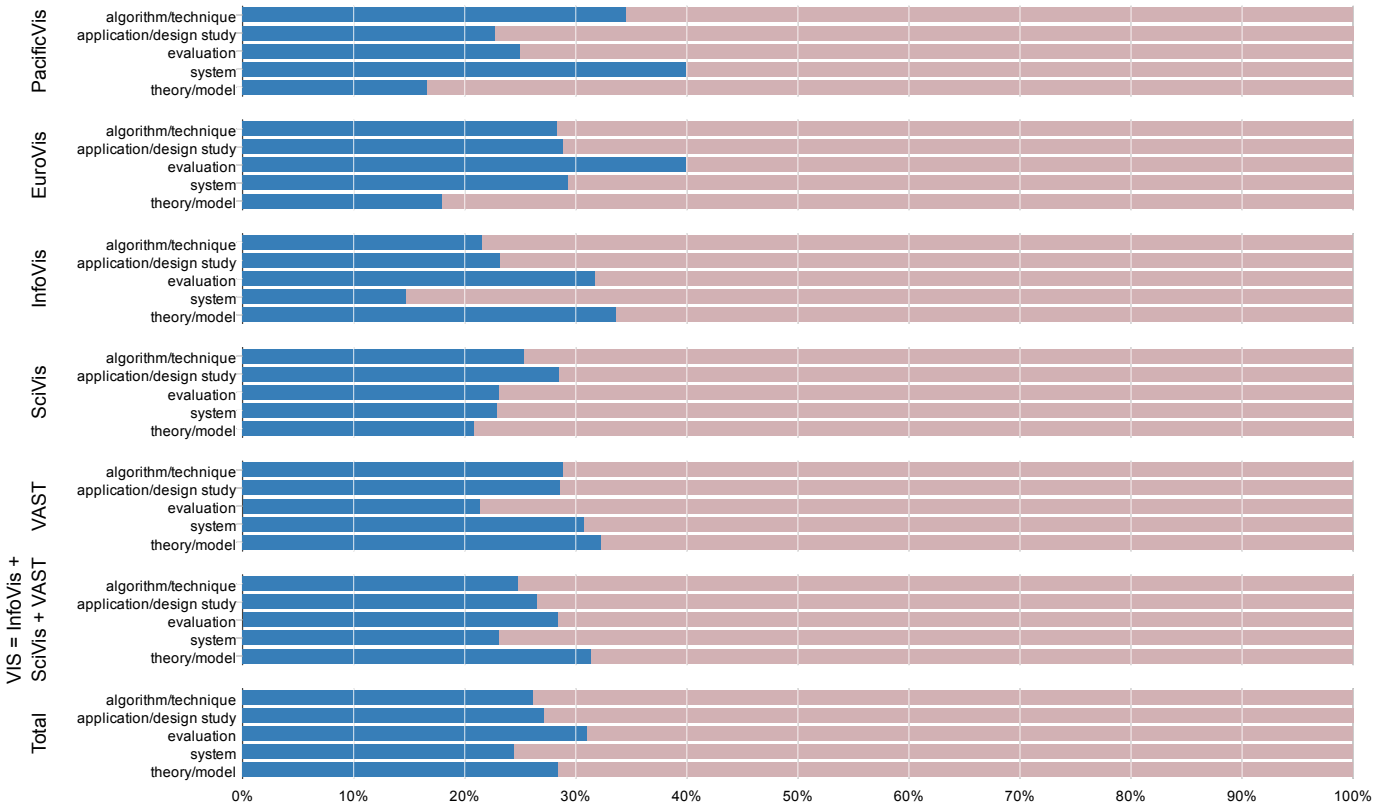


Fig. 21. **Acceptance percentages** (blue–accepted, red–rejected) for the five different **paper types** for all papers submitted to **PacificVis, EuroVis, InfoVis, SciVis, and VAST** in **2010–2015** (VAST from 2011, PacificVis from 2015).

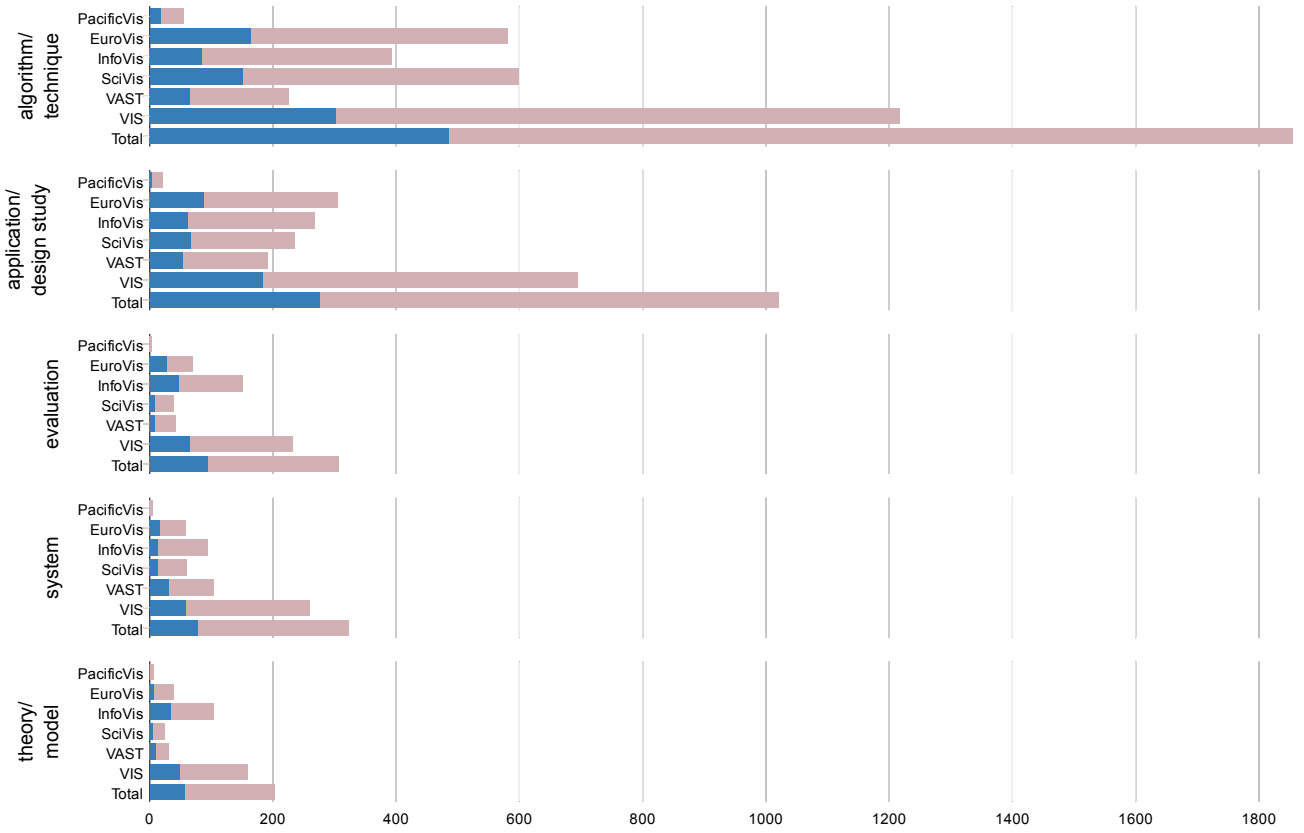


Fig. 22. Total **paper numbers** for the five different **paper types** with the **acceptance rate** (blue–accepted, red–rejected) for all papers submitted to **PacificVis, EuroVis, InfoVis, SciVis, and VAST** in **2010–2015** (VAST from 2011, PacificVis from 2015). Same as Fig. 20 but by paper type first.

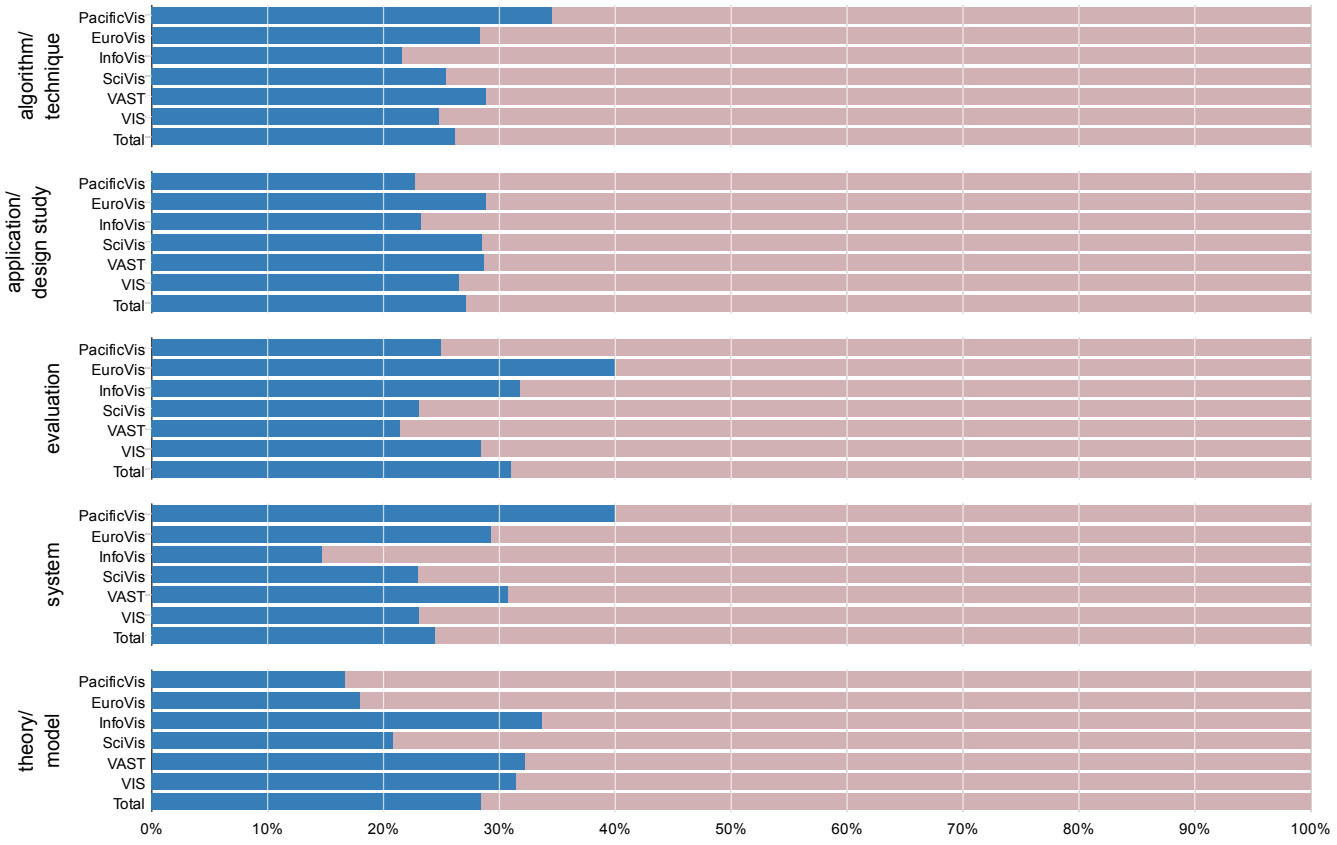


Fig. 23. **Acceptance percentages** (blue–accepted, red–rejected) for the five different **paper types** for all papers submitted to **PacificVis, EuroVis, InfoVis, SciVis, and VAST** in **2010–2015** (VAST from 2011, PacificVis from 2015). Same as Fig. 21 but by paper type first.

Table 1. Summary of the use of the PCS taxonomy (all submitted VIS papers 2008–2015), part 1.

higher-level keyword	lower-level keyword	all	by conference				by year							
		Σ	InfoVis	SciVis	VAST	Vis	2008	2009	2010	2011	2012	2013	2014	2015
Applications	Bioinformatics Visualization	106	61	6	27	12	14	15	17	10	10	11	16	13
	Biomedical and Medical Visualization	286	30	43	20	193	29	31	43	47	31	37	33	35
	Business and finance Visualization	58	19	0	38	1	2	5	6	9	15	10	5	6
	Data Warehousing, Database Visualization and Data Mining	55	23	2	26	4	11	4	4	6	7	8	9	6
	Flow Visualization	195	0	39	2	154	28	25	34	25	21	23	20	19
	Geographic/Geospatial Visualization	269	112	13	104	40	29	15	26	34	31	34	45	55
	Molecular Visualization	45	3	13	0	29	3	6	8	3	2	9	7	7
	Multimedia (Image/Video/Music) Visualization	78	35	2	21	20	19	2	9	11	10	10	9	8
	Software Visualization	43	23	1	12	7	1	5	5	6	11	3	7	5
	Terrain Visualization	22	0	3	2	17	9	2	5	1	2	0	2	1
	Visualization for the Masses	116	90	3	17	6	8	10	17	14	13	12	20	22
	Visualization in Earth, Space, and Environmental Sciences	127	13	24	26	64	15	9	13	16	20	17	17	20
	Visualization in Education	40	18	2	11	9	2	3	8	3	7	4	7	6
	Visualization in Mathematics	28	1	4	5	18	0	5	6	5	4	2	3	3
	Visualization in Physical Sciences and Engineering	156	18	21	24	93	24	14	18	23	21	17	15	24
	Visualization in Social and Information Sciences	152	83	4	58	7	12	16	20	27	16	19	21	21
	Visualization in the Humanities	50	24	0	21	5	0	3	3	9	4	10	6	15
Data Handling, Processing and Analysis	Data Acquisition and Management	59	13	4	25	17	0	8	4	6	10	14	9	8
	Data Aggregation	84	37	2	33	12	0	7	14	8	12	15	12	16
	Data Cleaning	23	5	1	11	6	2	0	3	0	6	3	2	7
	Data Clustering	180	60	9	80	31	0	13	27	28	24	34	25	29
	Data filtering	78	19	4	28	27	0	4	12	14	13	16	10	9
	Data Fusion and Integration	44	5	5	18	16	4	4	4	5	8	6	10	3
	Data Registration	17	0	2	0	15	0	3	3	3	2	4	1	1
	Data Segmentation	64	4	14	13	33	0	13	11	8	7	4	13	8
	Data Smoothing	21	6	4	1	10	0	3	3	3	3	3	3	3
	Data Transformation and Representation	269	94	34	66	75	8	26	37	40	35	35	45	43
	Feature Detection and Tracking	189	13	29	30	117	37	22	24	22	16	26	24	18
	Machine Learning	97	24	5	59	9	0	13	9	7	13	21	15	19
Display and Interaction Technology	Haptics for Visualization	6	2	0	1	3	0	0	2	2	0	0	2	0
	Immersive and Virtual Environments	47	9	5	5	28	8	6	8	7	4	6	4	4
	Large and High-res Displays	72	24	4	18	26	9	8	9	9	12	11	7	7
	Multimodal Input Devices	14	8	0	0	6	0	0	3	1	4	3	2	1
	Stereo Displays	18	3	4	2	9	0	1	2	3	4	2	4	2
Evaluation	Field Studies	44	23	0	14	7	0	2	5	7	12	7	6	5
	Laboratory Studies	104	68	0	25	11	0	7	19	6	20	21	19	12
	Metrics and Benchmarks	50	30	3	4	13	2	8	8	5	3	9	8	7
	Qualitative Evaluation	190	95	5	57	33	18	14	23	25	29	22	28	31
	Quantitative Evaluation	277	169	18	28	62	18	14	32	35	39	38	49	52
	Task and Requirements Analysis	70	35	0	32	3	6	3	4	4	9	14	13	17
	Usability Studies	124	68	5	30	21	15	10	22	9	14	14	16	24
General Topics and Techniques	Aesthetics in Visualization	84	69	4	2	9	3	12	9	9	15	8	13	15
	Animation	68	39	2	8	19	4	5	8	12	9	9	13	8
	Collaborative and Distributed Visualization	82	28	2	34	18	11	12	15	10	11	9	8	6
	Design Studies	165	103	7	41	14	6	9	17	31	23	21	28	30
	Glyph-based Techniques	103	50	8	9	36	6	7	14	16	20	12	14	14
	Illustrative Visualization	108	31	8	5	64	16	9	21	19	13	11	8	11
	Integrating Spatial and Non-Spatial Data Visualization	130	50	19	31	30	11	15	16	9	16	13	27	23
	Mathematical Foundations for Visualization	128	38	11	11	68	19	17	25	16	15	11	11	14
	Mobile and Ubiquitous Visualization	50	26	1	11	12	1	2	8	9	9	8	8	5
	Presentation, Production, and Dissemination	54	37	0	11	6	4	3	9	6	7	10	6	9
	Scalability Issues	109	52	12	19	26	7	13	14	12	16	16	15	16
	Sonification	3	0	0	1	2	2	0	0	0	0	0	1	0
	Uncertainty Visualization	139	39	20	21	59	8	12	14	12	22	23	26	22
	View-dependent Visualization	58	8	8	1	41	1	6	13	13	11	5	6	3
	Visual Design	209	148	6	32	23	7	12	26	29	32	22	42	39
	Visualization System and Toolkit Design	262	113	14	72	63	53	15	27	37	28	34	34	34
Hardware Acceleration	CPU and GPU clusters	12	1	2	0	9	0	1	2	1	5	1	1	1
	Distributed Systems and Grid Environments	22	6	5	3	8	6	2	1	1	1	4	4	3
	GPUs and Multi-core Architectures	188	19	19	3	147	32	26	34	31	20	19	11	15
	Parallel Systems	30	4	4	1	21	0	4	4	4	8	6	3	1
	Special Purpose Hardware	2	0	0	1	1	1	0	0	0	0	0	1	0
	Volume Graphics Hardware	4	0	0	1	3	0	1	1	0	1	1	0	0

Table 2. Summary of the use of the PCS taxonomy (all submitted VIS papers 2008–2015), part 2.

higher-level keyword	lower-level keyword	all	by conference				by year							
		Σ	InfoVis	SciVis	VAST	Vis	2008	2009	2010	2011	2012	2013	2014	2015
Interaction Techniques	Coordinated and Multiple Views	336	134	21	118	63	16	29	42	57	46	43	46	57
	Data Editing	22	7	1	9	5	0	0	3	2	7	2	3	5
	Focus + Context Techniques	184	98	12	31	43	19	20	29	30	20	21	24	21
	Human Factors	52	22	0	16	14	6	9	6	6	6	7	3	9
	Human-Computer Interaction	218	104	7	68	39	19	29	30	23	27	27	28	35
	Interaction Design	256	128	10	65	53	19	24	36	28	46	32	36	35
	Manipulation and Deformation	68	30	6	9	23	0	7	5	12	15	12	14	3
	User Interfaces	298	138	12	82	66	19	24	43	44	45	46	38	39
	Zooming and Navigation Techniques	128	71	11	19	27	4	15	19	18	21	18	20	13
Large Data Vis	Compression Techniques	46	9	11	2	24	3	2	5	6	9	8	8	5
	Multi-field, Multi-modal and Multi-variate Data	120	3	28	12	77	18	16	13	10	13	17	14	19
	Multidimensional Data	260	117	14	86	43	31	30	28	32	31	33	40	35
	Multiresolution Techniques	79	17	12	2	48	11	10	13	14	5	9	10	7
	Petascale Techniques	17	0	3	0	14	0	1	4	4	2	3	2	1
	Streaming Data	75	24	5	21	25	4	8	17	8	14	8	9	7
	Time-varying Data	278	68	32	60	118	28	37	41	35	34	29	35	39
Non-Spatial Data and	Dimensionality Reduction	114	47	4	47	16	0	9	17	15	22	20	13	18
Techniques	Graph/Network Data	383	271	10	91	11	48	42	43	39	59	42	54	56
	Hierarchy Data	127	98	3	19	7	19	15	16	12	23	15	18	9
	High-Dimensional Data	254	123	6	92	33	18	22	35	38	37	41	35	28
	Parallel Coordinates	84	51	2	20	11	12	11	11	16	11	6	6	11
	Pixel-oriented Techniques	51	32	1	11	7	0	3	9	7	11	8	7	6
	Statistical Graphics	94	58	5	21	10	8	5	9	12	13	13	19	15
	Tabular Data	46	31	0	15	0	0	3	6	11	5	8	10	3
	Text and Document Data	233	108	0	121	4	13	23	33	29	34	28	34	39
	Time Series Data	279	143	5	99	32	15	21	34	34	44	37	44	50
Perception & Cognition	Attention and Blindness	18	8	3	1	6	1	1	1	3	2	2	3	5
	Cognition Theory	44	20	2	18	4	6	1	5	9	4	6	5	8
	Cognitive and Perceptual Skill	45	29	3	10	3	1	0	9	4	7	6	8	10
	Color Perception	48	23	4	3	18	4	7	6	7	4	4	6	10
	Distributed Cognition	11	4	1	6	0	3	0	2	2	2	0	0	2
	Embodied / Enactive Cognition	7	3	0	4	0	1	1	1	0	1	2	0	1
	Motion Perception	19	11	1	3	4	0	1	2	1	3	5	3	4
	Perception Theory	43	28	2	5	8	6	6	2	7	4	4	6	8
	Perceptual Cognition	54	38	4	6	6	4	4	4	4	8	9	7	14
	Scene Perception	39	6	5	1	27	8	2	5	6	6	5	3	4
	Texture Perception	13	2	1	1	9	2	2	1	4	1	2	0	1
Spatial Data and Techniques	Extraction of Surfaces (Isosurfaces, Material Boundaries)	118	0	20	1	97	18	17	20	15	14	14	11	9
	Geometry-based Techniques	123	0	19	7	97	0	18	18	23	18	24	10	12
	Irregular and Unstructured Grids	45	0	8	0	37	8	4	4	8	9	4	4	4
	PDE's for Visualization	16	0	0	0	16	3	4	2	3	1	3	0	0
	Point-Based Data	80	6	8	8	58	9	15	11	13	9	12	2	9
	Scalar field Data	171	1	54	2	114	0	22	25	26	22	21	26	29
	Tensor field Data	54	0	11	1	42	7	8	10	7	6	4	5	7
	Topology-based Techniques	121	1	24	8	88	6	20	21	17	15	15	14	13
	Vector field Data	179	1	44	1	133	11	22	27	28	21	25	18	27
	Volume Modeling	36	0	4	0	32	11	5	6	2	3	5	1	3
	Volume Rendering	279	0	42	2	235	32	42	39	48	40	36	25	17
Theory of Visual Data	Design Methodologies	93	59	1	20	13	0	8	14	14	14	15	12	16
Analysis	Taxonomies	86	52	3	25	6	14	4	6	10	12	15	9	16
	Visual Analysis Models	130	39	5	73	13	0	15	19	12	22	17	23	22
	Visualization Models	174	109	12	25	28	14	19	22	20	18	26	27	28
Visual Analysis and	Hypothesis Forming	69	20	0	40	9	0	10	8	10	11	14	4	12
Knowledge Discovery	Hypothesis Testing, Visual Evidence	81	27	2	39	13	0	11	11	10	8	13	11	17
	Knowledge Externalization	44	9	0	35	0	0	1	5	10	7	7	6	8
	Visual Knowledge Discovery	430	137	16	240	37	31	38	53	47	65	62	64	70
	Visual Knowledge Representation	170	84	2	69	15	5	20	34	23	25	25	22	16
Visual Analytics Applications	Emergency/Disaster Management	41	5	2	26	8	4	3	3	5	11	3	8	4
	Intelligence Analysis	82	12	2	64	4	10	6	11	9	11	12	14	9
	Network Security and Intrusion	24	9	0	14	1	3	4	2	2	4	3	4	2
	Privacy and Security	11	5	1	3	2	3	0	1	1	2	1	1	2
	Sensor Networks	23	8	1	10	4	5	2	4	6	1	1	4	0
	Situational Awareness	60	21	1	34	4	6	5	5	8	11	7	13	5
	Time Critical Applications	16	2	0	10	4	4	4	0	1	4	3	0	0
Grand Total		13176	4939	1018	3263	3956	1101	1309	1774	1750	1832	1762	1798	1850

Table 3. Summary of the use of the PCS taxonomy (all submitted PacificVis, EuroVis, and VIS papers 2008–2015, PacificVis from 2009), part 1.

higher-level keyword	lower-level keyword	all	by conference			by year							
		Σ	PacificVis	EuroVis	VIS	2008	2009	2010	2011	2012	2013	2014	2015
Applications	Bioinformatics Visualization	169	19	44	106	18	22	25	23	18	23	19	21
	Biomedical and Medical Visualization	486	55	145	286	47	54	75	68	69	66	53	54
	Business and finance Visualization	78	6	14	58	3	7	8	14	19	14	6	7
	Data Warehousing, Database Visualization and Data Mining	75	7	13	55	12	6	8	9	8	10	10	12
	Flow Visualization	353	61	97	195	38	38	47	50	52	42	43	43
	Geographic/Geospatial Visualization	400	42	89	269	36	19	39	53	49	55	68	81
	Molecular Visualization	82	11	26	45	5	6	12	10	6	15	14	14
	Multimedia (Image/Video/Music) Visualization	105	12	15	78	19	3	14	16	13	13	13	14
	Software Visualization	92	18	31	43	9	10	11	13	17	16	7	9
	Terrain Visualization	34	3	9	22	9	2	8	4	8	0	2	1
	Visualization for the Masses	142	13	13	116	9	12	22	18	16	13	27	25
	Visualization in Earth, Space, and Environmental Sciences	201	24	50	127	22	15	19	29	33	29	24	30
	Visualization in Education	56	7	9	40	3	6	8	3	9	8	8	11
	Visualization in Mathematics	37	3	6	28	0	7	6	5	6	4	5	4
	Visualization in Physical Sciences and Engineering	280	39	85	156	38	28	36	40	34	31	33	40
	Visualization in Social and Information Sciences	209	20	37	152	14	22	24	36	25	28	27	33
	Visualization in the Humanities	68	6	12	50	0	3	4	14	5	12	11	19
Data Handling, Processing and Analysis	Data Acquisition and Management	78	5	14	59	0	11	5	10	12	16	13	11
	Data Aggregation	99	10	5	84	0	10	19	10	13	16	14	17
	Data Cleaning	26	2	1	23	3	0	3	0	6	3	3	8
	Data Clustering	280	31	69	180	0	19	40	44	40	54	38	45
	Data filtering	121	10	33	78	0	8	17	24	18	23	13	18
	Data Fusion and Integration	62	4	14	44	4	6	7	7	14	9	12	3
	Data Registration	20	0	3	17	0	3	5	3	2	4	2	1
	Data Segmentation	91	7	20	64	0	14	12	13	12	11	18	11
	Data Smoothing	25	2	2	21	0	4	4	4	3	3	3	4
	Data Transformation and Representation	374	37	68	269	11	35	48	55	45	58	62	60
	Feature Detection and Tracking	265	29	47	189	46	33	30	32	24	38	32	30
	Machine Learning	127	7	23	97	0	14	11	7	19	30	20	26
Display and Interaction Technology	Haptics for Visualization	9	2	1	6	0	1	3	2	1	0	2	0
	Immersive and Virtual Environments	78	7	24	47	13	10	13	11	7	15	5	4
	Large and High-res Displays	99	13	14	72	11	11	12	15	16	17	10	7
	Multimodal Input Devices	17	1	2	14	0	0	3	2	5	3	2	2
	Stereo Displays	27	2	7	18	0	2	4	3	5	5	5	3
Evaluation	Field Studies	51	3	4	44	0	2	6	9	14	9	6	5
	Laboratory Studies	131	8	19	104	0	8	23	8	22	25	26	19
	Metrics and Benchmarks	75	9	16	50	5	11	10	9	6	12	12	10
	Qualitative Evaluation	262	16	56	190	20	22	30	30	40	36	40	44
	Quantitative Evaluation	373	20	76	277	20	19	48	46	51	57	67	65
	Task and Requirements Analysis	91	7	14	70	6	5	5	5	10	17	19	24
	Usability Studies	183	20	39	124	22	16	26	17	16	24	27	35
General Topics and Techniques	Aesthetics in Visualization	124	19	21	84	3	15	18	16	17	13	20	22
	Animation	120	18	34	68	8	10	14	22	17	20	17	12
	Collaborative and Distributed Visualization	108	14	12	82	11	16	20	16	13	13	11	8
	Design Studies	234	17	52	165	9	11	25	41	38	35	37	38
	Glyph-based Techniques	151	10	38	103	8	10	20	20	29	18	22	24
	Illustrative Visualization	184	20	56	108	28	19	29	27	27	21	17	16
	Integrating Spatial and Non-Spatial Data Visualization	172	7	35	130	11	18	19	14	26	20	36	28
	Mathematical Foundations for Visualization	181	17	36	128	25	20	39	21	19	20	18	19
	Mobile and Ubiquitous Visualization	67	7	10	50	1	3	10	12	13	11	11	6
	Presentation, Production, and Dissemination	66	2	10	54	5	3	9	7	10	13	7	12
	Scalability Issues	155	12	34	109	9	18	19	19	27	24	19	20
	Sonification	6	1	2	3	3	0	0	0	0	2	1	0
	Uncertainty Visualization	226	19	68	139	11	16	21	23	43	38	35	39
	View-dependent Visualization	112	21	33	58	4	10	22	23	22	10	15	6
	Visual Design	278	22	47	209	12	16	31	36	41	36	54	52
	Visualization System and Toolkit Design	367	35	70	262	55	23	41	53	48	54	49	44
Hardware Acceleration	CPU and GPU clusters	18	5	1	12	0	1	3	2	5	3	2	2
	Distributed Systems and Grid Environments	35	6	7	22	6	5	1	3	4	6	5	5
	GPUs and Multi-core Architectures	260	32	40	188	45	45	57	34	26	24	12	17
	Parallel Systems	55	8	17	30	0	8	8	11	11	9	6	2
	Special Purpose Hardware	4	0	2	2	1	0	0	0	2	0	1	0
	Volume Graphics Hardware	8	1	3	4	0	3	2	0	1	2	0	0

Table 4. Summary of the use of the PCS taxonomy (all submitted PacificVis, EuroVis, and VIS papers 2008–2015, PacificVis from 2009), part 2.

higher-level keyword	lower-level keyword	all	by conference			by year							
		Σ	PacificVis	EuroVis	VIS	2008	2009	2010	2011	2012	2013	2014	2015
Interaction Techniques	Coordinated and Multiple Views	474	44	94	336	16	36	57	76	73	65	69	82
	Data Editing	28	5	1	22	0	0	6	2	7	3	4	6
	Focus + Context Techniques	320	40	96	184	27	38	45	54	40	39	40	37
	Human Factors	74	1	21	52	6	14	8	11	6	8	9	12
	Human-Computer Interaction	301	18	65	218	28	37	33	41	37	40	44	41
	Interaction Design	329	25	48	256	19	29	47	41	62	47	43	41
	Manipulation and Deformation	104	10	26	68	0	9	6	18	22	20	23	6
	User Interfaces	382	50	34	298	28	39	65	53	52	54	41	50
	Zooming and Navigation Techniques	197	13	56	128	7	20	25	32	39	27	30	17
Large Data Vis	Compression Techniques	81	11	24	46	5	2	8	8	15	16	16	11
	Multi-field, Multi-modal and Multi-variate Data	224	25	79	120	30	26	24	22	29	33	32	28
	Multidimensional Data	431	33	138	260	44	47	43	53	61	58	71	54
	Multiresolution Techniques	132	13	40	79	17	16	21	21	13	18	14	12
	Petascale Techniques	24	4	3	17	0	2	6	5	3	3	3	2
	Streaming Data	102	12	15	75	4	15	20	13	18	13	11	8
	Time-varying Data	451	56	117	278	45	54	55	63	63	54	59	58
Non-Spatial Data and	Dimensionality Reduction	180	18	48	114	0	10	24	24	33	30	30	29
Techniques	Graph/Network Data	637	106	148	383	69	71	78	72	85	85	90	87
	Hierarchy Data	213	28	58	127	31	30	24	21	34	24	26	23
	High-Dimensional Data	379	35	90	254	25	30	49	58	55	61	54	47
	Parallel Coordinates	162	21	57	84	17	21	18	29	33	11	15	18
	Pixel-oriented Techniques	101	9	41	51	0	4	15	19	22	17	11	13
	Statistical Graphics	128	5	29	94	10	8	13	19	20	18	20	20
	Tabular Data	62	1	15	46	0	3	9	13	11	9	10	7
	Text and Document Data	315	27	55	233	15	29	38	41	46	39	51	56
	Time Series Data	428	53	96	279	22	30	51	62	70	58	58	77
Perception & Cognition	Attention and Blindness	22	0	4	18	1	1	3	4	2	3	3	5
	Cognition Theory	55	2	9	44	12	3	5	11	4	7	5	8
	Cognitive and Perceptual Skill	59	1	13	45	1	1	10	6	9	9	11	12
	Color Perception	71	6	17	48	6	13	9	10	5	8	8	12
	Distributed Cognition	11	0	0	11	3	0	2	2	2	0	0	2
	Embodied / Enactive Cognition	7	0	0	7	1	1	1	0	1	2	0	1
	Motion Perception	30	5	6	19	0	2	2	5	7	6	3	5
	Perception Theory	56	4	9	43	12	8	3	9	5	4	7	8
	Perceptual Cognition	68	2	12	54	4	5	7	5	10	11	11	15
	Scene Perception	47	4	4	39	8	3	8	7	6	7	3	5
	Texture Perception	25	4	8	13	7	3	1	5	4	2	2	1
Spatial Data and Techniques	Extraction of Surfaces (Isosurfaces, Material Boundaries)	206	23	65	118	27	24	34	27	29	26	22	17
	Geometry-based Techniques	226	31	72	123	0	20	37	35	38	43	29	24
	Irregular and Unstructured Grids	86	15	26	45	11	10	8	13	16	9	12	7
	PDE's for Visualization	24	3	5	16	4	7	5	4	1	3	0	0
	Point-Based Data	148	15	53	80	13	23	24	20	15	24	10	19
	Scalar field Data	284	29	84	171	0	26	39	46	48	38	46	41
	Tensor field Data	91	13	24	54	9	11	18	14	12	6	9	12
	Topology-based Techniques	191	20	50	121	6	25	32	30	24	30	22	22
	Vector field Data	300	44	77	179	16	35	40	45	41	42	37	44
	Volume Modeling	51	7	8	36	14	9	11	3	3	7	1	3
	Volume Rendering	520	74	167	279	52	70	96	83	79	66	43	31
Theory of Visual Data	Design Methodologies	126	11	22	93	0	9	19	18	17	21	18	24
Analysis	Taxonomies	118	8	24	86	16	7	11	13	21	21	12	17
	Visual Analysis Models	183	17	36	130	0	19	26	16	30	28	32	32
	Visualization Models	252	23	55	174	16	30	32	32	30	38	41	33
Visual Analysis and	Hypothesis Forming	88	5	14	69	0	12	8	15	15	15	5	18
Knowledge Discovery	Hypothesis Testing, Visual Evidence	111	8	22	81	0	12	14	13	14	22	15	21
	Knowledge Externalization	56	5	7	44	0	1	8	10	8	8	11	10
	Visual Knowledge Discovery	601	54	117	430	43	50	75	73	88	85	89	98
	Visual Knowledge Representation	234	33	31	170	9	29	40	31	37	31	33	24
Visual Analytics Applications	Emergency/Disaster Management	67	6	20	41	4	5	4	9	14	9	13	9
	Intelligence Analysis	106	7	17	82	13	11	14	13	14	14	16	11
	Network Security and Intrusion	36	6	6	24	3	5	2	4	4	6	7	5
	Privacy and Security	21	2	8	11	4	1	2	2	2	2	4	4
	Sensor Networks	36	3	10	23	6	3	6	10	1	3	7	0
	Situational Awareness	79	8	11	60	6	7	6	10	12	13	17	8
	Time Critical Applications	23	1	6	16	4	6	1	4	4	3	0	1
Grand Total		19736	2053	4507	13176	1494	1921	2609	2699	2848	2778	2694	2693

Table 5. Cluster result for PCS taxonomy keywords. Keywords are sorted by frequency with the two most frequent keywords highlighted in bold. We report the keywords assigned to each cluster, the size of the cluster (N), the average amount of times (median) each keyword occurred in the whole corpus ($\tilde{\#}$), the average amount of times (mean) the keywords in each cluster co-occur (cw-#), the centrality of the subnetworks created from each cluster (centr.), and the density of the subnetworks (dens.). The cluster color is the same as in Fig. 25 and Fig. 33(a).

ID	keywords (EuroVis, PacificVis, InfoVis, Vis/SciVis, VAST; 2008–2013)	N	$\tilde{\#}$	cw-#	centr.	dens.
P1	**volume rendering**; **biomedical and medical visualization**; scalar field data; gpus and multi-core architectures; extraction of surfaces (isosurfaces, material boundaries); irregular and unstructured grids; volume modeling; pde's for visualization	8	110.5	8.36	0.41	0.063
P2	**time-varying data**; **vis. in physical sciences and engineering**; vis. in earth, space, and environmental sciences; glyph-based techniques; point-based data; multi-field, multi-modal and multi-variate data; tensor field data; molecular vis.	8	71.5	4.54	0.33	0.038
P3	**feature detection and tracking**; **vector field data**; flow visualization; topology-based techniques; geometry-based techniques; mathematical foundations for visualization; visualization in mathematics; data registration	8	91.0	7.61	0.47	0.068
P4	**visual knowledge discovery**; **graph/network data**; text and document data; visual knowledge representation; data clustering; visual analysis models; hierarchy data; visualization in social and information sciences; machine learning; data segmentation; pixel-oriented techniques; software visualization; visualization in the humanities	13	107.0	8.18	0.63	0.033
P5	**high-dimensional data**; **multidimensional data**; dimensionality reduction; parallel coordinates; bioinformatics visualization	5	81.0	11.40	0.29	0.066
P6	**coordinated and multiple views**; **time series data**; visualization system and toolkit design; geographic/geospatial visualization; uncertainty visualization; integrating spatial and non-spatial data visualization; statistical graphics; hypothesis testing, visual evidence; hypothesis forming; tabular data; business and finance visualization	11	80.0	6.38	0.45	0.025
P7	**collaborative and distributed vis.**; **large and high-res displays**; multimodal input devices; embodied / enactive cognition	4	34.0	2.83	0.53	0.135
P8	**intelligence analysis**; **situational awareness**; emergency/disaster management; network security and intrusion; time critical applications; privacy and security; distributed cognition; special purpose hardware	8	10.0	0.82	0.59	0.082
P9	**scalability issues**; **streaming data**; vis. for the masses; mobile and ubiquitous vis.; parallel systems; distributed systems and grid environments; data warehousing, database vis. and data mining; cpu and gpu clusters; sensor networks; petascale techn.	10	18.0	1.58	0.74	0.055
P10	**multiresolution techniques**; **compression techniques**; terrain visualization	3	20.0	1.33	0.25	0.112
P11	**scene perception**; **stereo displays**; sonification	3	13.0	1.00	0.29	0.094
P12	**data transformation and representation**; **data aggregation**; data filtering; data acquisition and management; data fusion and integration; data cleaning; data smoothing; data editing; volume graphics hardware	9	42.0	4.83	0.96	0.127
P13	**illustrative vis.**; **multimedia (image/video/music) vis.**; animation; manipulation & deformation; immersive & virtual envi- ronm.; presentation, production, & dissemination; view-dependent vis.; vis. in education; motion perception; haptics for vis.	10	28.5	1.96	0.73	0.059
P14	**quantitative evaluation**; **laboratory studies**; metrics and benchmarks; color perception; perceptual cognition; perception theory; cognition theory; cognitive and perceptual skill; attention and blindness; texture perception	10	33.5	3.64	0.63	0.077
P15	**user interfaces**; **interaction design**; human-computer interaction; focus+context techn.; zooming and navigation techn.	5	168.0	17.10	0.49	0.131
P16	**visualization models**; **qualitative evaluation**; design studies; usability studies; design methodologies; visual design; taxonomies; aesthetics in vis.; task and requirements analysis; human factors; knowledge externalization; field studies	12	81.0	6.05	0.83	0.062

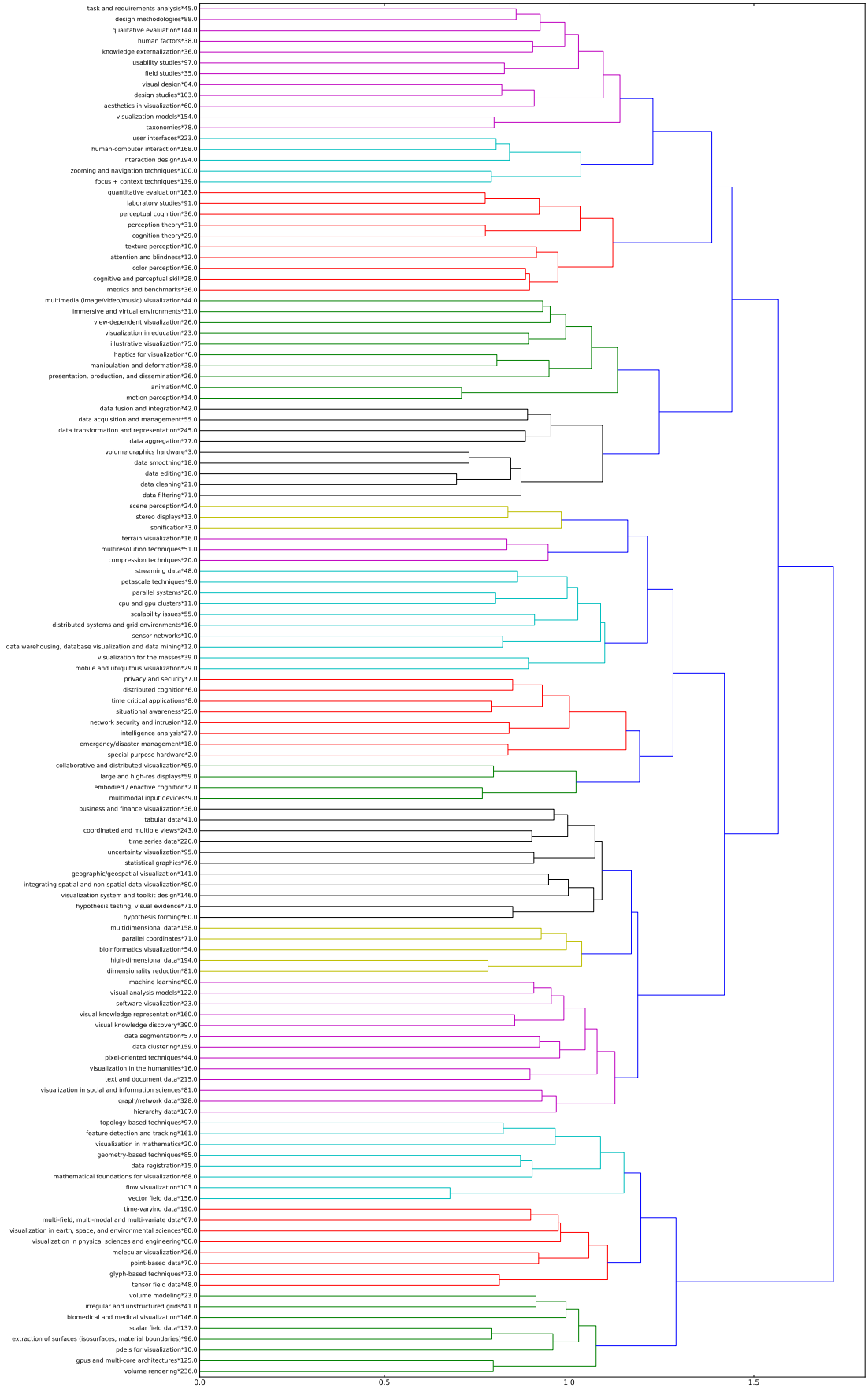


Fig. 24. Cluster hierarchy from hierarchical clustering for PCS taxonomy keywords. Colors are randomly chosen and do not have a meaning other than to distinguish the clusters.

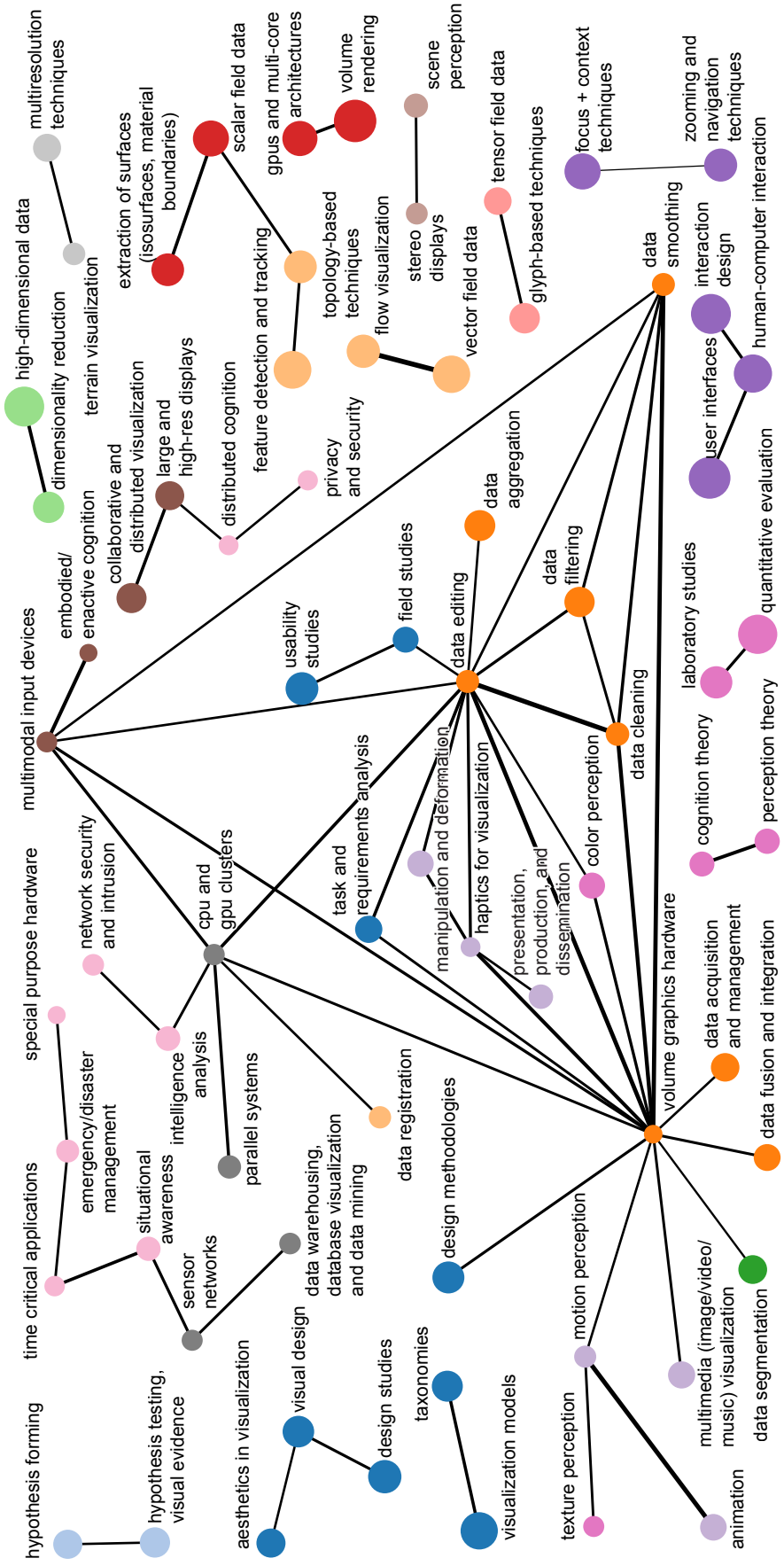


Fig. 25. Keyword map from hierarchical clustering for PCS taxonomy keywords; showing only connected nodes with correlation strength ≥ 0.15. Same colors indicate that the respective keywords belong to the same cluster in Table 5, the cluster color is the same as in Table 5 and Fig. 33(a).

Table 6. Cluster result for author-specified keywords. Keywords are sorted by frequency with the two most frequent keywords highlighted in bold. We report the keywords assigned to each cluster, the size of the cluster (N), the average amount of times (median) each keyword occurred in the whole corpus ($\tilde{\#}$), the average amount of times (mean) the keywords in each cluster co-occur (cw-#), the centrality of the subnetworks created from each cluster (centr.), and the density of the subnetworks (dens.). The cluster color is the same as in Fig. 27 and Fig. 33(b).

ID	keywords (InfoVis, Vis/SciVis, VAST; 2000–2015)	N	$\tilde{\#}$	cw-#	centr.	dens.
A1	**parallel coordinates**, **user interface**, high-dimensional data, multivariate data, multi-dimensional visualization, scatterplot, multiple views, dimension reduction, multi-dimensional scaling, multi-dimensional data, time-series, visual data mining	12	13.5	0.74	0.29	0.045
A2	**uncertainty**, **classification**, glyph, principal component analysis, data transformation, distance field, linked views, spatio-temporal visualization	8	9.0	0.61	0.22	0.053
A3	**evaluation**, **design**, animation, framework, experiment	5	14.0	1.80	0.18	0.097
A4	**treemap**, **hierarchy**, data mining, graph	4	10.0	1.17	0.17	0.097
A5	**clustering**, **graph visualization**, user study, graph drawing, user interaction, optimization	6	23.5	1.07	0.25	0.048
A6	**sensemaking**, **visual knowledge discovery**, collaboration, intelligence analysis	4	14.0	1.00	0.10	0.082
A7	**interaction**, **focus+context**, design study, coordinated & multiple views, topology, geovis., network vis., human-computer interaction, interactive vis., comparative vis., text vis., visual analysis, interactive visual analysis, time-series data, graph layout, data exploration, focus+context vis., bioinformatics, exploratory data analysis, navigation, taxonomy, knowledge discovery, mathematical vis., simulation, surface reconstruction, visual exploration	26	12.0	0.23	0.32	0.013
A8	**illustrative visualization**, **focus+context technique**	2	14.5	4.00	0.11	0.279
A9	**volume rendering**, **uncertainty visualization**, medical visualization, multivariate visualization, segmentation, virtual reality, hardware acceleration, non-photorealistic rendering, visualization systems, diffusion tensor imaging, medical imaging	11	14.0	0.71	0.29	0.025
A10	**volume visualization**, **feature extraction**, graphics hardware, gpu, texture mapping, level sets, unsteady flow visualization	7	14.0	1.10	0.31	0.063
A11	**isosurface extraction**, **marching cubes**	2	12.5	4.00	0.23	0.318
A12	**reconstruction**, **sampling**, interpolation	3	9.0	1.00	0.11	0.111
A13	**isosurface**, **direct volume rendering**, transfer function, raycasting, time-varying data, molecular visualization, surface extraction, time-varying	8	14.0	1.36	0.35	0.067
A14	**level-of-detail**, **perception**, multi-resolution, rendering	4	19.0	2.83	0.23	0.160
A15	**vector field**, **streamlines**, line integral convolution, critical points	4	11.5	1.33	0.22	0.115
A16	**flow visualization**, **simplification**, morse-smale complex, unstructured grid, vector field visualization, vector field topology	6	11.0	1.47	0.30	0.087

AUTHOR-ASSIGNED KEYWORDS

CLUSTER ANALYSIS: We created 16 clusters from the 112 author-assigned keywords. The number of clusters was based on manual inspection of the content validity of the hierarchical clustering result. Table 6 summarizes the clusters (A1–A16) that were created. In the table we report the keywords assigned to each cluster, the size of the cluster (N), the average amount of times each keyword occurred in the whole corpus ($\tilde{\#}$), the average amount of times the keywords in each cluster co-occur (cw-#), the centrality of the subnetworks created from each cluster (centr.), and the density of the subnetworks (dens.). Keywords are sorted by frequency in the dataset and the top two keywords are bolded and are used to refer to the clusters in the text. The keyword map that results from the hierarchical clustering is shown in Fig. 27.

It is important to note, however, that keywords are clustered together when they frequently co-occurred on a paper—not necessarily because they are semantically similar. For example, A8 is a two-keyword cluster including *illustrative visualization* and *focus+context technique*. *Focus+context technique* also occurred with other keywords, and in particular frequently with *volume visualization* as is evident in Fig. 27; yet, the connection to *illustrative visualization* was strongest, which can be explained through their common focus on emphasis and abstraction. The data also shows similar keywords occurring such as *focus+context* (A7), *focus+context technique* (A8), or *focus+context visualization* (A7). This is an indication that authors have not settled on a common vocabulary and that different subcommunities may be adopting different keywords.

NETWORK ANALYSIS: Next, we analyzed the strategic diagram in Fig. 33(b). The clusters in Quadrant I of the strategic diagram (top right) are considered motor themes or "mainstream" topics as they are both internally coherent and central to the research network. Visualization seems to lack such motor themes. Instead, it has several clusters in Quadrant II (bottom right) which are considered "basic and transversal" themes as they are weakly linked together (low density) but well connected to the remainder of the network (high centrality). Hence, work here can be of significance to the entire network. In particular, volume visualization-related keywords, md-data visualization, and interaction stand out here as exemplified by Clusters A7 (*interaction, focus+context*), A13 (*isosurface, direct volume rendering*), A9 (*volume rendering, uncertainty vis*), A1 (*parallel coordinates, user interface*), and A10 (*volume visualization, feature extraction*). Visualization also has few clearly developed but isolated themes in Quadrant III (top left). Only Cluster A8 (*illustrative visualization, focus+context technique*) emerges as a clear member of this quadrant with A11 (*isosurface extraction, marching cubes*) also showing high internal density. Themes in the lower left quadrant are weakly developed and marginal and are considered either declining or emerging. Only A2 (*uncertainty, classification*) falls marginally in this quadrant.

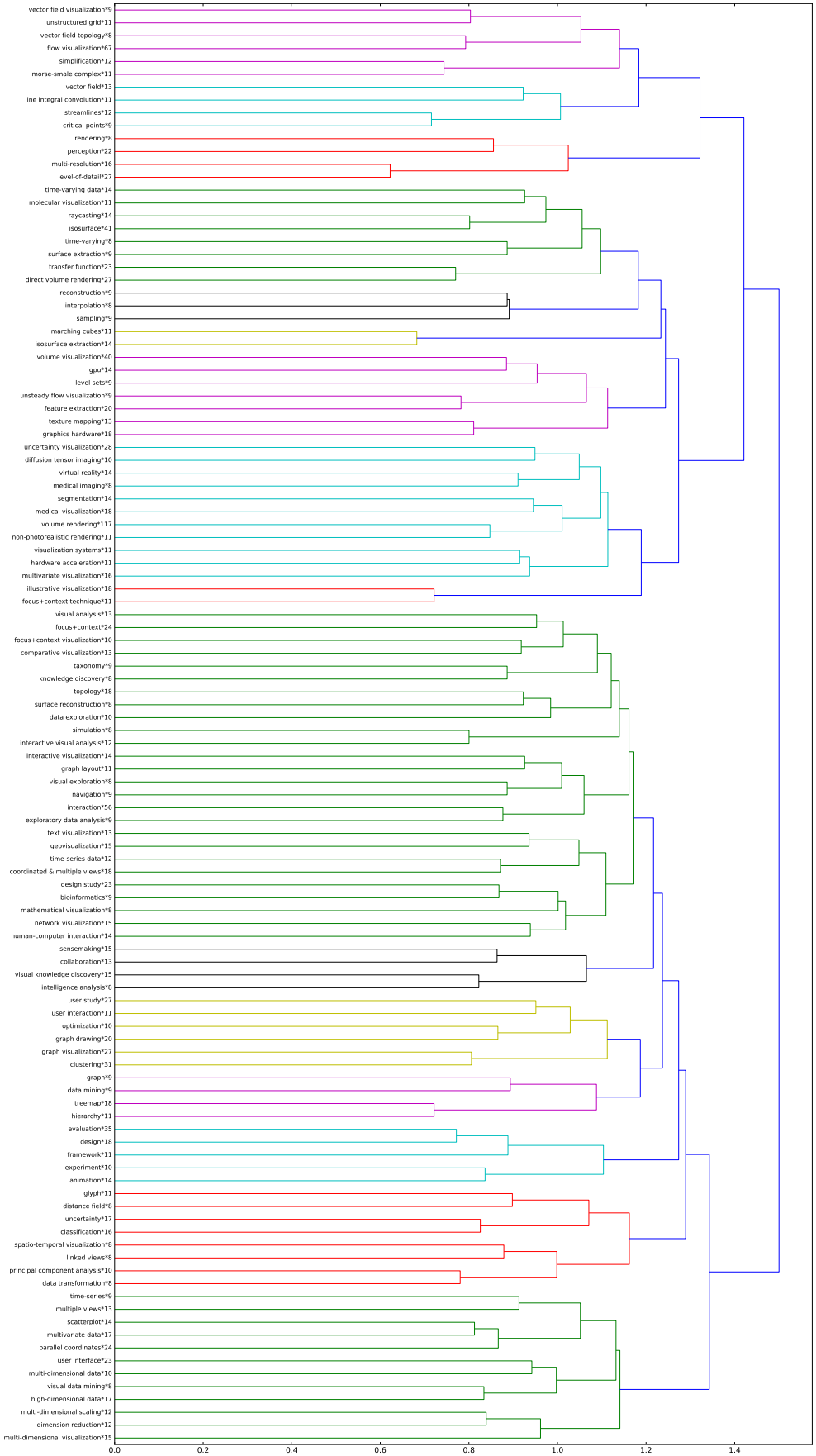


Fig. 26. Cluster hierarchy from hierarchical clustering for author keywords. Colors are randomly chosen and do not have a meaning other than to distinguish the clusters.

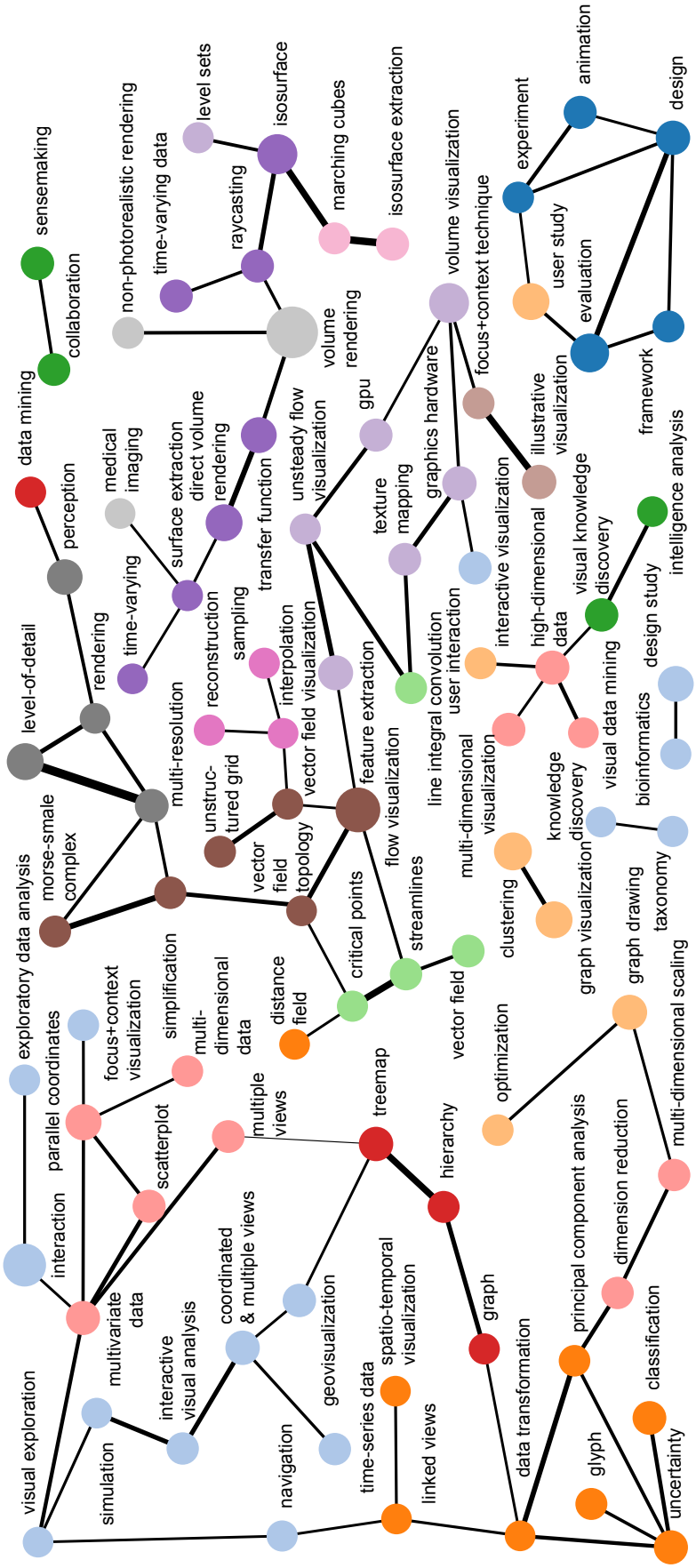


Fig. 27. Keyword map from hierarchical clustering for author-assigned keywords; showing only connected nodes with correlation strength ≥ 0.13. Same colors indicate that the respective keywords belong to the same cluster in Table 6, the cluster color is the same as in Table 6 and Fig. 33(b).

Table 7. Cluster result for expert-coded topic keywords. Keywords are sorted by frequency with the two most frequent keywords highlighted in bold. We report the keywords assigned to each cluster, the size of the cluster (N), the average amount of times (median) each keyword occurred in the whole corpus ($\tilde{\#}$), the average amount of times (mean) the keywords in each cluster co-occur (cw-#), the centrality of the subnetworks created from each cluster (centr.), and the density of the subnetworks (dens.). The cluster color is the same as in Fig. 29 and Fig. 34.

ID	keywords (InfoVis, Vis/SciVis, VAST; 2004–2013)	N	$\tilde{\#}$	cw-#	centr.	dens.
T1	**interaction techniques—general**; **graph/network data & techniques**; analysis process—general; multidimensional/ multivariate/multifield data & techn.; data clustering & aggregation; visual encoding & layout—general; hierarchical/tree data & techn.; charts, diagrams, plots; focus + context techn.; dimensionality reduction; multiple linked/coordinated views; queries & search; parallel coordinates; zooming & navigation techn.; multi-scale data & techn.	15	61.0	5.15	0.49	0.038
T2	**machine learning & statistics**; **uncertainty techn. & vis.**; simulation; data transformation	4	44.0	5.50	0.21	0.090
T3	**timeseries, time-varying data & techn.**; **animation & motion**; spatiotemporal data & techn.; knowledge discovery; events, trends, outlier detection, analysis, & vis.; multimedia (image/video/music); privacy, security, intelligence analysis; reasoning, problem solving, & decision making	8	25.5	2.04	0.35	0.048
T4	**evaluation general**; **cognition**; visual design, design guidelines; human-computer interaction, human factors; design methodologies & interaction design; visualization theory, models, & methods; taxonomies	7	45.0	5.24	0.39	0.079
T5	**programming, algorithms, & data structures**; **geography, geospatial vis, cartography, terrain vis**; visualization systems, toolkits, & environments; user interfaces—general; maps; optimization	6	53.0	3.47	0.38	0.059
T6	**applications—general & other**; **text, document, topic analysis, data, & techn.**; social networks & social media; earth, space, & environmental sciences; databases & data mining; collaborative vis.; internet, web, vis. for the masses; design studies & case studies; social science & humanities; tasks, task & requirements analysis; neurosciences & brain vis.; provenance & history; qualitative evaluation	13	31.0	1.76	0.47	0.038
T7	**abstraction, simplification, approximation**; **multiresolution techn.**; level-of-detail; view-dependent vis.	4	34.5	5.83	0.44	0.172
T8	**numerical methods/mathematics**; **meshes, grids, & lattices**; surface-related data & techn.; isosurface & surface extraction techn.; geometric modeling; interpolation; curves & curvature; compression techn.; sampling; adaptive processing & refinement	10	37.5	4.58	0.51	0.079
T9	**tensor data & techn.**; **tractography**	2	34.5	15.00	0.35	0.497
T10	**topology-based techn.**; **scalar field data & techn.**	2	46.0	12.00	0.22	0.324
T11	**flow vis., data, & techn.**; **vector fields, data, & techn.**; algorithmic pattern/feature detection/tracking; streamlines, pathlines, streaklines	4	51.0	11.83	0.43	0.169
T12	**biology & bioinformatics**; **molecular science & chemistry**; space-related, spatial data & techn.; genetics	4	23.0	3.33	0.25	0.111
T13	**large scale data & scalability**; **data acquisition & management**; hardware acceleration & computation—general; data features & attributes; point-based data & techn.; particle vis. & techn.; out-of-core processing; astronomy/astrophysics; filtering techn.	9	26.0	1.28	0.52	0.039
T14	**displays—general**; **large & high-res displays**	2	23.5	9.00	0.24	0.375
T15	**volume rendering, modeling, & vis.**; **gpu-based techn.**; rendering; illumination; raytracing/raycasting	5	48.0	10.50	0.46	0.112
T16	**biomedical science & medicine**; **vis. techn. & tools—general**; perception; image-based data, image/signal processing; segmentation & classification; physics & physical sciences; textures; input & output devices—general; comparison, comparative vis. & similarity; illustrative vis.; color & color perception; glyphs, glyph-based techn.; computer graphics techn.—general; immersive & virtual environments; cameras, camera views, & projections; computer networks & network security; evaluation metrics & benchmarks; material science; visual pattern/feature detection & tracking; art & aesthetics in vis.; distributed systems & grid environments	21	34.0	1.27	0.67	0.018

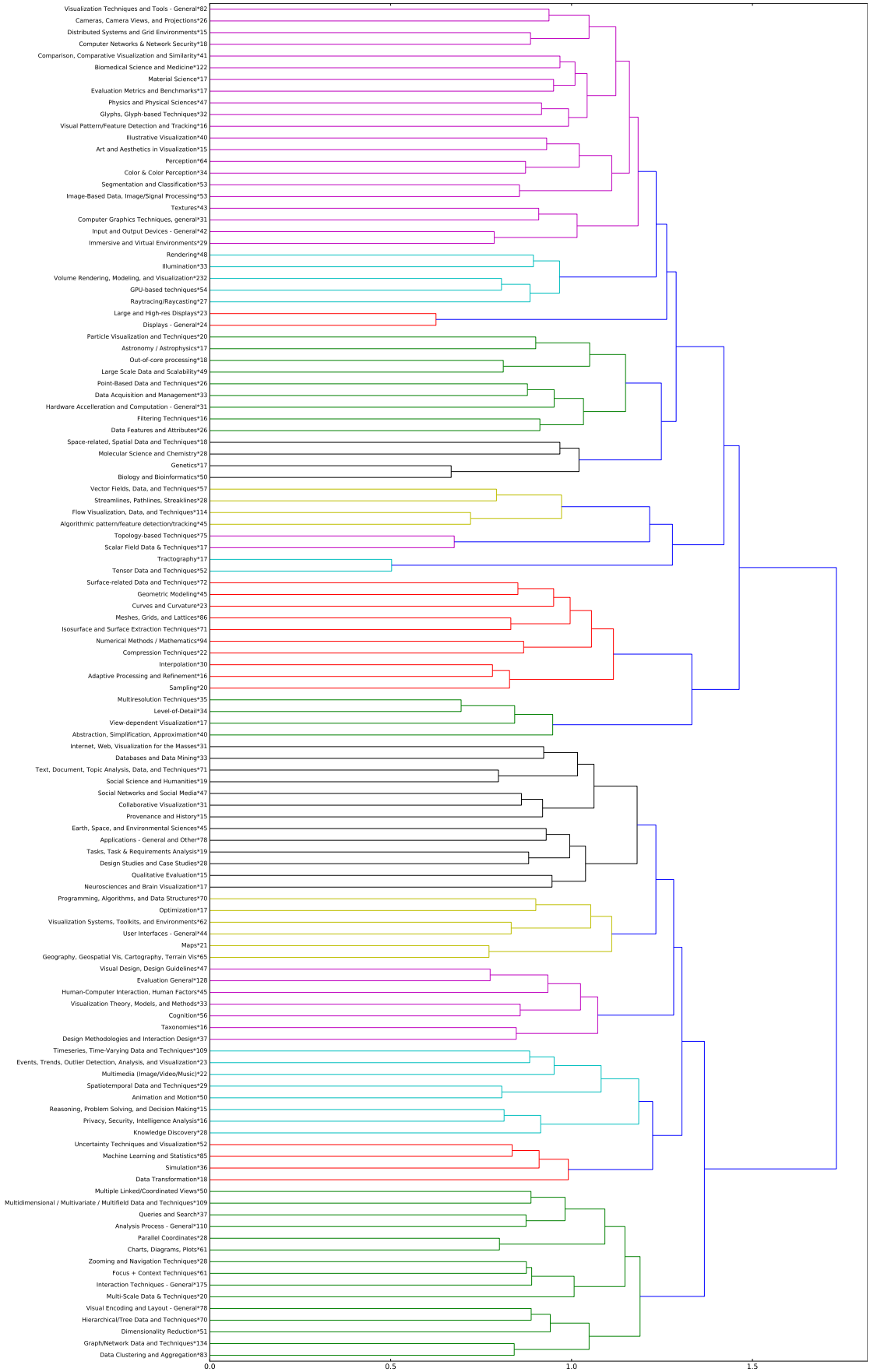


Fig. 28. Cluster hierarchy from hierarchical clustering for expert-coded topic keywords. Colors are randomly chosen and do not have a meaning other than to distinguish the clusters.

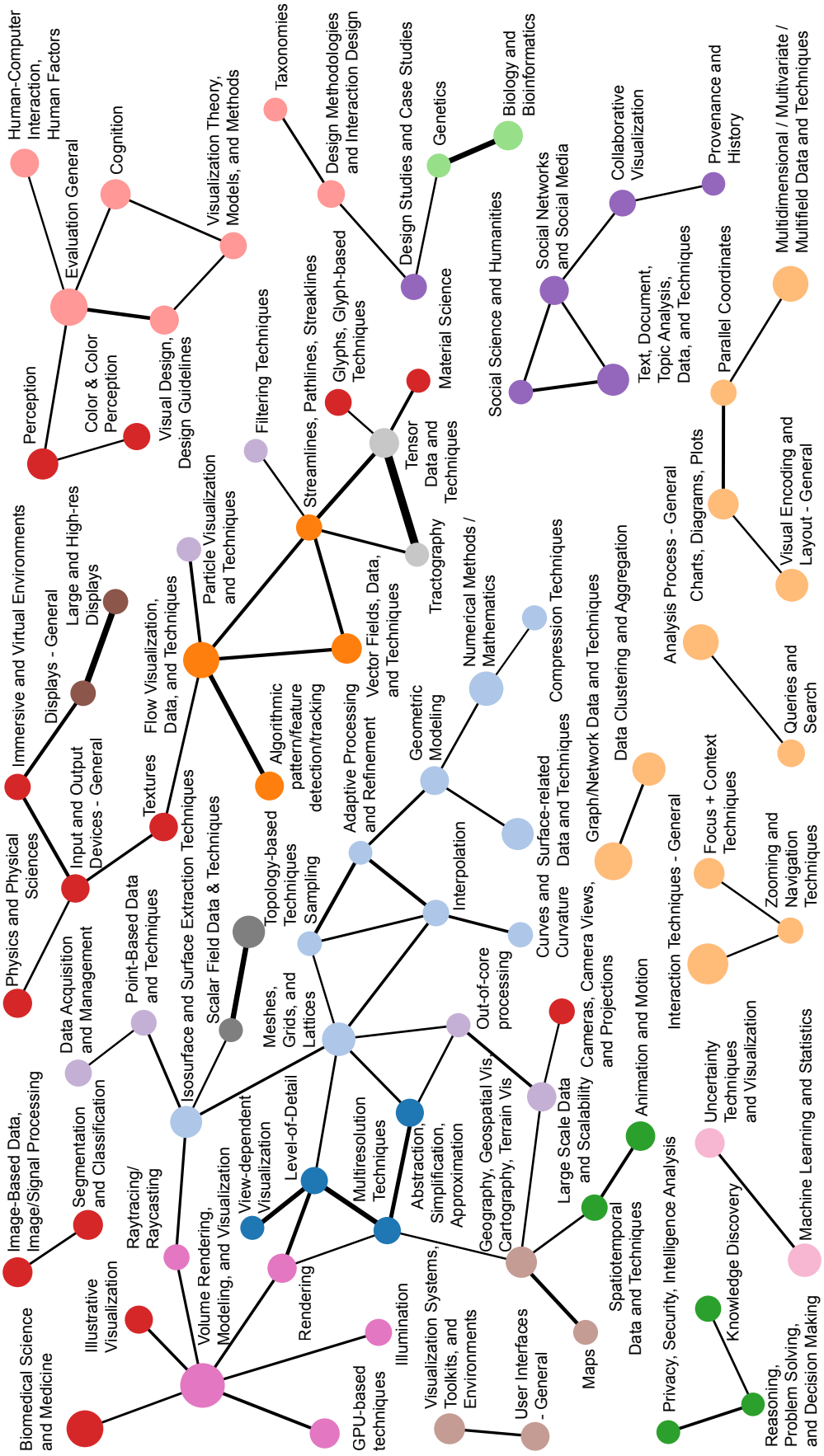


Fig. 29. Keyword map from hierarchical clustering of the expert-coded topic keywords; showing only connected nodes with correlation strength ≥ 0.12. Same colors indicate that the respective keywords belong to the same cluster in Table 7, the cluster color is the same as in Table 7 and Fig. 34.

Table 8. Historical trends for 50 most frequently used keywords for each of the author, topic, and PCS datasets. Significant trends highlighted. For each of the three keyword sets, we report the keyword, its frequency (#), the slope of its linearly fitted trend line, the standard error (SE) of the fit, the degrees of freedom (DF) of the ANOVA for the fit, as well as the p-value and the t-value of the ANOVA for the fit.

author (2000–2015)							topic (2000–2015)							PCS (2008–2015)						
keyword	#	slope	SE	DF	p-val.	t-val.	keyword	#	slope	SE	DF	p-val.	t-val.	keyword	#	slope	SE	DF	p-val.	t-val.
design study	**23**	**0.51**	**0.11**	**6**	**0.004**	**4.575**	**interaction techn.—general**	**175**	**1.12**	**0.15**	**14**	**<0.001**	**7.503**	**quantitative evaluation**	**266**	**4.40**	**0.73**	**6**	**0.001**	**6.072**
interaction	**56**	**0.46**	**0.09**	**13**	**<0.001**	**5.174**	**evaluation general**	**128**	**0.81**	**0.20**	**13**	**0.001**	**4.068**	**visual knowledge discovery**	**416**	**4.33**	**1.07**	**6**	**0.007**	**4.044**
evaluation	35	0.20	0.10	11	0.071	2.002	**machine learning and statistics**	**85**	**0.73**	**0.11**	**14**	**<0.001**	**6.881**	**time series data**	**276**	**4.31**	**0.76**	**6**	**0.001**	**5.662**
coordinated & multiple views	18	0.19	0.11	8	0.126	1.709	**timeseries, time-varying data and techn.**	**109**	**0.60**	**0.18**	**14**	**0.005**	**3.294**	**geographic/geospatial vis.**	**269**	**4.20**	**1.05**	**6**	**0.007**	**4.000**
uncertainty vis.	28	0.19	0.10	10	0.075	1.987	**multidimensional/multivariate/multifield data and techn.**	**109**	**0.57**	**0.12**	**14**	**<0.001**	**4.555**	**coordinated and multiple views**	**334**	**4.17**	**1.47**	**6**	**0.030**	**2.840**
gpu	14	0.19	0.15	6	0.255	1.260	**text, document, topic analysis, data, and techn.**	**71**	**0.56**	**0.17**	**12**	**0.007**	**3.223**	**visual design**	**202**	**3.81**	**1.02**	**6**	**0.010**	**3.722**
sensemaking	15	0.15	0.08	6	0.124	1.786	**charts, diagrams, plots**	**61**	**0.51**	**0.15**	**13**	**0.004**	**3.447**	**data transformation and representation**	**267**	**3.75**	**1.20**	**6**	**0.020**	**3.123**
high-dimensional data	17	0.13	0.08	8	0.130	1.690	**analysis process—general**	**110**	**0.47**	**0.18**	**12**	**0.024**	**2.580**	**design studies**	**163**	**3.04**	**0.89**	**6**	**0.014**	**3.418**
scatterplot	14	0.13	0.08	7	0.133	1.698	**graph/network data and techn.**	**134**	**0.46**	**0.15**	**14**	**0.007**	**3.169**	**text and document data**	**233**	**2.70**	**0.78**	**6**	**0.013**	**3.478**
perception	22	0.13	0.10	7	0.234	1.302	**cognition**	**56**	**0.40**	**0.14**	**11**	**0.018**	**2.786**	**uncertainty vis.**	**139**	**2.44**	**0.47**	**6**	**0.002**	**5.190**
uncertainty	**17**	**0.12**	**0.04**	**9**	**0.018**	**2.879**	**uncertainty techn. and vis.**	**52**	**0.40**	**0.13**	**13**	**0.009**	**3.047**	integrating spatial and non-spatial data vis.	128	1.55	0.69	6	0.066	2.248
raycasting	14	0.09	0.11	5	0.438	0.842	**visual encoding and layout—general**	**78**	**0.32**	**0.09**	**13**	**0.004**	**3.455**	interaction design	246	1.45	1.21	6	0.275	1.200
user interface	23	0.08	0.05	9	0.144	1.600	**visual design, design guidelines**	**47**	**0.32**	**0.11**	**12**	**0.012**	**2.941**	**vis. for the masses**	**114**	**1.45**	**0.48**	**6**	**0.022**	**3.056**
user study	27	0.07	0.06	11	0.281	1.134	social networks and social media	47	0.25	0.12	10	0.071	2.018	data clustering	175	1.32	1.18	5	0.314	1.119
human-computer interaction	14	0.07	0.07	7	0.394	0.907	applications—general and other	78	0.24	0.13	14	0.083	1.866	**vis. models**	**166**	**1.14**	**0.45**	**6**	**0.044**	**2.549**
comparative vis.	13	0.06	0.06	7	0.327	1.054	human-computer interaction, human factors	45	0.22	0.11	12	0.064	2.044	**vis. in earth, space, and environmental sciences**	**127**	**1.08**	**0.42**	**6**	**0.040**	**2.605**
design	18	0.06	0.07	9	0.441	0.805	**data clustering and aggregation**	**83**	**0.21**	**0.08**	**12**	**0.030**	**2.465**	laboratory studies	104	1.07	1.24	5	0.427	0.865
transfer function	23	0.04	0.05	11	0.441	0.799	vis. techn. and tools—general	82	0.18	0.10	14	0.085	1.853	**scalability issues**	**109**	**0.99**	**0.31**	**6**	**0.020**	**3.145**
visual knowledge discovery	15	0.03	0.14	6	0.807	0.255	perception	64	0.17	0.13	14	0.204	1.332	glyph-based techn.	101	0.92	0.66	6	0.212	1.396
multivariate vis.	16	0.03	0.08	8	0.705	0.393	dimensionality reduction	51	0.15	0.11	14	0.206	1.328	graph/network data	373	0.89	1.03	6	0.419	0.868
parallel coordinates	24	0.03	0.09	9	0.762	0.313	multiple linked/coordinated views	50	0.14	0.11	12	0.229	1.267	vis. in social and information sciences	152	0.88	0.65	6	0.226	1.349
classification	16	0.03	0.05	8	0.612	0.527	vis. systems, toolkits, and environments	62	0.12	0.07	13	0.136	1.589	visual analysis models	126	0.86	0.63	5	0.231	1.362
topology	18	0.02	0.06	10	0.721	0.367	animation and motion	50	0.11	0.06	13	0.101	1.767	vector field data	177	0.77	0.87	6	0.409	0.887
graph vis.	27	0.01	0.07	12	0.826	0.225	hierarchical/tree data and techn.	70	0.10	0.13	13	0.459	0.763	multidimensional data	255	0.75	0.32	6	0.056	2.369
focus+context	24	0.01	0.06	11	0.928	0.092	biology and bioinformatics	50	0.09	0.13	13	0.493	0.705	usability studies	121	0.70	0.84	6	0.433	0.840
geovis.	15	0.00	0.09	8	0.958	0.054	earth, space, and environmental sciences	45	0.03	0.07	14	0.683	0.417	dimensionality reduction	112	0.68	0.87	5	0.473	0.776
medical vis.	18	0.00	0.05	9	0.958	0.054	segmentation and classification	53	0.00	0.12	14	0.990	0.012	qualitative evaluation	172	0.62	0.71	6	0.415	0.876
isosurface extraction	14	0.00	0.05	9	0.979	-0.027	algorithmic pattern/feature detection/tracking	45	0.00	0.09	13	0.975	-0.032	user interfaces	270	0.60	1.93	6	0.768	0.309
time-varying data	14	-0.01	0.04	10	0.853	-0.190	geography, geospatial vis, cartography, terrain vis	65	-0.01	0.09	14	0.911	-0.114	visual knowledge representation	168	0.60	1.38	6	0.682	0.430
animation	14	-0.01	0.05	8	0.848	-0.198	large scale data and scalability	49	-0.01	0.08	14	0.893	-0.137	high-dimensional data	236	0.45	1.61	6	0.788	0.281
feature extraction	20	-0.01	0.03	11	0.754	-0.321	topology-based techn.	75	-0.02	0.12	14	0.894	-0.136	zooming and navigation techn.	116	0.24	0.96	6	0.812	0.248
interactive vis.	14	-0.02	0.08	7	0.804	-0.258	programming, algorithms, and data structures	70	-0.02	0.14	13	0.890	-0.141	scalar field data	166	0.14	0.40	5	0.738	0.354
collaboration	13	-0.02	0.07	6	0.770	-0.305	biomedical science and medicine	122	-0.02	0.13	14	0.855	-0.187	biomedical and medical vis.	284	0.07	1.07	6	0.949	0.067
graphics hardware	18	-0.04	0.13	7	0.743	-0.341	focus + context techn.	61	-0.03	0.13	14	0.833	-0.215	multi-field, multi-modal and multi-variate data	119	0.06	0.47	6	0.904	0.125
network vis.	15	-0.05	0.07	8	0.525	-0.665	user interfaces—general	44	-0.04	0.09	12	0.653	-0.460	vis. in physical sciences and engineering	155	-0.08	0.65	6	0.902	-0.129
multi-resolution	16	-0.05	0.18	6	0.797	-0.269	physics and physical sciences	47	-0.06	0.10	14	0.560	-0.598	human-computer interaction	200	-0.10	0.67	6	0.892	-0.142
treemap	18	-0.05	0.08	9	0.529	-0.655	vector fields, data, and techn.	57	-0.06	0.08	13	0.431	-0.813	topology-based techn.	118	-0.24	0.80	6	0.777	-0.296
multi-dimensional vis.	15	-0.06	0.03	10	0.080	-1.951	gpu-based techn.	54	-0.07	0.18	12	0.724	-0.362	bioinformatics vis.	106	-0.24	0.44	6	0.609	-0.539
clustering	31	-0.06	0.08	11	0.435	-0.810	image-based data, image/signal processing	53	-0.11	0.11	14	0.337	-0.994	vis. system and toolkit design	262	-0.31	1.78	6	0.868	-0.174
direct volume rendering	27	-0.07	0.07	10	0.298	-1.098	flow vis., data, and techn.	114	-0.11	0.16	14	0.488	-0.713	hierarchy data	125	-0.70	0.69	6	0.346	-1.021
flow vis.	67	-0.08	0.15	13	0.613	-0.519	tensor data and techn.	52	-0.14	0.16	12	0.393	-0.885	focus + context techn.	174	-0.74	0.80	6	0.391	-0.925
virtual reality	14	-0.09	0.08	6	0.313	-1.102	input and output devices—general	42	-0.24	0.12	8	0.086	-1.958	time-varying data	263	-0.77	0.71	6	0.315	-1.096
segmentation	14	-0.09	0.09	7	0.321	-1.067	**surface-related data and techn.**	**72**	**-0.26**	**0.08**	**14**	**0.004**	**-3.441**	illustrative vis.	107	-0.96	0.71	6	0.226	-1.349
multivariate data	17	-0.10	0.12	7	0.441	-0.817	**geometric modeling**	**45**	**-0.36**	**0.10**	**12**	**0.003**	**-3.656**	geometry-based techn.	123	-1.18	0.93	5	0.260	-1.269
graph drawing	20	-0.10	0.05	10	0.078	-1.961	**rendering**	**48**	**-0.36**	**0.13**	**13**	**0.012**	**-2.901**	mathematical foundations for vis.	128	-1.29	0.55	6	0.058	-2.332
illustrative vis.	18	-0.12	0.10	6	0.271	-1.211	**textures**	**43**	**-0.38**	**0.12**	**9**	**0.012**	**-3.162**	**extraction of surfaces (isosurfaces, material boundaries)**	**118**	**-1.33**	**0.26**	**6**	**0.002**	**-5.159**
level-of-detail	27	-0.22	0.19	7	0.284	-1.160	**numerical methods/mathematics**	**94**	**-0.42**	**0.15**	**14**	**0.016**	**-2.752**	**flow vis.**	**194**	**-1.55**	**0.55**	**6**	**0.031**	**-2.801**
volume vis.	**40**	**-0.25**	**0.07**	**12**	**0.004**	**-3.506**	**isosurface and surface extraction techn.**	**71**	**-0.43**	**0.13**	**13**	**0.007**	**-3.215**	feature detection and tracking	185	-1.73	0.83	6	0.081	-2.091
isosurface	41	-0.26	0.17	11	0.156	-1.523	**meshes, grids, and lattices**	**86**	**-0.68**	**0.10**	**14**	**<0.001**	**-6.869**	volume rendering	278	-2.52	1.33	6	0.107	-1.897
volume rendering	**117**	**-0.53**	**0.15**	**14**	**0.004**	**-3.436**	**volume rendering, modeling, and vis.**	**232**	**-0.92**	**0.19**	**14**	**<0.001**	**-4.776**	**gpus and multi-core architectures**	**188**	**-2.98**	**0.73**	**6**	**0.006**	**-4.082**

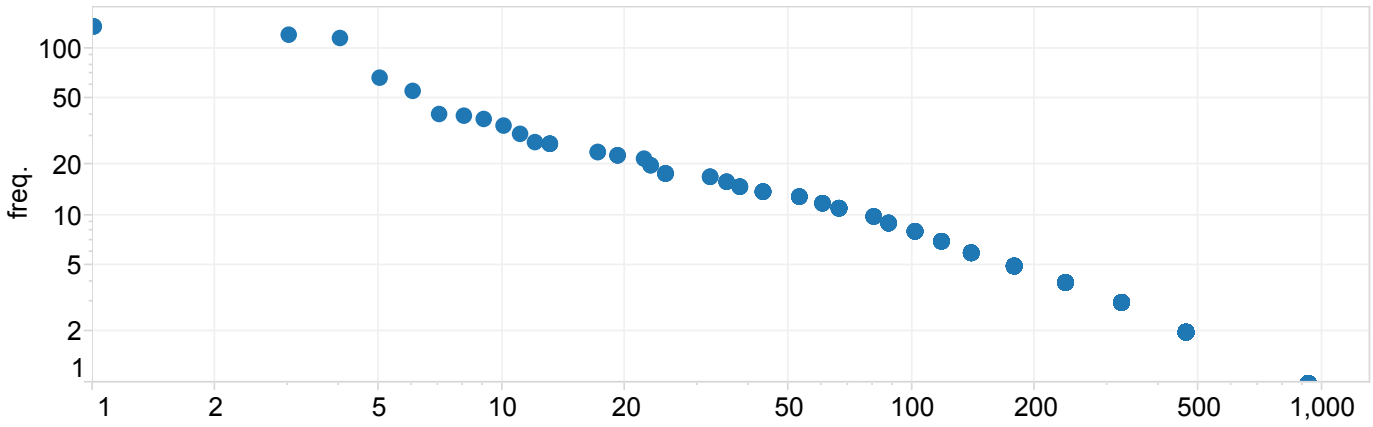


Fig. 30. The frequency of the author-assigned keywords (2000–2015, accepted submissions), sorted by their rank (both axes log-transformed). The power law can be observed from the linear arrangement of the data points.

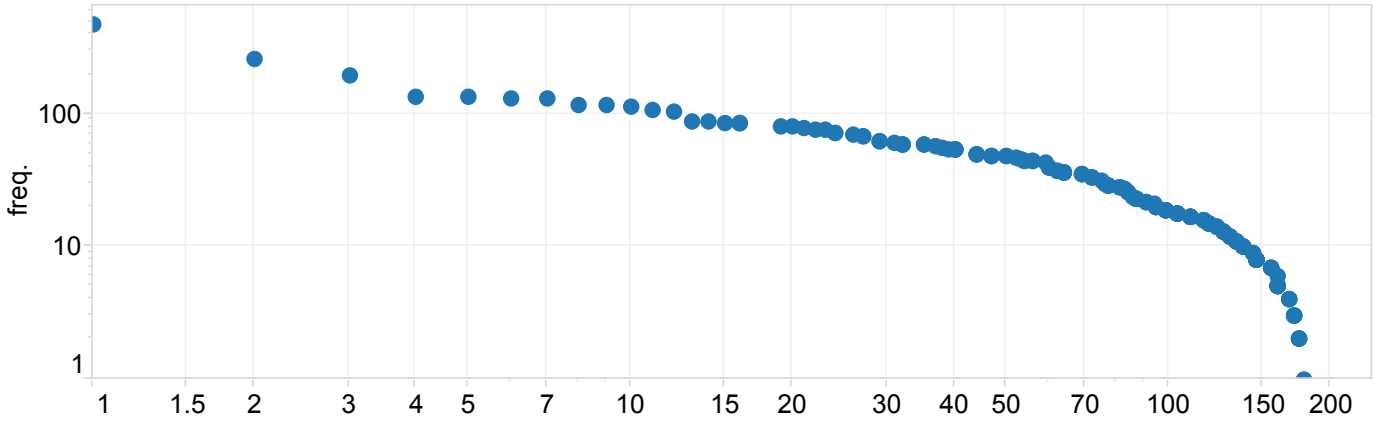


Fig. 31. The frequency of the topic keywords (2000–2015, accepted submissions), sorted by their rank (both axes log-transformed). This distribution does not follow a power law.

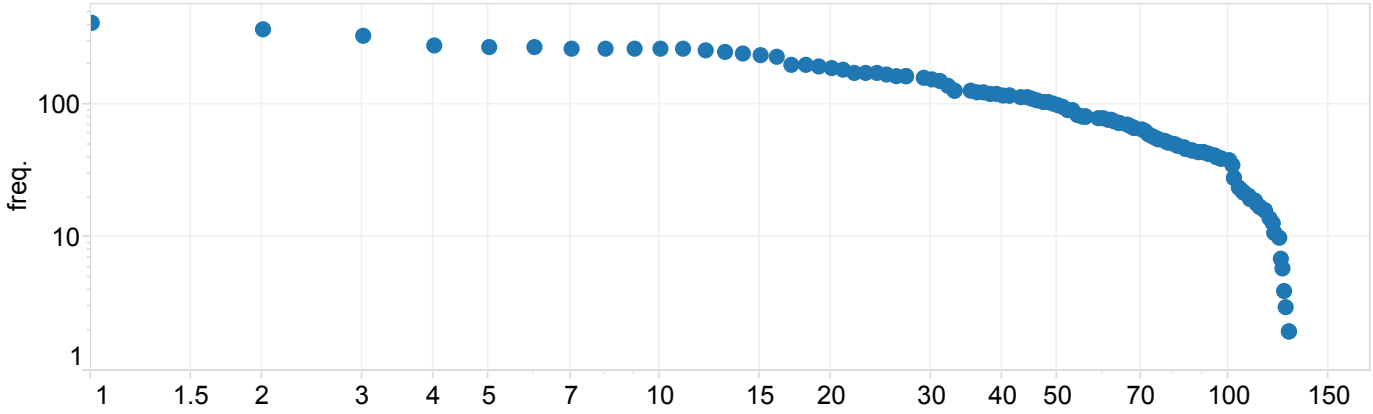
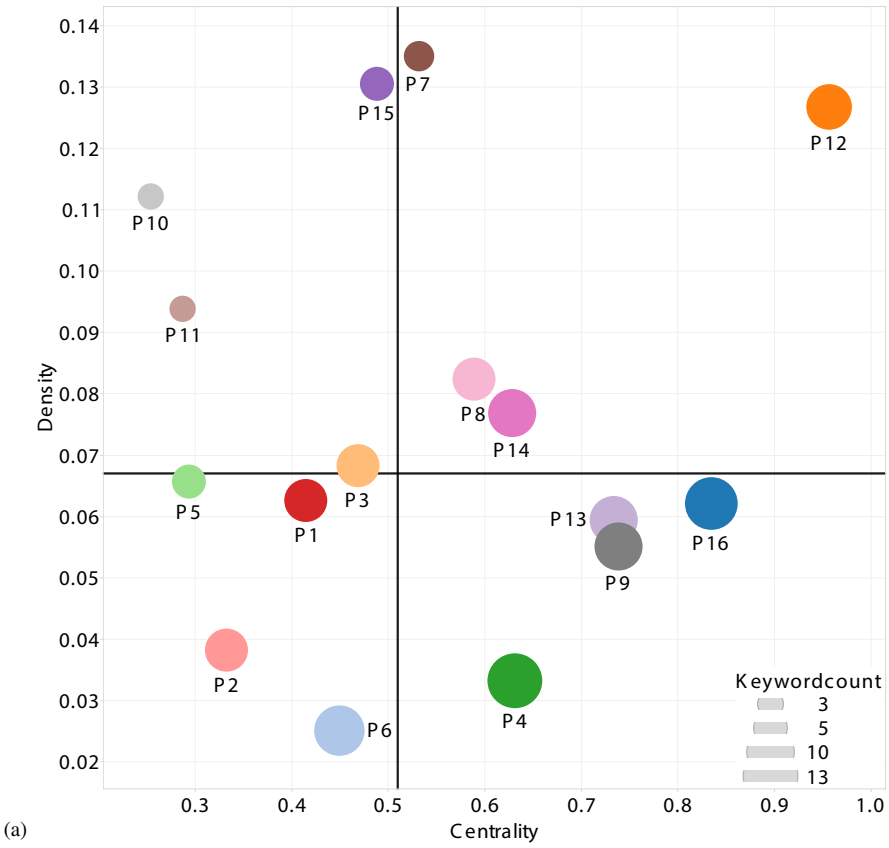
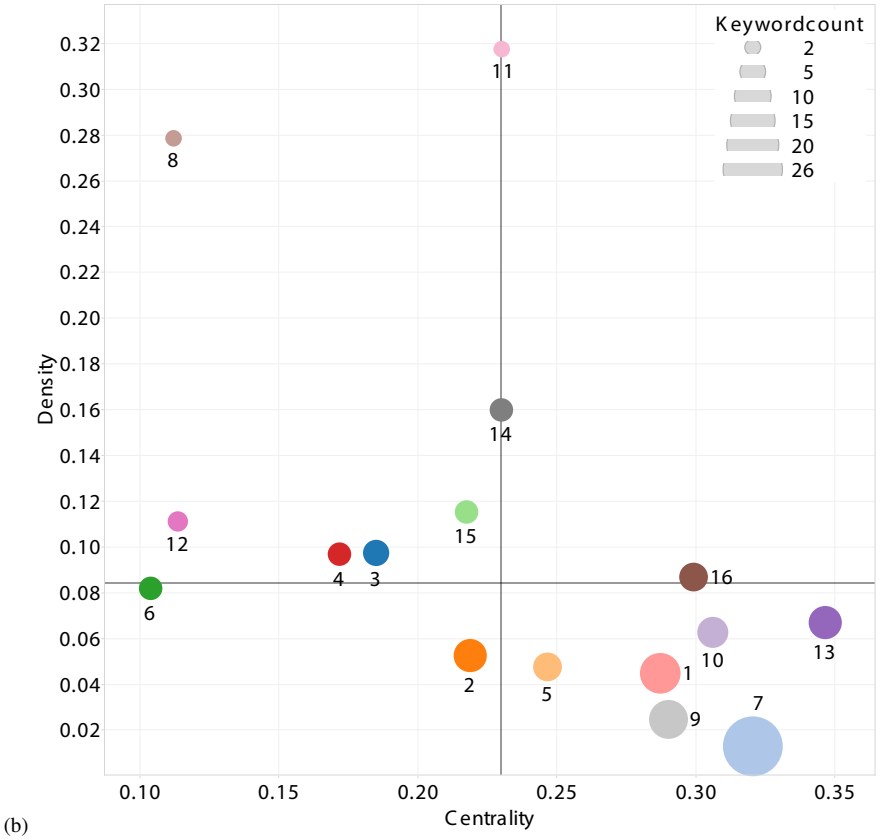


Fig. 32. The frequency of the PCS taxonomy keywords (2008–2015, all submissions), sorted by their rank (both axes log-transformed). This distribution does not follow a power law.

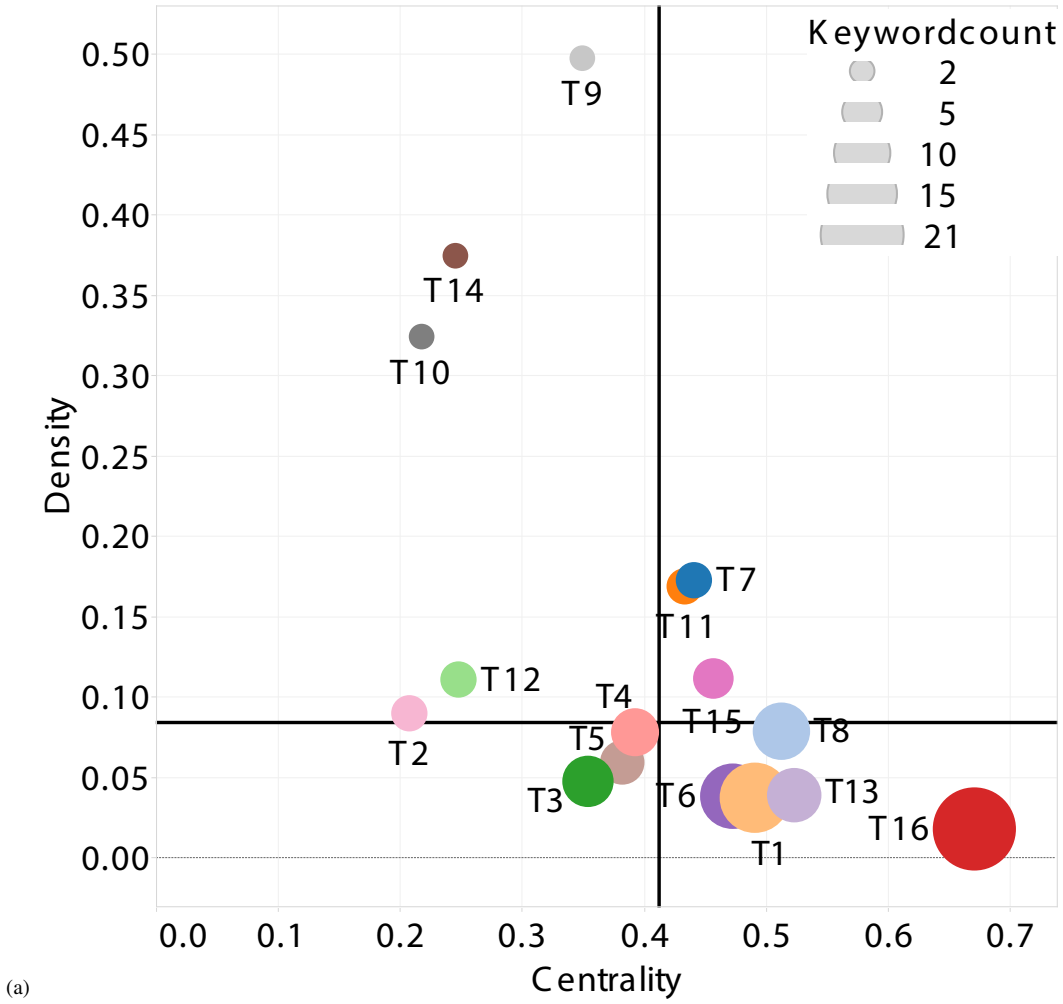


(a)

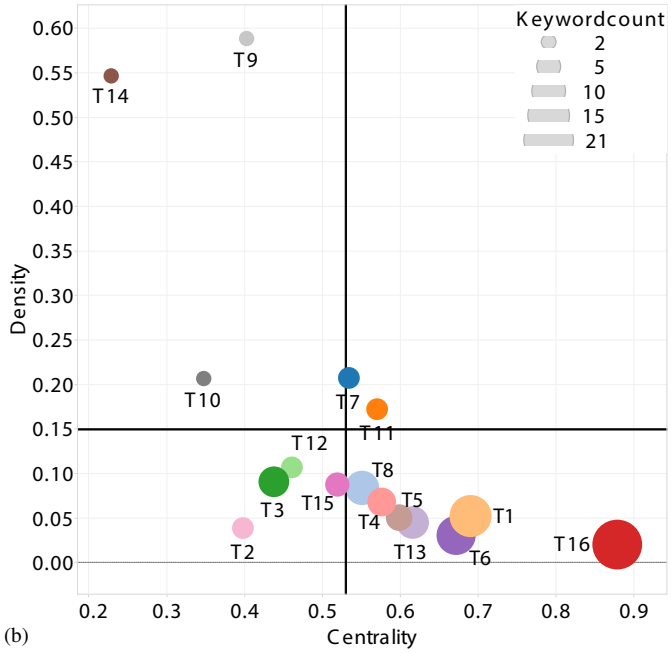


(b)

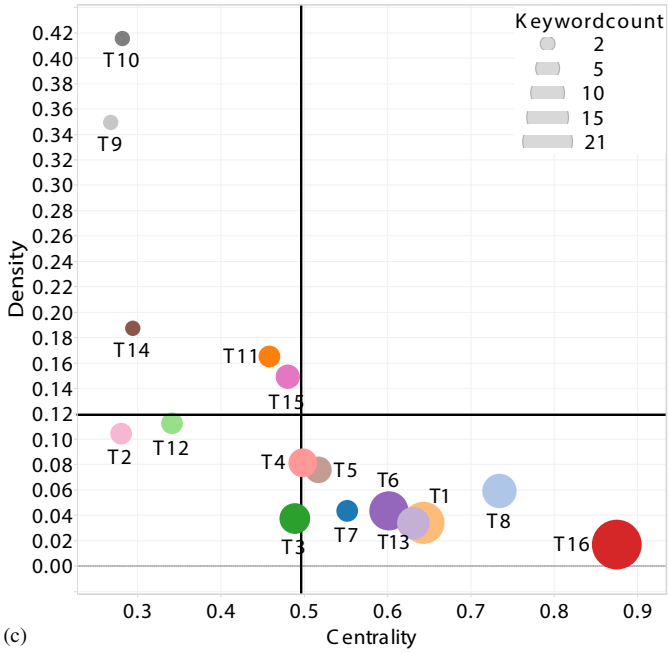
Fig. 33. Strategic diagrams of the cluster results for (a) PCS and (b) author-assigned keywords. Black lines indicate the medians. The interpretation of these diagrams is explained in the paper. For (a): the cluster color is the same as in Fig. 25 and Table 5; for (b): the cluster color is the same as in Fig. 27 and Table 6.



(a)



(b)



(c)

Fig. 34. Strategic diagrams of the cluster results for (a) topic keywords for the time period 2000–2015, (b) the same topic keyword clusters for years 2000–2007, and (c) for 2008–2015. Black lines indicate the medians. The interpretation of these diagrams is explained in the paper. The cluster color is the same as in Fig. 29 and Table 7.

Table 9. Topic keywords, part 1.

new topic	topic category
Analysis Process—General	Analysis Processeses, Perception, Cognition
Cognition	Analysis Processeses, Perception, Cognition
Color & Color Perception	Analysis Processeses, Perception, Cognition
Hypothesis Forming, Testing, and Visual Evidence	Analysis Processeses, Perception, Cognition
Knowledge Discovery	Analysis Processeses, Perception, Cognition
Perception	Analysis Processeses, Perception, Cognition
Reasoning, Problem Solving, and Decision Making	Analysis Processeses, Perception, Cognition
Visual Clutter and its Reduction	Analysis Processeses, Perception, Cognition
Visual Knowledge Representation and Externalization	Analysis Processeses, Perception, Cognition
Visual Pattern/Feature Detection and Tracking	Analysis Processeses, Perception, Cognition
Applications—General and Other	Applications
Astronomy/Astrophysics	Applications
Biomedical Science and Medicine	Applications
Business, Finance, Economy, Manufacturing	Applications
Computer Networks & Network Security	Applications
Earth, Space, and Environmental Sciences	Applications
Education	Applications
Emergency/Disaster Management	Applications
Engineering	Applications
Geography, Geospatial Vis, Cartography, Terrain Vis	Applications
Internet, Web, Visualization for the Masses	Applications
Material Science	Applications
Mathematics	Applications
Molecular Science and Chemistry	Applications
Multimedia (Image/Video/Music)	Applications
Physics and Physical Sciences	Applications
Privacy, Security, Intelligence Analysis	Applications
Sensor Networks	Applications
Social Networks and Social Media	Applications
Social Science and Humanities	Applications
Software Visualization	Applications
Sports Visualization	Applications
Time Critical Applications	Applications
Traffic	Applications
CPU and GPU clusters	Computation Hardware
Distributed Systems and Grid Environments	Computation Hardware
GPU-based techniques	Computation Hardware
Hardware Accelleration and Computation—General	Computation Hardware
Multi-core processing	Computation Hardware
Out-of-core processing	Computation Hardware
Parallel Systems and Parallel Processing	Computation Hardware
Realtime Processing, Rendering, and Visualization—General	Computation Hardware
Animation and Motion	Computer Graphics Methods and Techniques
Cameras, Camera Views, and Projections	Computer Graphics Methods and Techniques
Computer Graphics Techniques, general	Computer Graphics Methods and Techniques
Contour/Creases/Ridges/Valleys	Computer Graphics Methods and Techniques
Curves and Curvature	Computer Graphics Methods and Techniques
Geometric Modeling	Computer Graphics Methods and Techniques
Illumination	Computer Graphics Methods and Techniques
Line-based Techniques and Approaches	Computer Graphics Methods and Techniques
Raytracing/Raycasting	Computer Graphics Methods and Techniques
Rendering	Computer Graphics Methods and Techniques
Textures	Computer Graphics Methods and Techniques
Transitions and Morphing	Computer Graphics Methods and Techniques
Voronoi-based Techniques	Computer Graphics Methods and Techniques

Table 10. Topic keywords, part 2.

new topic	topic category
Acoustics, Sound, Sonification	Data Types, and Data-specific Encodings and Techniques
Categorical Data and Techniques	Data Types, and Data-specific Encodings and Techniques
Data-Types General	Data Types, and Data-specific Encodings and Techniques
Graph/Network Data and Techniques	Data Types, and Data-specific Encodings and Techniques
Hierarchical/Tree Data and Techniques	Data Types, and Data-specific Encodings and Techniques
Maps	Data Types, and Data-specific Encodings and Techniques
Matrix-related Techniques	Data Types, and Data-specific Encodings and Techniques
Multidimensional/Multivariate/Multifield Data and Techniques	Data Types, and Data-specific Encodings and Techniques
Multimodal Data & Techniques	Data Types, and Data-specific Encodings and Techniques
Multi-Scale Data & Techniques	Data Types, and Data-specific Encodings and Techniques
Set-related Data & Techniques	Data Types, and Data-specific Encodings and Techniques
State-related Data & Techniques	Data Types, and Data-specific Encodings and Techniques
Tabular Data and Techniques	Data Types, and Data-specific Encodings and Techniques
Text, Document, Topic Analysis, Data, and Techniques	Data Types, and Data-specific Encodings and Techniques
Timeseries, Time-Varying Data and Techniques	Data Types, and Data-specific Encodings and Techniques
Design Studies and Case Studies	Evaluation Methods + Types
Evaluation General	Evaluation Methods + Types
Evaluation Metrics and Benchmarks	Evaluation Methods + Types
Field Studies	Evaluation Methods + Types
Laboratory Studies	Evaluation Methods + Types
Qualitative Evaluation	Evaluation Methods + Types
Quantitative Evaluation	Evaluation Methods + Types
Tasks, Task & Requirements Analysis	Evaluation Methods + Types
Usability Studies	Evaluation Methods + Types
Ambient Visualization	General Visualization/Analytics Techniques and Encodings
Art and Aesthetics in Visualization	General Visualization/Analytics Techniques and Encodings
Automatic Analysis/Visualization Techniques	General Visualization/Analytics Techniques and Encodings
Charts, Diagrams, Plots	General Visualization/Analytics Techniques and Encodings
Comparison, Comparative Visualization and Similarity	General Visualization/Analytics Techniques and Encodings
Data Facets and Techniques	General Visualization/Analytics Techniques and Encodings
Data Features and Attributes	General Visualization/Analytics Techniques and Encodings
Dynamic Data and Techniques	General Visualization/Analytics Techniques and Encodings
Dynamic Visualization, Visualization of Change	General Visualization/Analytics Techniques and Encodings
Focus + Context Techniques	General Visualization/Analytics Techniques and Encodings
Glyphs, Glyph-based Techniques	General Visualization/Analytics Techniques and Encodings
Illustrative Visualization	General Visualization/Analytics Techniques and Encodings
Integrating Spatial and Non-Spatial Data Visualization	General Visualization/Analytics Techniques and Encodings
Labeling	General Visualization/Analytics Techniques and Encodings
Large Scale Data and Scalability	General Visualization/Analytics Techniques and Encodings
Multiple Linked/Coordinated Views	General Visualization/Analytics Techniques and Encodings
Occlusion Problems/Techniques	General Visualization/Analytics Techniques and Encodings
Parallel Coordinates	General Visualization/Analytics Techniques and Encodings
Pixel-oriented Encodings	General Visualization/Analytics Techniques and Encodings
Provenance and History	General Visualization/Analytics Techniques and Encodings
Semantics/Semiotics-related Techniques	General Visualization/Analytics Techniques and Encodings
Small, Mobile, and Ubiquitous Visualization	General Visualization/Analytics Techniques and Encodings
Storytelling	General Visualization/Analytics Techniques and Encodings
Streaming Data and Techniques	General Visualization/Analytics Techniques and Encodings
Uncertainty Techniques and Visualization	General Visualization/Analytics Techniques and Encodings
View-dependent Visualization	General Visualization/Analytics Techniques and Encodings
Visual Design, Design Guidelines	General Visualization/Analytics Techniques and Encodings
Visual Encoding and Layout—General	General Visualization/Analytics Techniques and Encodings
Visualization Techniques and Tools—General	General Visualization/Analytics Techniques and Encodings
Displays—General	Input and Output Devices/Displays
Input and Output Devices—General	Input and Output Devices/Displays
Large and High-res Displays	Input and Output Devices/Displays
Small, Mobile, Ubiquitous Devices/Displays	Input and Output Devices/Displays
Collaborative Visualization	Interaction Techniques and General HCI
Data Editing	Interaction Techniques and General HCI
Human-Computer Interaction, Human Factors	Interaction Techniques and General HCI
Interaction Techniques—General	Interaction Techniques and General HCI
Manipulation and Deformation	Interaction Techniques and General HCI
Presentation, Production, and Dissemination	Interaction Techniques and General HCI
Queries and Search	Interaction Techniques and General HCI
User Interfaces—General	Interaction Techniques and General HCI
Zooming and Navigation Techniques	Interaction Techniques and General HCI

Table 11. Topic keywords, part 3.

new topic	topic category
Biology and Bioinformatics	Life Sciences
Genetics	Life Sciences
Microscopy	Life Sciences
Neurosciences and Brain Visualization	Life Sciences
Cutting Planes	Spatial Data, its Encoding, and its Visualization Techniques
Diffusion-related Techniques	Spatial Data, its Encoding, and its Visualization Techniques
Flow Visualization, Data, and Techniques	Spatial Data, its Encoding, and its Visualization Techniques
Geometry-based Techniques	Spatial Data, its Encoding, and its Visualization Techniques
Isosurface and Surface Extraction Techniques	Spatial Data, its Encoding, and its Visualization Techniques
Meshes, Grids, and Lattices	Spatial Data, its Encoding, and its Visualization Techniques
Particle Visualization and Techniques	Spatial Data, its Encoding, and its Visualization Techniques
Point-Based Data and Techniques	Spatial Data, its Encoding, and its Visualization Techniques
Scalar Field Data & Techniques	Spatial Data, its Encoding, and its Visualization Techniques
Shape-related Techniques	Spatial Data, its Encoding, and its Visualization Techniques
Space-related, Spatial Data and Techniques	Spatial Data, its Encoding, and its Visualization Techniques
Spatiotemporal Data and Techniques	Spatial Data, its Encoding, and its Visualization Techniques
Streamlines, Pathlines, Streaklines	Spatial Data, its Encoding, and its Visualization Techniques
Surface-related Data and Techniques	Spatial Data, its Encoding, and its Visualization Techniques
Tensor Data and Techniques	Spatial Data, its Encoding, and its Visualization Techniques
Tractography	Spatial Data, its Encoding, and its Visualization Techniques
Vector Fields, Data, and Techniques	Spatial Data, its Encoding, and its Visualization Techniques
Volume Rendering, Modeling, and Visualization	Spatial Data, its Encoding, and its Visualization Techniques
Abstraction, Simplification, Approximation	Tech for Data Processing + Data Aggregation
Adaptive Processing and Refinement	Tech for Data Processing + Data Aggregation
Algorithmic pattern/feature detection/tracking	Tech for Data Processing + Data Aggregation
Compression Techniques	Tech for Data Processing + Data Aggregation
Data Acquisition and Management	Tech for Data Processing + Data Aggregation
Data and Analysis Metrics	Tech for Data Processing + Data Aggregation
Data Cleaning and Smoothing	Tech for Data Processing + Data Aggregation
Data Clustering and Aggregation	Tech for Data Processing + Data Aggregation
Data Registration, Fusion, and Integration	Tech for Data Processing + Data Aggregation
Data Transformation	Tech for Data Processing + Data Aggregation
Databases and Data Mining	Tech for Data Processing + Data Aggregation
Dimensionality Reduction	Tech for Data Processing + Data Aggregation
Events, Trends, Outlier Detection, Analysis, and Visualization	Tech for Data Processing + Data Aggregation
Filtering Techniques	Tech for Data Processing + Data Aggregation
Image-Based Data, Image/Signal Processing	Tech for Data Processing + Data Aggregation
Information Processing and Handling	Tech for Data Processing + Data Aggregation
Interpolation	Tech for Data Processing + Data Aggregation
Level-of-Detail	Tech for Data Processing + Data Aggregation
Machine Learning and Statistics	Tech for Data Processing + Data Aggregation
Multiresolution Techniques	Tech for Data Processing + Data Aggregation
Numerical Methods/Mathematics	Tech for Data Processing + Data Aggregation
Optimization	Tech for Data Processing + Data Aggregation
Parameterization	Tech for Data Processing + Data Aggregation
PDE's for Visualization	Tech for Data Processing + Data Aggregation
Ranking	Tech for Data Processing + Data Aggregation
Sampling	Tech for Data Processing + Data Aggregation
Segmentation and Classification	Tech for Data Processing + Data Aggregation
Simulation	Tech for Data Processing + Data Aggregation
Topology-based Techniques	Tech for Data Processing + Data Aggregation
Design Methodologies and Interaction Design	Theory
Information Theory	Theory
Taxonomies	Theory
Visual Analysis Models	Theory
Visualization Theory, Models, and Methods	Theory
Immersive and Virtual Environments	Visualization Software
Programming, Algorithms, and Data Structures	Visualization Software
Visualization Systems, Toolkits, and Environments	Visualization Software

REFERENCES

[1] P. Isenberg, F. Heimerl, S. Koch, T. Isenberg, P. Xu, C. Stolper, M. Sedlmair, J. Chen, T. Möller, and J. Stasko. Visualization publication dataset. Dataset: http://vispubdata.org/ , 2015. Published Jun. 2015.

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