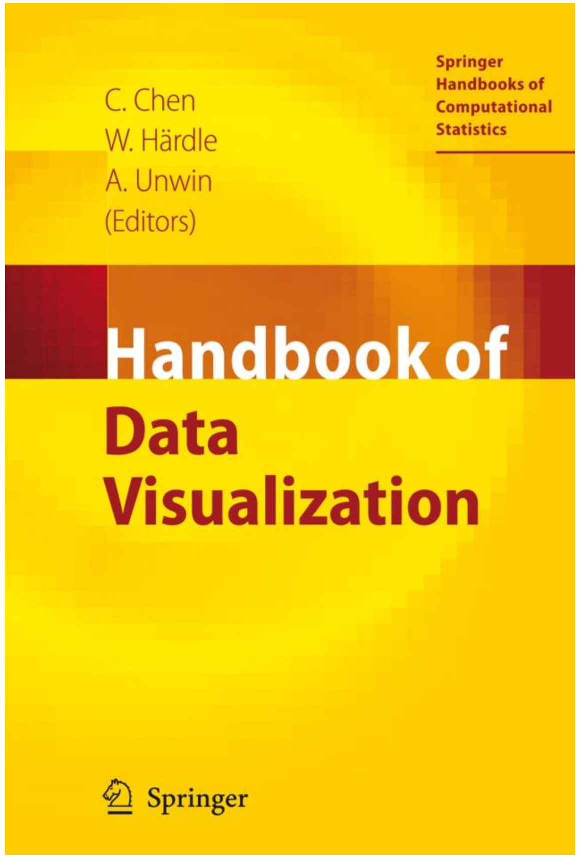
Visualization as Seen Through its Research Paper Keywords

Petra Isenberg, Tobias Isenberg, Michael Sedlmair, Jian Chen, Torsten Möller

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

WHAT IS VISUALIZATION?



III. Methodologies

The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations

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Abstract

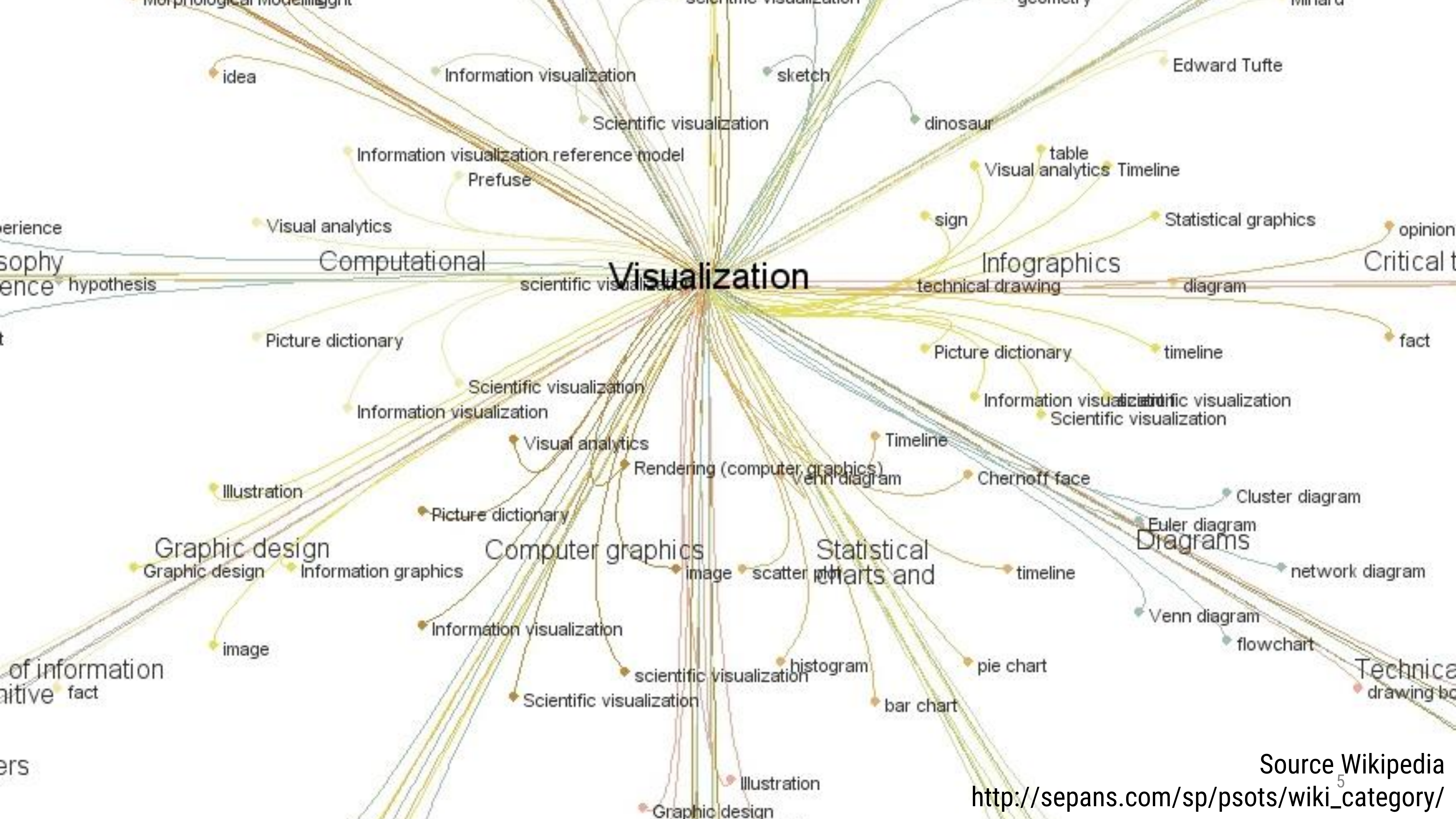
A useful starting point for designing advanced graphical user interfaces is the Visual Information-Seeking Mantra: overview first, zoom and filter, then details on demand. But this is only a starting point in trying to understand the rich and varied set of information visualizations that have been proposed in recent years. This paper offers a task by data type taxonomy with seven data types (one-, two-, three-dimensional data, temporal and multi-dimensional data, and tree and network data) and seven tasks (overview, zoom, filter, details-on-demand, relate, history, and extracts).

> Everything points to the conclusion that the phrase 'the language of art' is more than a loose metaphor, that even to describe the visible world in images we need a developed system of schemata.

keys), are being pushed aside by newer notions of information gathering, seeking, or visualization and data mining, warehousing, or filtering. While distinctions are subtle, the common goals reach from finding a narrow set of items in a large collection that satisfy a well-understood information need (known-item search) to developing an understanding of unexpected patterns within the collection (browse) (Marchionini, 1995).

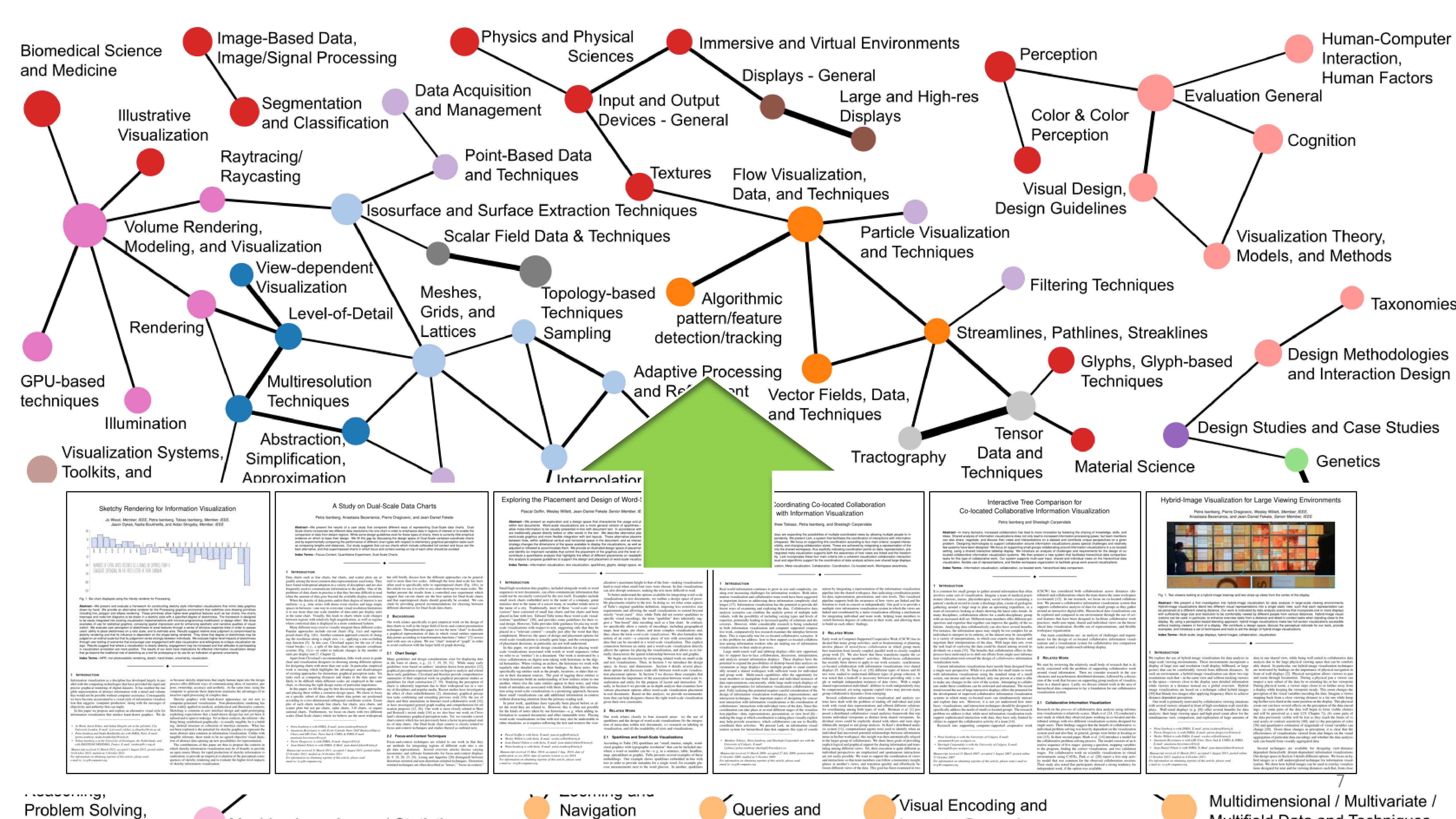
Exploring information collections becomes increasingly difficult as the volume grows. A page of information is easy to explore, but when the information becomes the size of a book, or library, or even larger, it may be difficult to locate known items or to browse to gain an overview.

Designers are just discovering how to use the rapid and high resolution color displays to present large amounts of information in orderly and user-controlled ways. Perceptual psychologists, statisticians, and graphic designers (Bertin, 1983; Cleveland, 1993; Tufte, 1983, 1990) offer valuable guidance about presenting static information, but the



Source Wikipedia
http://sepans.com/sp/psots/wiki_category/


information visualization tools
Visualisation
DATA
Figure
Display Window
Profile Window
Menu
Data Visuali
Chart.js
Simple, clean and engaging charts for designers and developers
visual.ly
Wheel-Like Data Visualization With MooWheel
dygraphs
Polymaps



Biomedical Science and Medicine
Image-Based Data, Image/Signal Processing
Physics and Physical Sciences
Immersive and Virtual Environments
Perception
Human-Computer Interaction, Human Factors
Displays - General
Large and High-res Displays
Evaluation General
Illustrative Visualization
Segmentation and Classification
Data Acquisition and Management
Input and Output Devices - General
Color & Color Perception
Cognition
Raytracing/ Raycasting
Point-Based Data and Techniques
Textures
Flow Visualization, Data, and Techniques
Visual Design, Design Guidelines
Isosurface and Surface Extraction Techniques
Volume Rendering, Modeling, and Visualization
Scalar Field Data & Techniques
Particle Visualization and Techniques
Visualization Theory, Models, and Methods
View-dependent Visualization
Meshes, Grids, and Lattices
Topology-based Techniques
Algorithmic pattern/feature detection/tracking
Filtering Techniques
Taxonomies
Level-of-Detail
Rendering
Sampling
Streamlines, Pathlines, Streaklines
Glyphs, Glyph-based Techniques
Design Methodologies and Interaction Design
GPU-based techniques
Multiresolution Techniques
Adaptive Processing
Vector Fields, Data, and Techniques
Illumination
Tensor Data and Techniques
Design Studies and Case Studies
Abstraction, Simplification, Approximation
Tractography
Visualization Systems, Toolkits, and
Material Science
Genetics
Sketchy Rendering for Information Visualization
A Study on Dual-Scale Data Charts
Exploring the Placement and Design of Word-
Coordinating Co-located Collaboration with Information Visualization
Interactive Tree Comparison for Co-located Collaborative Information Visualization
Hybrid-Image Visualization for Large Viewing Environments
Problem Solving,
Navigation
Queries and
Visual Encoding and
Multidimensional / Multivariate /

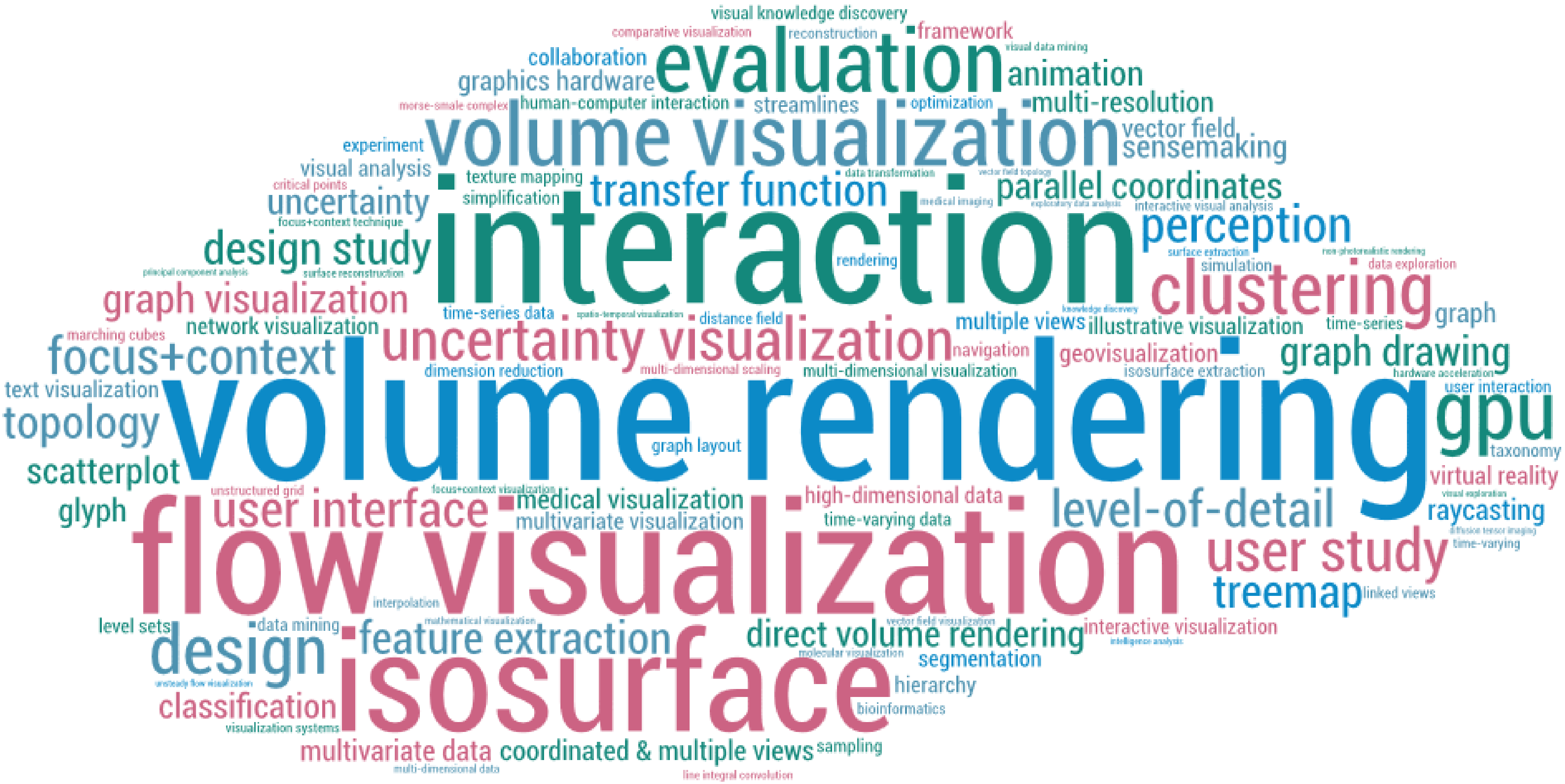
WHAT IS VISUALIZATION?

WHY?

CURIOSITY

- major themes?
- relationship of themes?
- research trends?

TOWARDS A KEYWORD TAXONOMY



IMPROVE THE SCIENTIFIC PROCESS

Keywords

To describe your submission, select one primary keyword (with a radio button) and one to three secondary keywords (with the checkboxes).

Interaction Techniques

- Coordinated and Multiple Views
- Data Editing
- Focus + Context Techniques
- Human Factors
- Human-Computer Interaction
- Interaction Design
- Manipulation and Deformation
- User Interfaces
- Zooming and Navigation Techniques

Display and Interaction Technology

- Haptics for Visualization
- Immersive and Virtual Environments
- Large and High-res Displays
- Multimodal Input Devices
- Stereo Displays

Evaluation

- Field Studies
- Laboratory Studies
- Metrics and Benchmarks
- Qualitative Evaluation
- Quantitative Evaluation
- Task and Requirements Analysis
- Usability Studies

Expert : *``I am an expert in this area: I have published or worked in the area and follow the literature closely."*

	expert	knowledgeable	passing	no knowledge
Human Factors	●	○	○	○
Human-Computer Interaction	●	○	○	○
User Interfaces	●	○	○	○
Large and High-res Displays	●	○	○	○
Usability Studies	●	○	○	○
Laboratory Studies	●	○	○	○

	expert	knowledgeable	passing	no knowledge
Qualitative Evaluation	●	○	○	○
Quantitative Evaluation	●	○	○	○
Collaborative and Distributed Visualization	●	○	○	○
Visualization for the Masses	●	○	○	○

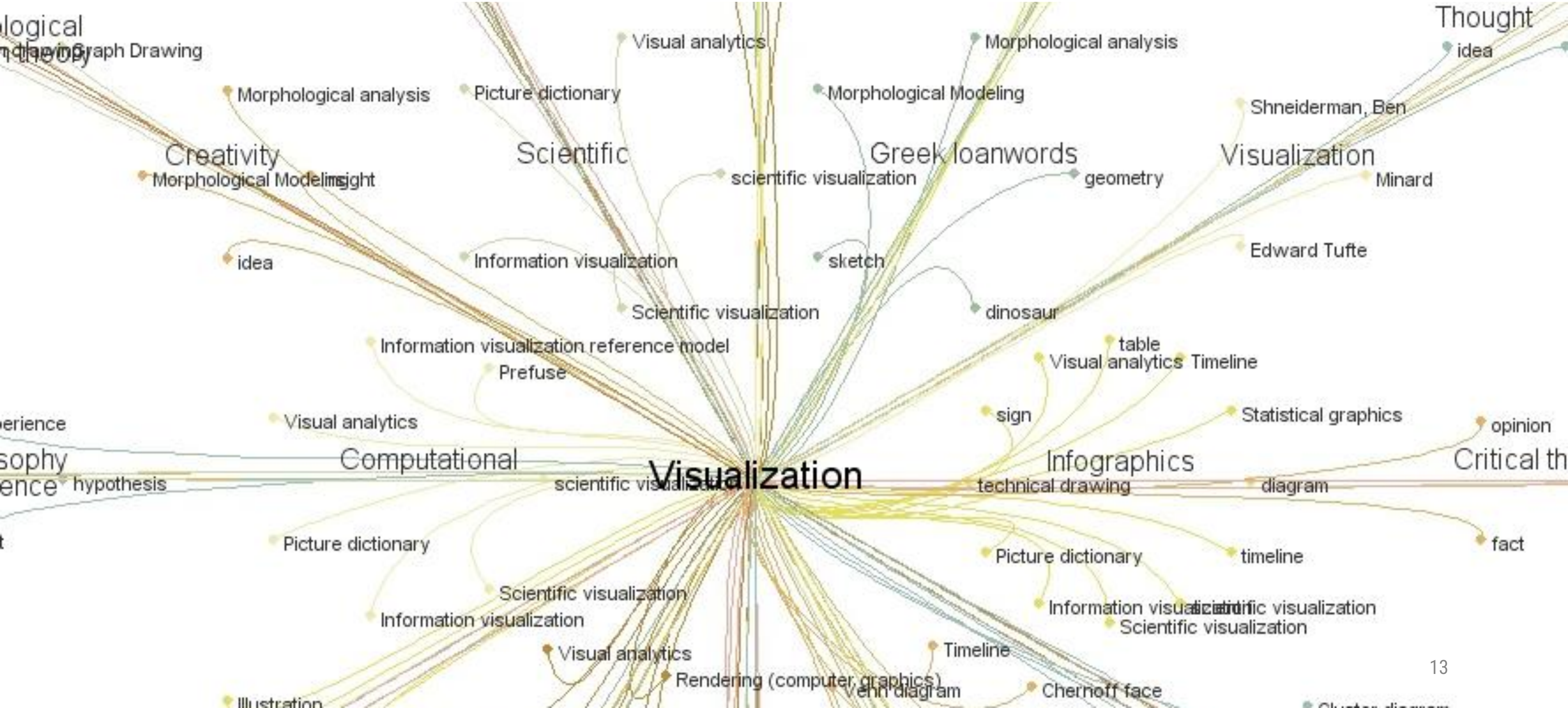
Knowledgeable : *``I have some expertise in this area: I've worked in the area and follow its literature."*

	expert	knowledgeable	passing	no knowledge
Taxonomies	○	●	○	○
Design Methodologies	○	●	○	○
Hierarchy Data	○	●	○	○
Text and Document Data	○	●	○	○
Tabular Data	○	●	○	○
Time Series Data	○	●	○	○

	expert	knowledgeable	passing	no knowledge
High-Dimensional Data	○	●	○	○
Parallel Coordinates	○	●	○	○
Interaction Design	○	●	○	○
Zooming and Navigation Techniques	○	●	○	○
Focus + Context Techniques	○	●	○	○
Coordinated and Multiple Views	○	●	○	○

	expert	knowledgeable	passing	no knowledge

COMMUNICATE "WHAT IS VIS ?"



RESEARCH METHODOLOGY

IEEE VIS papers 1990-2015

File Edit View Insert Format Data Tools Add-ons Help All changes saved in Drive

235223

Conference	Year	Paper Title	Paper DOI	Link	First page	Last page	Panel, Keynote, Captstone, Demo, Poster, ...	Paper type: C=conference paper, J = journal paper, M=miscellaneous (capstone, keynote, VAST challenge, panel, poster, ...)	Abstract	or Na
Vis	1994	VolVis: a diversified volume visualization system	10.1109/VISUAL.1994.346340	http://dx.doi.org/10.1109	31	38, C3		C	VolVis is a divers	R.;Ta
Vis	1994	Vortex tubes in turbulent flows: identification, representatic	10.1109/VISUAL.1994.346327	http://dx.doi.org/10.1109	132	139, C14		C	A new algorithm	s, D.C
Vis	1994	Wavelet-based volume morphing	10.1109/VISUAL.1994.346333	http://dx.doi.org/10.1109	85	92, C8		C	This paper prese	ong He
Vis	1994	XmdvTool: integrating multiple methods for visualizing mult	10.1109/VISUAL.1994.346302	http://dx.doi.org/10.1109	326	333		C	Much of the atter	, M.O
Vis	1993	3D simulation of delivery	10.1109/VISUAL.1993.398903	http://dx.doi.org/10.1109	416	419		C	We show how to	sonnat
Vis	1993	A climate simulation case study	10.1109/VISUAL.1993.398900	http://dx.doi.org/10.1109	397	401		C	A supercomputin	P.C.
Vis	1993	A probe for local flow field visualization	10.1109/VISUAL.1993.398849	http://dx.doi.org/10.1109	39	45		C	A probe for the interactive visualization of flow fields is presented. The	de Leeuw,
Vis	1993	Accelerating volume animation by space-leaping	10.1109/VISUAL.1993.398852	http://dx.doi.org/10.1109	62	69		C	In this work we present a method for speeding the process of volume a	Yagel, R.;S
Vis	1993	An architecture for rule-based visualization	10.1109/VISUAL.1993.398874	http://dx.doi.org/10.1109	236	243		C	In Rogowitz and Treinish (1993), we introduced an architecture for inco	Rogowitz,
Vis	1993	An environment for telecollaborative data exploration	10.1109/VISUAL.1993.398858	http://dx.doi.org/10.1109	110	117		C	This paper presents an environment for telecollaborative data explorati	Klinker, G.
Vis	1993	Applying observations of work activity in designing prototy	10.1109/VISUAL.1993.398873	http://dx.doi.org/10.1109	228	235		C	Designers, implementers, and marketers of data analysis tools typical	Springmey
Vis	1993	Bridging the gap between visualization and data managem	10.1109/VISUAL.1993.398856	http://dx.doi.org/10.1109	94	101		C	A prototype visualization management system is described which mer	Kochevar,
Vis	1993	Cloud tracing in convection-diffusion systems	10.1109/VISUAL.1993.398876	http://dx.doi.org/10.1109	253	260		C	The paper describes a highly interactive method for computer visualiza	Ma, K.-L.;S
Vis	1993	Computer visualization of long genomic sequences	10.1109/VISUAL.1993.398883	http://dx.doi.org/10.1109	308	315		C	Human beings find it difficult to analyze local and global oligonucleotid	Wu, D.;Ro
Vis	1993	Data shaders	10.1109/VISUAL.1993.398879	http://dx.doi.org/10.1109	275	282		C	The process of visualizing a scientific data set requires an extensive k	Corrie, B.;
Vis	1993	Developing modular application builders to exploit MIMD p	10.1109/VISUAL.1993.398861	http://dx.doi.org/10.1109	134	141		C	Modular application builders (MABs), such as AVS and Iris Explorer a	Thornborro
Vis	1993	Dichromatic color representations for complex display sys	10.1109/VISUAL.1993.398871	http://dx.doi.org/10.1109	212	219		C	New display technologies have begun to provide more innovative and p	Peercy, M.
Vis	1993	DIVIDE: Distributed visual display of the execution of asyn	10.1109/VISUAL.1993.398865	http://dx.doi.org/10.1109	166	173		C	The issue of monitoring the execution of asynchronous, distributed alg	Morrow, T.
Vis	1993	Enhancing reality in the operating room	10.1109/VISUAL.1993.398902							
Vis	1993	Fanal: A relational analysis and visualization package for	10.1109/VISUAL.1993.398897							
Vis	1993	Fast analytical computation of Richard's smooth molecula	10.1109/VISUAL.1993.398882							
Vis	1993	Fast volume rendering of compressed data	10.1109/VISUAL.1993.398845							
Vis	1993	Feature extraction for oceanographic data using a 3D edge	10.1109/VISUAL.1993.398901							
Vis	1993	Fine-grain visualization algorithms in dataflow environment	10.1109/VISUAL.1993.398860							
Vis	1993	Flow volumes for interactive vector field visualization	10.1109/VISUAL.1993.398846	http://dx.doi.org/10.1109	19	24		C	Flow volumes are the volumetric equivalent of stream lines. They provi	Max, N.;Be
Vis	1993	Geometric clipping using Boolean textures	10.1109/VISUAL.1993.398878	http://dx.doi.org/10.1109	268	274		C	Texture mapping is normally used to convey geometric detail without a	Lorensen,
Vis	1993	Geometric optimization	[illegible]	[illegible]	[illegible]	[illegible]		C	[illegible]	[illegible]

http://vispubdata.org

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.

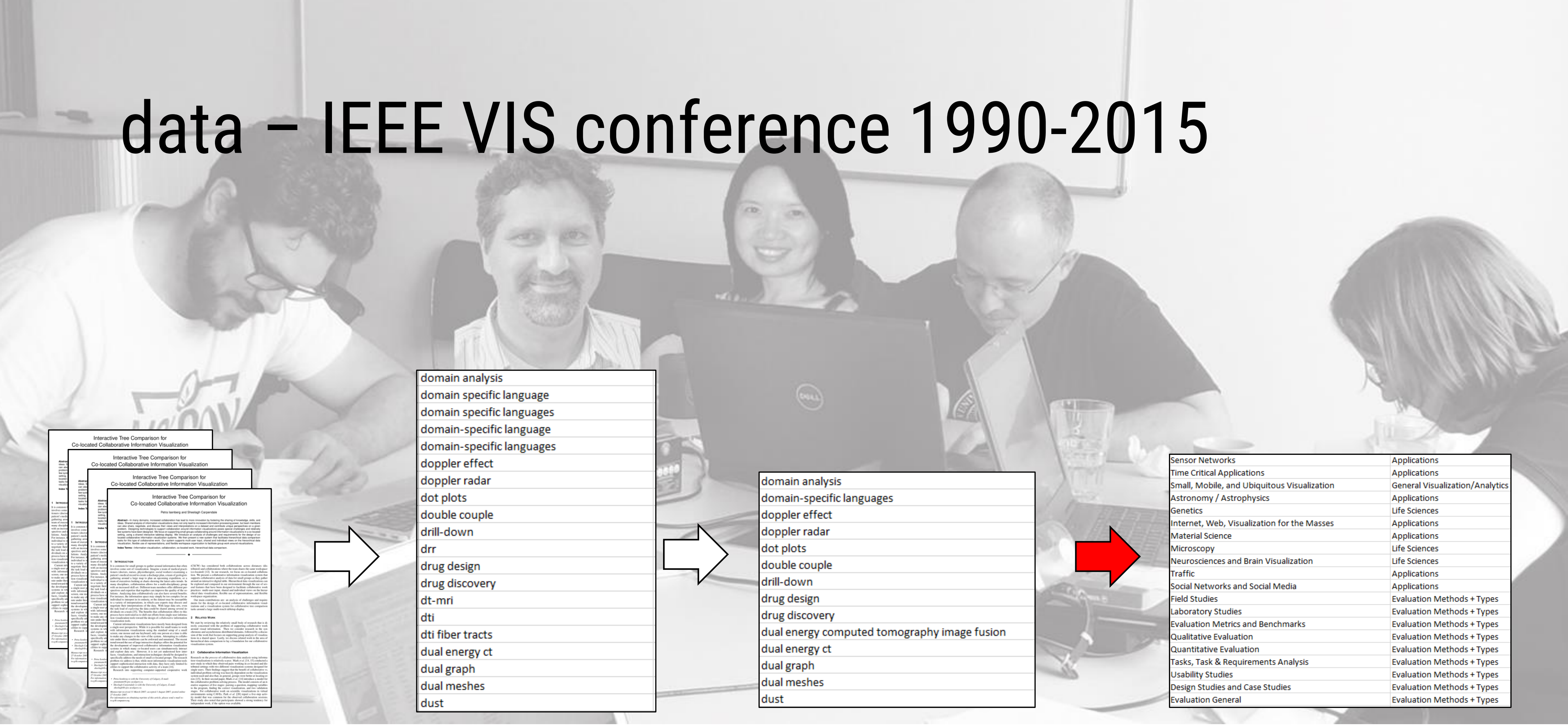
1 Motivation

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. 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

ANALYSIS ASSUMPTIONS

- authors choose keywords that best represent their work
- authors use a somewhat finite set of key terms
- co-occurrence represents meaningful relationships

data – IEEE VIS conference 1990-2015



2431 papers

domain analysis
domain specific language
domain specific languages
domain-specific language
domain-specific languages
doppler effect
doppler radar
dot plots
double couple
drill-down
drr
drug design
drug discovery
dt-mri
dti
dti fiber tracts
dual energy ct
dual graph
dual meshes
dust

4319 unique keywords

domain analysis
domain-specific languages
doppler effect
doppler radar
dot plots
double couple
drill-down
drug design
drug discovery
dual energy computed tomography image fusion
dual energy ct
dual graph
dual meshes
dust

3952 unique cleaned keywords

Sensor Networks	Applications
Time Critical Applications	Applications
Small, Mobile, and Ubiquitous Visualization	General Visualization/Analytics
Astronomy / Astrophysics	Applications
Genetics	Life Sciences
Internet, Web, Visualization for the Masses	Applications
Material Science	Applications
Microscopy	Life Sciences
Neurosciences and Brain Visualization	Life Sciences
Traffic	Applications
Social Networks and Social Media	Applications
Field Studies	Evaluation Methods + Types
Laboratory Studies	Evaluation Methods + Types
Evaluation Metrics and Benchmarks	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
Design Studies and Case Studies	Evaluation Methods + Types
Evaluation General	Evaluation Methods + Types

180 topics
14 categories

KEYVIS

Getting started Search Topics About

Search for VIS paper keywords

Explore all topic clusters:

Abstraction, Simplification, Approximation

Acoustics, Sound, Sonification

Topic cluster containing **15** keywords :

auralization 2x | acoustic imaging 1x | acoustic metric 1x | acoustic propagation 1x | acoustic simulation 1x | acoustics 1x | midi 1x | musicology 1x | phonon map 1x | phonon tracing 1x | room acoustics 1x | sonar technology 1x | sonification 1x | sound analytics 1x | sound propagation 1x

All papers that include at least one of these keywords:

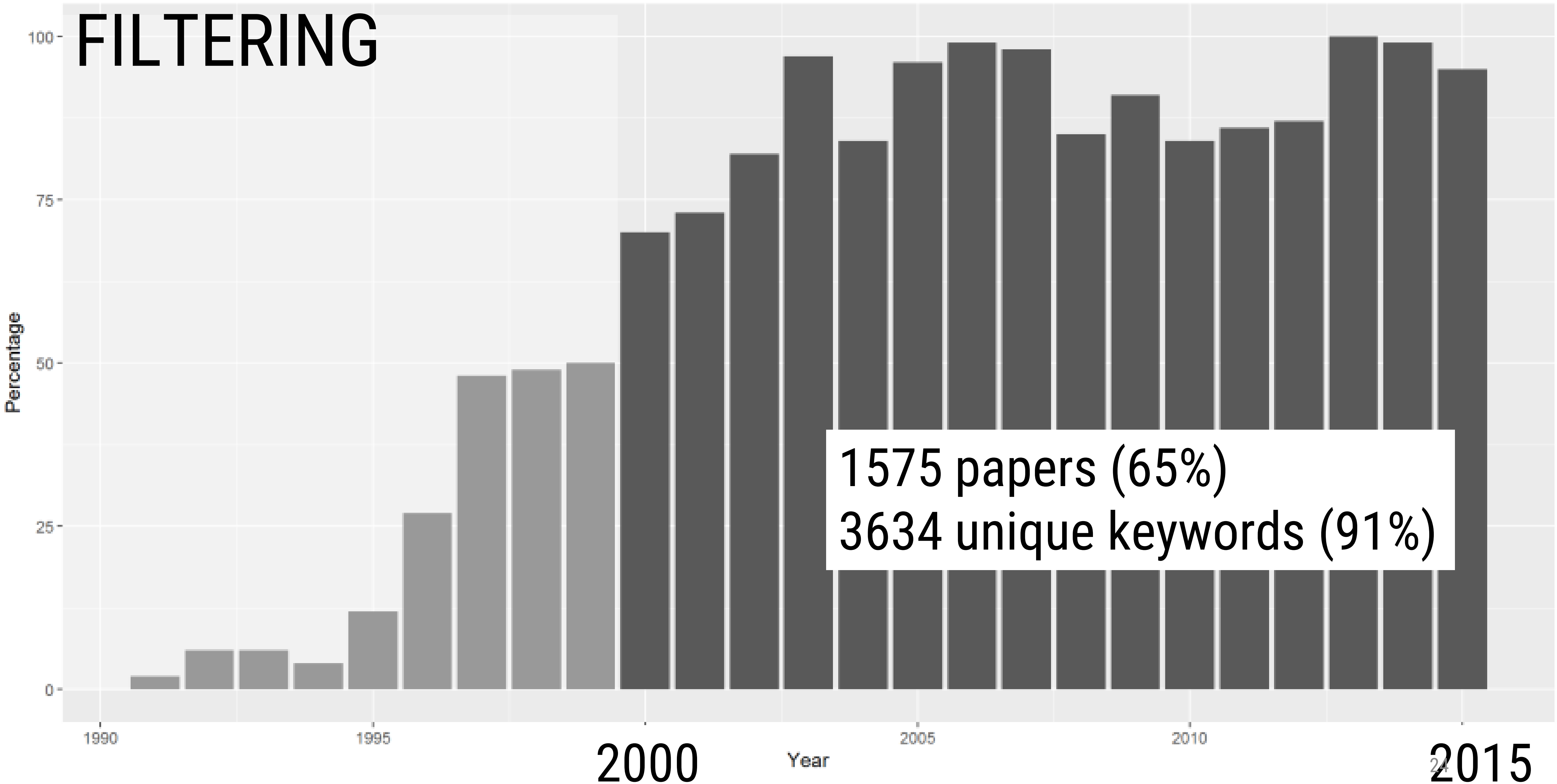
Conf.	Year ▲	Title
VAST	2015	Interactive Visual Profiling of Musicians
Vis	2008	AD-Frustum: Adaptive Frustum Tracing for Interactive Sound Propagation
Vis	2007	Interactive sound rendering in complex and dynamic scenes using frustum tracing
Vis	2007	Listener-based Analysis of Surface Importance for Acoustic Metrics
Vis	2006	Comparative Visualization for Wave-based and Geometri
Vis	2005	Phonon tracing for auralization and visualization of soun
Vis	2000	Real-time visualization of the clear-up of a former US nav
Vis	2000	Case study: a methodology for plume visualization with a
Vis	1996	LISTEN: sounding uncertainty visualization

Adaptive Processing and Refinement

http://keyvis.org

QUANTITATIVE ANALYSIS

FILTERING

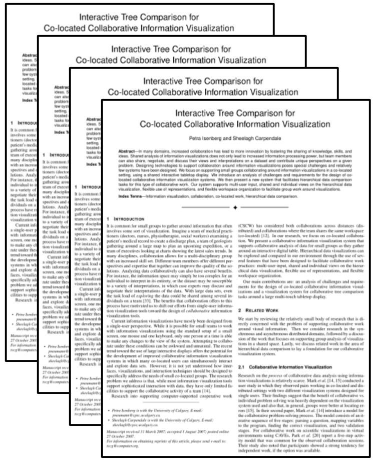


1575 papers (65%)
3634 unique keywords (91%)

2000

2015

Data – PCS Taxonomy 2008-2015 (for IEEE VIS papers)



3430 paper submissions

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	Data Acquisition and Management	59	13	4	25	17	0	8	4	6	10	14	9	8

127 unique keywords
14 categories

RESULTS

Only looking at topics and PCS keywords

GUIDING QUESTIONS

what did we learn about the field of Visualization?

what did we learn about building a Visualization taxonomy?

RESEARCH THEMES

CO-WORD ANA
NETWORK OF
TECHNOLOGIC

Centre de Sociologie de l'Inn

The goal of this interactions betwee content analysis of results concern a.) t interaction; b.) a trajectories" given f both science push research field. The between research in innovation.

One of the major qu played by scientific re diametrically opposed h push and market pull. situation is much more network of interactions (

Software En
Literature: A

Neal Coulter
Department of Compute
E-mail: neal@cse.fau.ed

Ira Monarch and Sures
Software Engineering In
E-mail: {iam}@sei.cmu.e

This empirical research c of content analysis to ma software engineering disc certain research themes remained constant, but themes have arisen, mat research topics, while sti mature. Co-word analysis This methodology identif cation descriptors (index puting Classification Sys descriptors that reveal t methodology is applicabl porting corpus of textual index terms from a fixed t inherent; the descriptors pus. Hence, co-word ana ware tools employed he into any discipline's evol

Scientometrics (20
DOI 10.1007/s111

A co-word
in China

Chang-Ping Hu

Received: 22 Augu
© Akadémiai Kiad

Abstract This Science (LIS) in and trends of LIS keywords extrac co-word analysis obtain 13 cluster strategic diagram can be drawn: ((ii) a few emerg topics in this LIS and immature to

CHI 1994-2013: Mapping Two Decades of Intellectual Progress through Co-word Analysis

Yong Liu[1], Jorge Goncalves[1], Denzil Ferreira[1], Bei Xiao[2], Simo Hosio[1], Vassilis Kostakos[1]
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ABSTRACT

This study employs hierarchical cluster analysis, strategic diagrams and network analysis to map and visualize the intellectual landscape of the CHI conference on Human Computer Interaction through the use of co-word analysis. The study quantifies and describes the thematic evolution of the field based on a total of 3152 CHI articles and their associated 16035 keywords published between 1994 and 2013. The analysis is conducted for two time periods (1994-2003, 2004-2013) and a comparison between them highlights the underlying trends in our community. More significantly, this study identifies the evolution of major themes in the discipline, and highlights individual topics as popular, core, or backbone research topics within HCI.

Author Keywords

Co-word analysis; bibliometric study; conceptual evolution; HCI; cohesion; coherence

ACM Classification Keywords

K.2. History Of Computing: Theory.

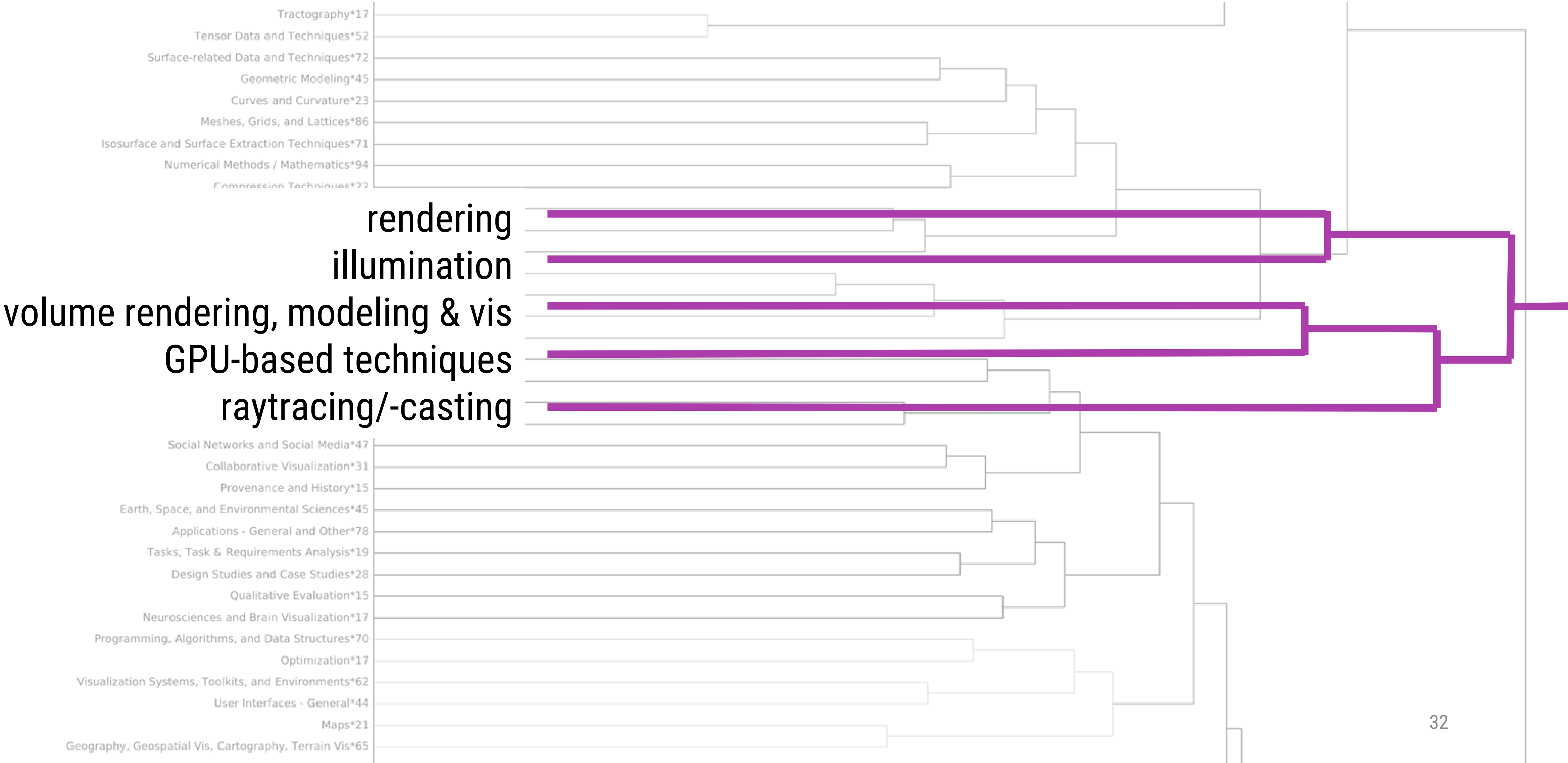
INTRODUCTION

The CHI conference has a long and rich history. In the last 20 years alone its 3152 publications have shaped and defined the field of human-computer interaction, making CHI a flagship HCI venue characterized by its strong multidisciplinarity. In this paper, we are interested in mapping how the landscape of the HCI field has evolved, as mobile) HCI. Since 2004, however, the field has grown at a high pace, due to the introduction of extended abstracts and electronic proceedings. The popularity of mobile phones, ambient media and social technologies has shifted HCI research towards mobile and social interaction, while new issues involving humans, such as crowdsourcing and privacy have taken the spotlight. We attempt to study and analyze HCI research foci transitions and reflect on their drivers and present status.

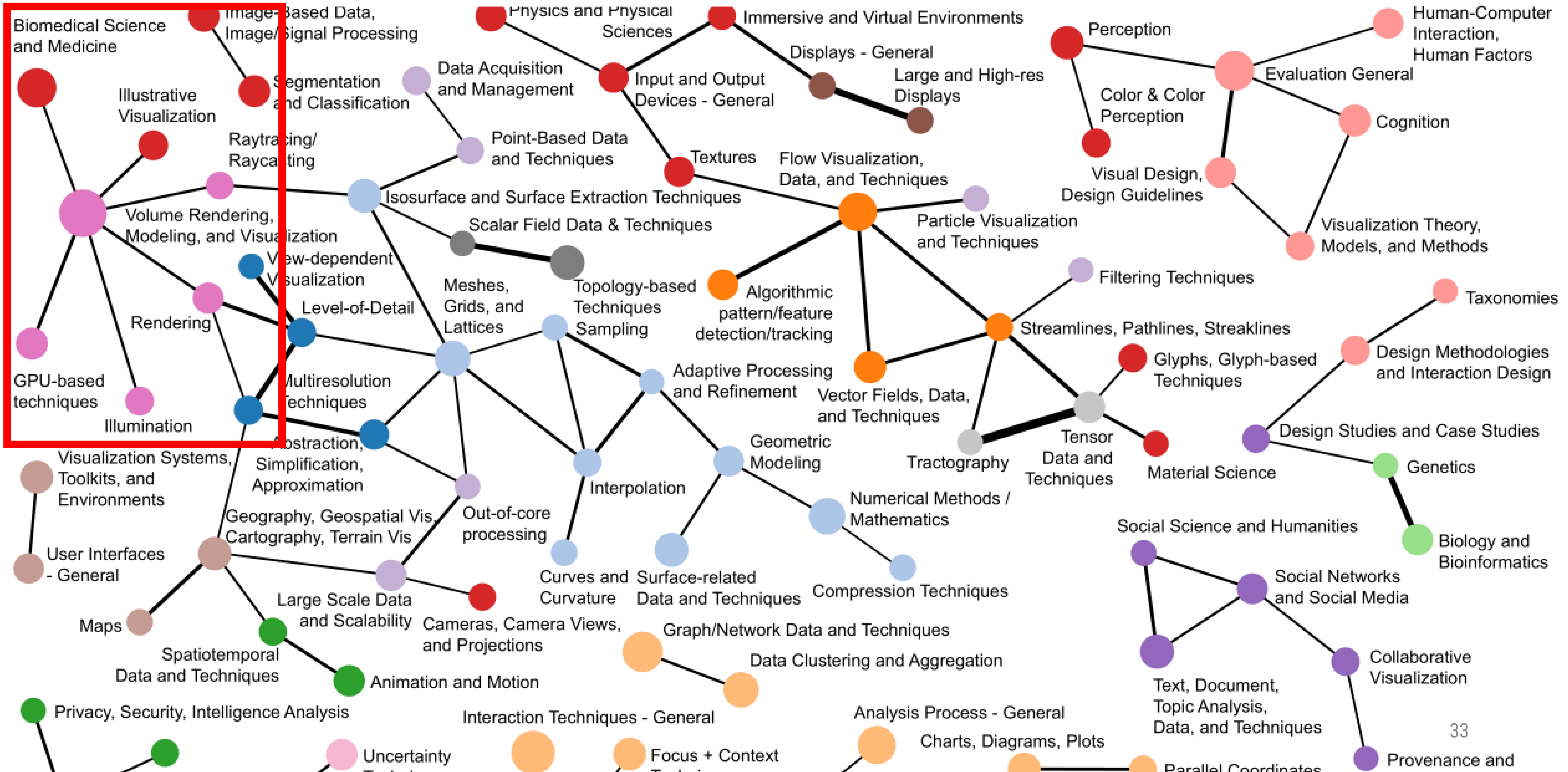
Our analysis relies on techniques from hierarchical cluster and graph theory, through the use of co-word analysis artifacts such as strategic diagrams and graphs. Co-word analysis is part of the co-occurrence analysis methods. It is a widely-applied bibliometric approach to describe the interactions among concepts, ideas, and problems and to explore the concept network within a scientific area [7,8]. A recently published paper of a *co-citation* analysis of the CHI proceedings [2] focused on authorship aspects of the proceedings and citation metrics for papers. Here we focus on the concepts that reflect our community and their evolution over time.

Co-word analysis rests on the assumption that a paper's keywords constitute an adequate description of its content as well as the links the paper established between problems: two keywords co-occurring within the same paper are an indication of a link between the topics to which they refer to [9]. The presence of many co-occurrences around the

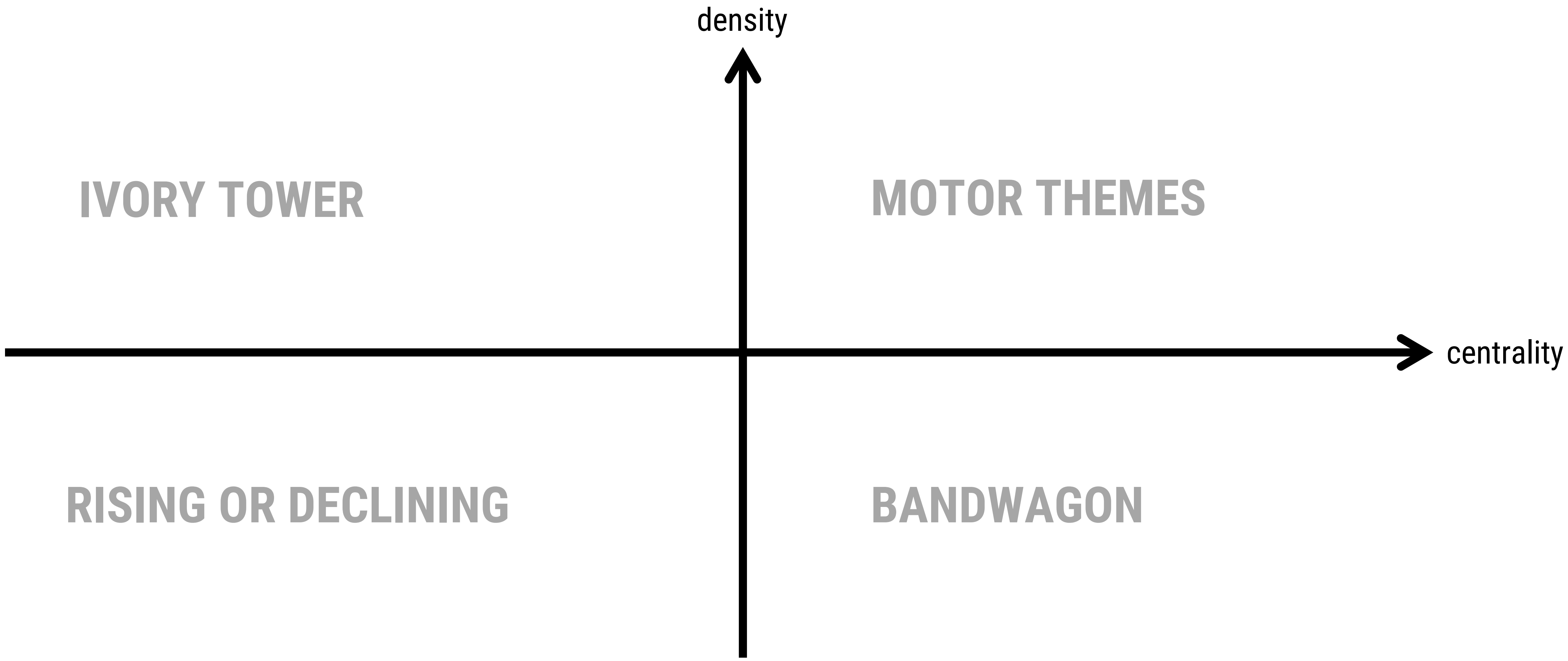
KEYWORD CORRELATION CLUSTERS

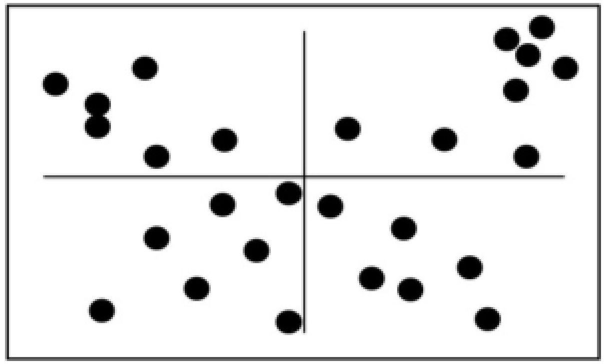


KEYWORD CORRELATION GRAPHS

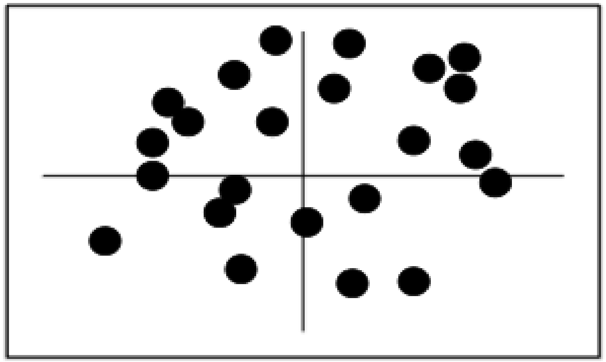


STRATEGIC DIAGRAMS

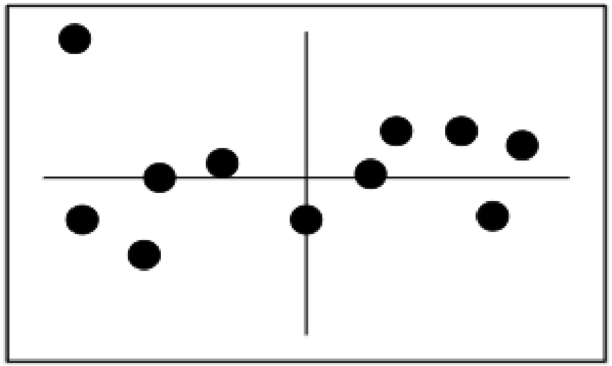




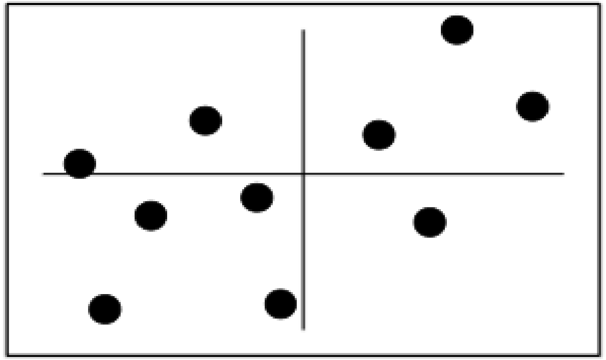
psychology



consumer behavior

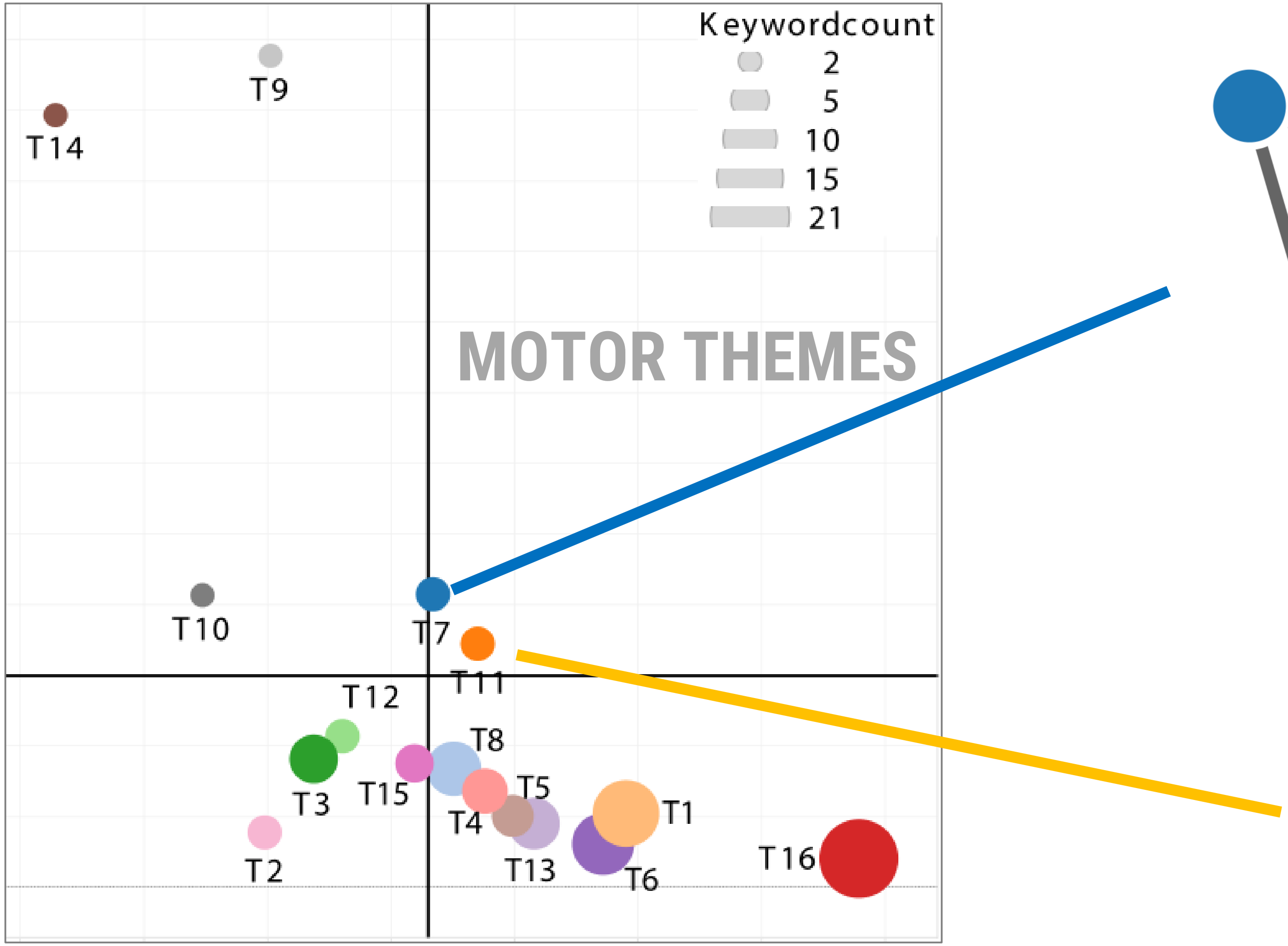


software engineering

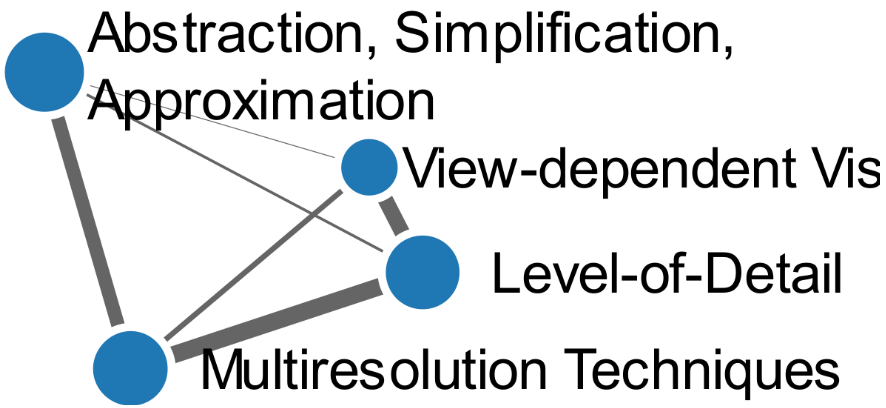


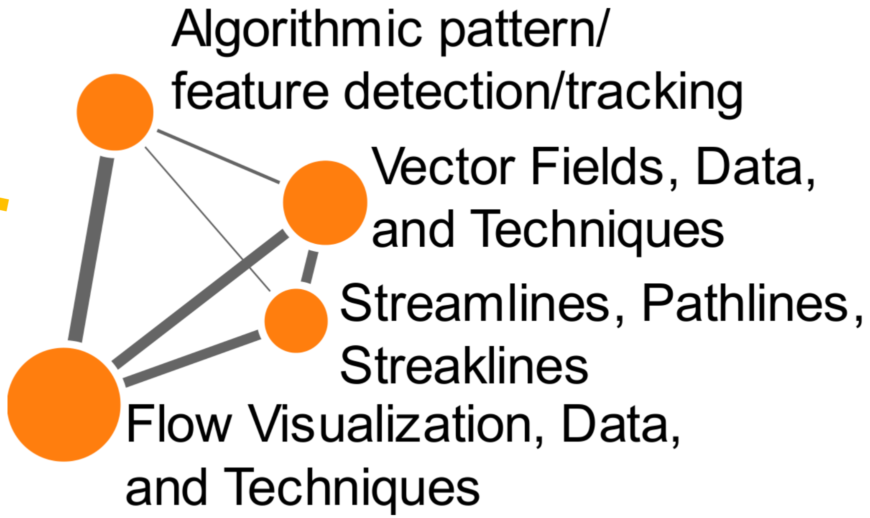
stem cell research

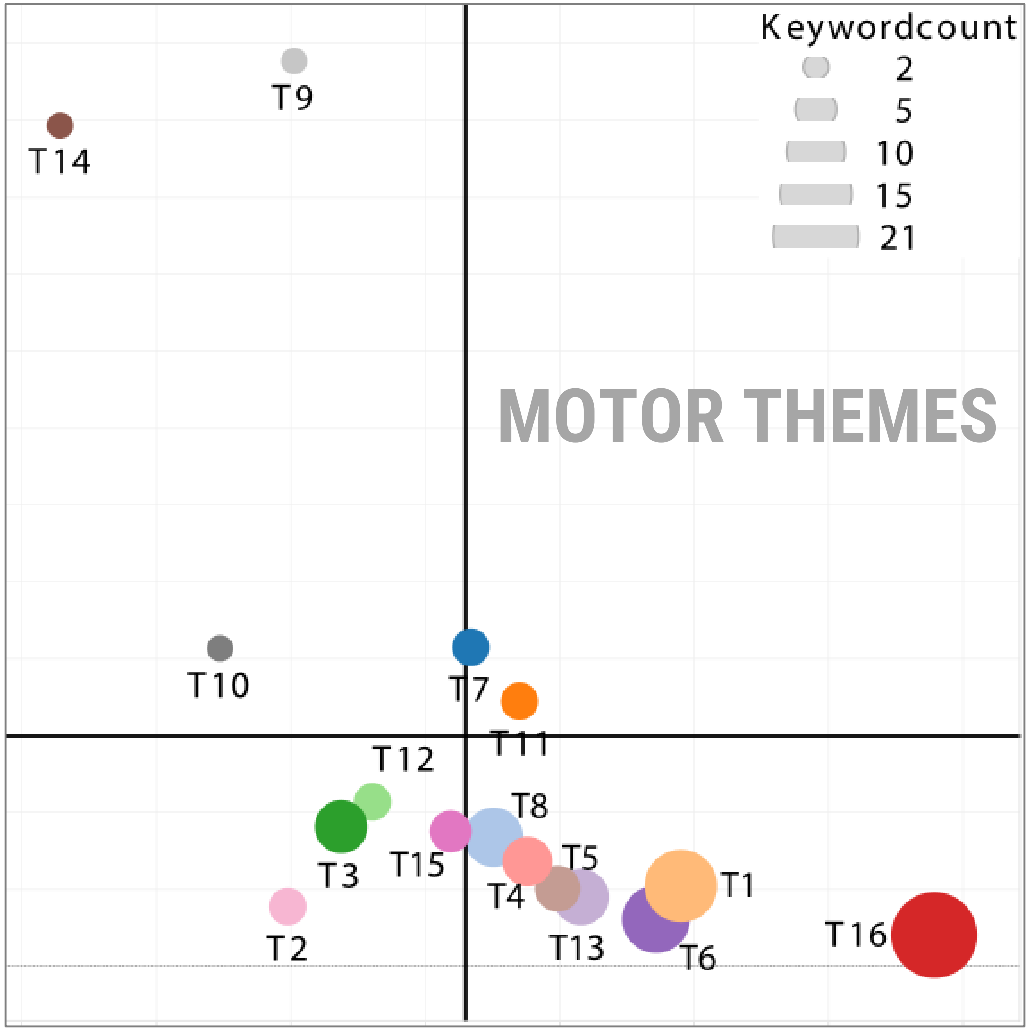
Y. Liu, et al. CHI (2014)



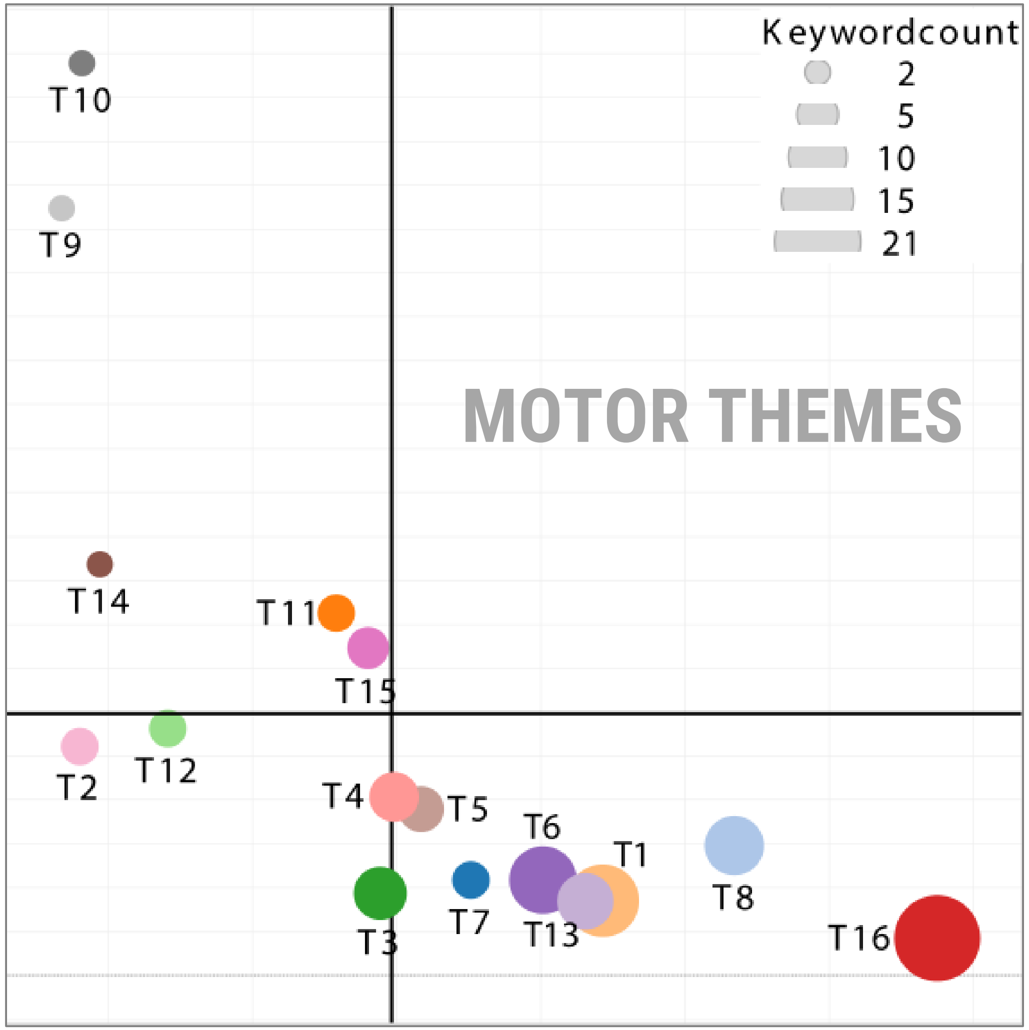
2000-2007
topic keywords







2000-2007



2008-2015

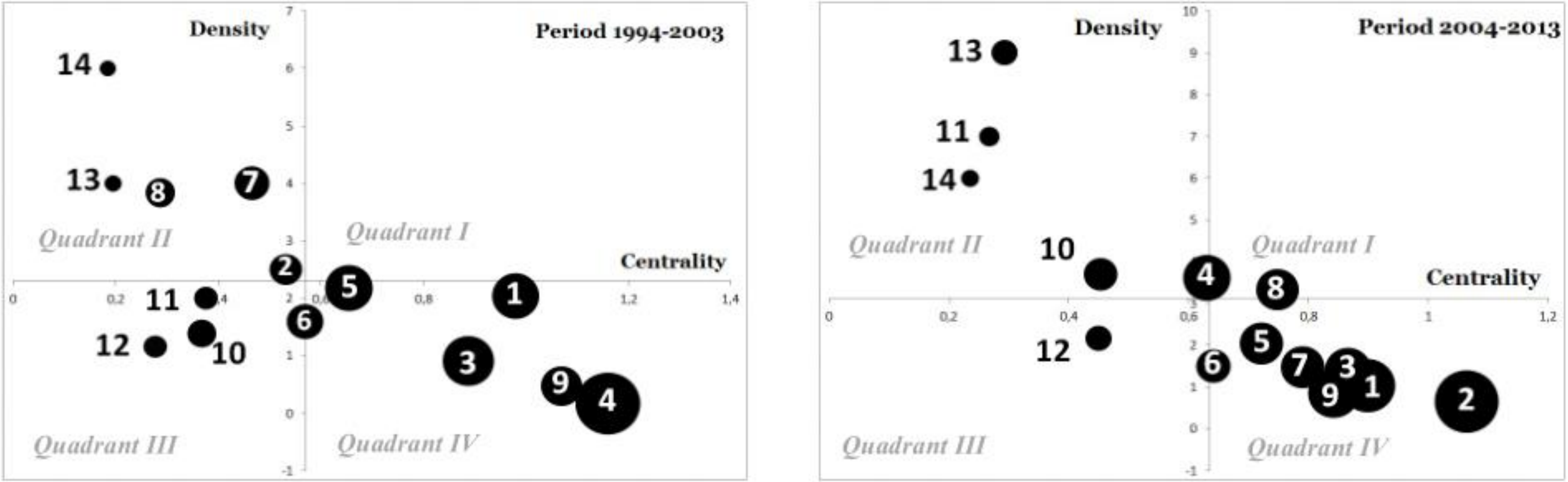
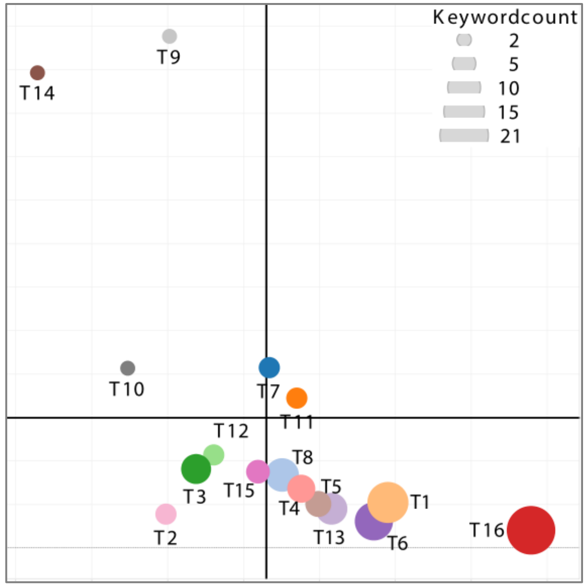


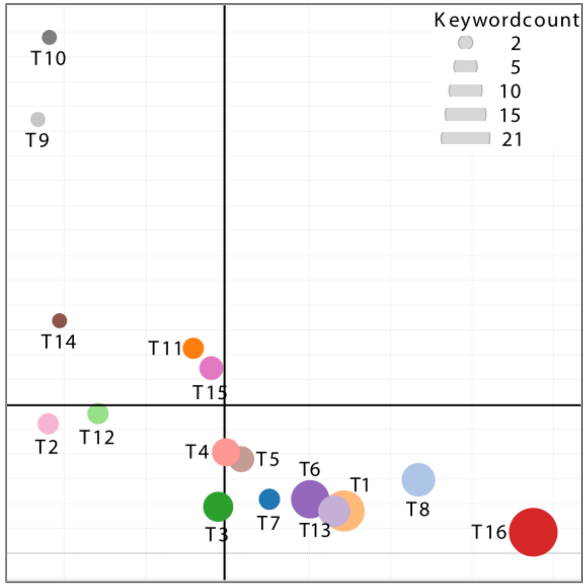
Figure 4. Strategic diagram for CHI for the period 1994-2003 (left), and 2004-2013 (right).

Y. Liu, et al. CHI (2014)

ACCUMULATED KNOWLEDGE?



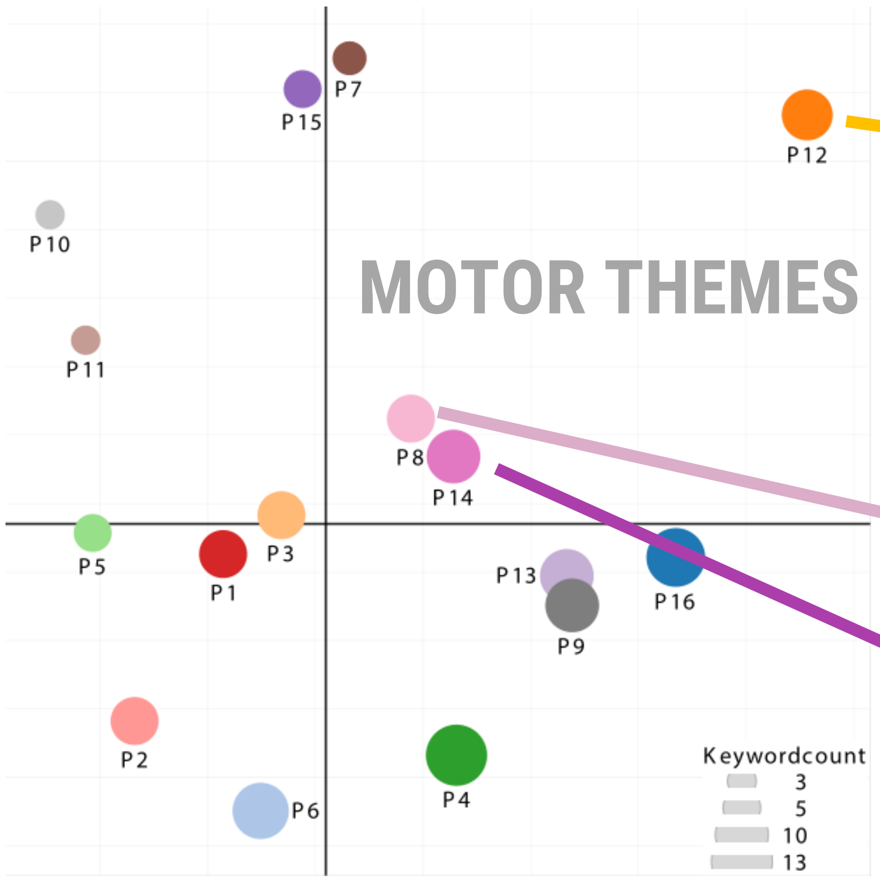
2000-2007



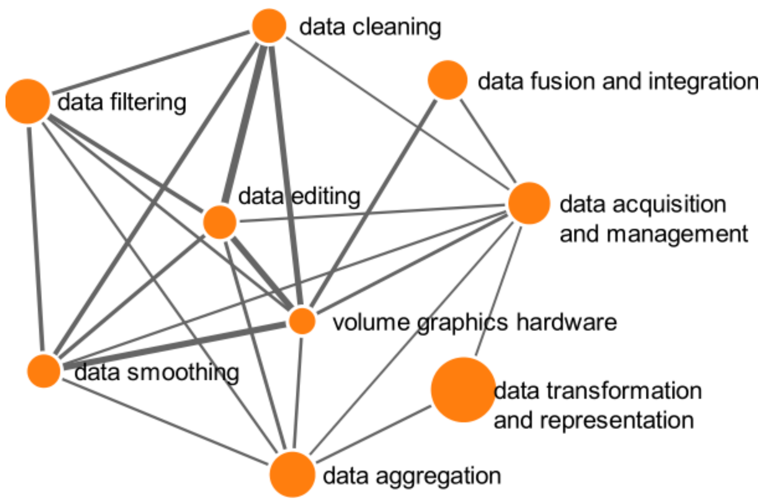
2008-2015

- is our research too contextual?
- do we focus too much on novel techniques and tools?
- is the field still growing too much to observe motor themes?
- do we not share a common vocabulary?

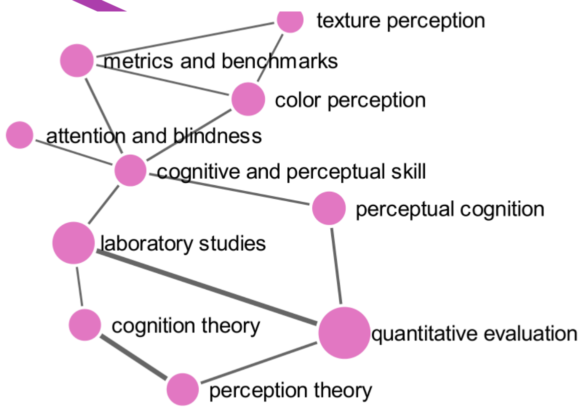
Y. Liu, et al. CHI (2014)



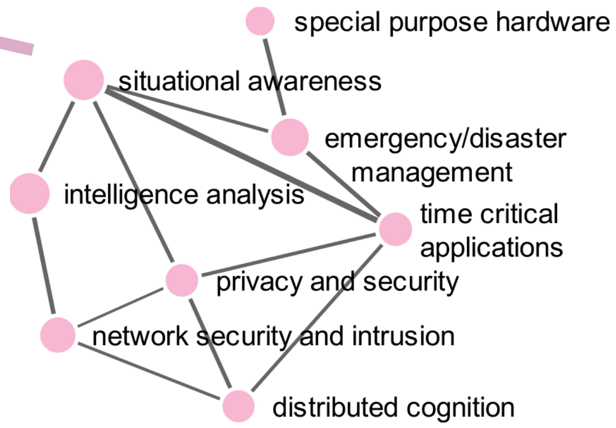
2008-2015
PCS KEYWORDS



DATA



PERCEPTION & COGNITION



VAST

INDIVIDUAL KEYWORDS

MOST COMMON KEYWORDS

TOPICS	PCS
volume rendering, modeling, & vis	visual knowledge discovery
interaction techniques – general	graph/network data
graph/network data & tech	coordinated & multiple views
evaluation – general	user interfaces
biomedical science & medicine	biomedical & medical vis

MOST COMMON KEYWORDS

TOPICS	**PCS**
volume rendering, modeling, & vis	visual knowledge discovery
interaction techniques – general	**graph/network data**
graph/network data & tech	coordinated & multiple views
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MOST COMMON KEYWORDS

TOPICS	PCS
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graph/network data & techn	coordinated & multiple views
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biomedical science & medicine	**biomedical & medical vis**

EVALUATION - GENERAL

Topic cluster containing **67** keywords :

evaluation 36x | user study 27x | experiment 10x | eye tracking 7x | crowdsourcing 5x | empirical evaluation 4x | empirical study 3x

insight-based evaluation 3x | visualization evaluation 3x | demand-driven evaluation 2x | evaluation methodology 2x

log file analysis 2x | non-destructive testing 2x | optimal visualization 2x | performance analysis 2x | validation 2x

verifiable visualization 2x | walkthrough 2x | confusion analysis 1x | confusion matrices 1x | crowdsourced study 1x

evaluation of visualization techniques 1x | experimental comparison 1x | experimental design 1x | experimental method 1x

experimental studies 1x | experimentation 1x | expert reviews 1x | eye gaze analysis 1x | eye tracking study 1x | funnel analysis 1x

game performance evaluation 1x | human subjects testing 1x | in situ analysis 1x | intent discernment 1x | interaction logs 1x

item response theory 1x | low-fidelity prototyping 1x | mechanical turk 1x | multi-factorial 1x

nondestructive testing and evaluation 1x | note taking 1x | online study 1x | quantification 1x | satisfaction survey 1x

session analysis 1x | standardized testing 1x | student performance analysis 1x | survey 1x | systematic review 1x

test and measurement 1x | testbed design and evaluation 1x | training 1x | user evaluation 1x | user experience 1x

user involvement 1x | user satisfaction 1x | user study evaluation 1x | user tracking 1x | verbal analysis 1x | verification 1x

verification and validation 1x | visineers' heuristics and expertise 1x | visual inspection 1x | visual testing 1x | visual verification 1x

wizard of oz 1x

EVALUATION - GENERAL

AUTHOR KEYWORDS		PCS – EVALUATION CATEGORY
		Field Studies
…	?	Laboratory Studies
experiment design		Metrics and Benchmarks
evaluation methodology	→	Qualitative Evaluation
empirical evaluation		Quantitative Evaluation
…		Task and Requirements Analysis
		Usability Studies

TERM FREQUENCY

OUR EVALUATION CATEGORY	PCS – EVALUATION CATEGORY
Field Studies	**Field Studies**
Laboratory Studies	Laboratory Studies
Evaluation Metrics and Benchmarks	**Metrics and Benchmarks**
Qualitative Evaluation	Qualitative Evaluation
Quantitative Evaluation	Quantitative Evaluation
Tasks, Task & Requirements Analysis	Task and Requirements Analysis
Usability Studies	Usability Studies
Design Studies and Case Studies	
Evaluation General	

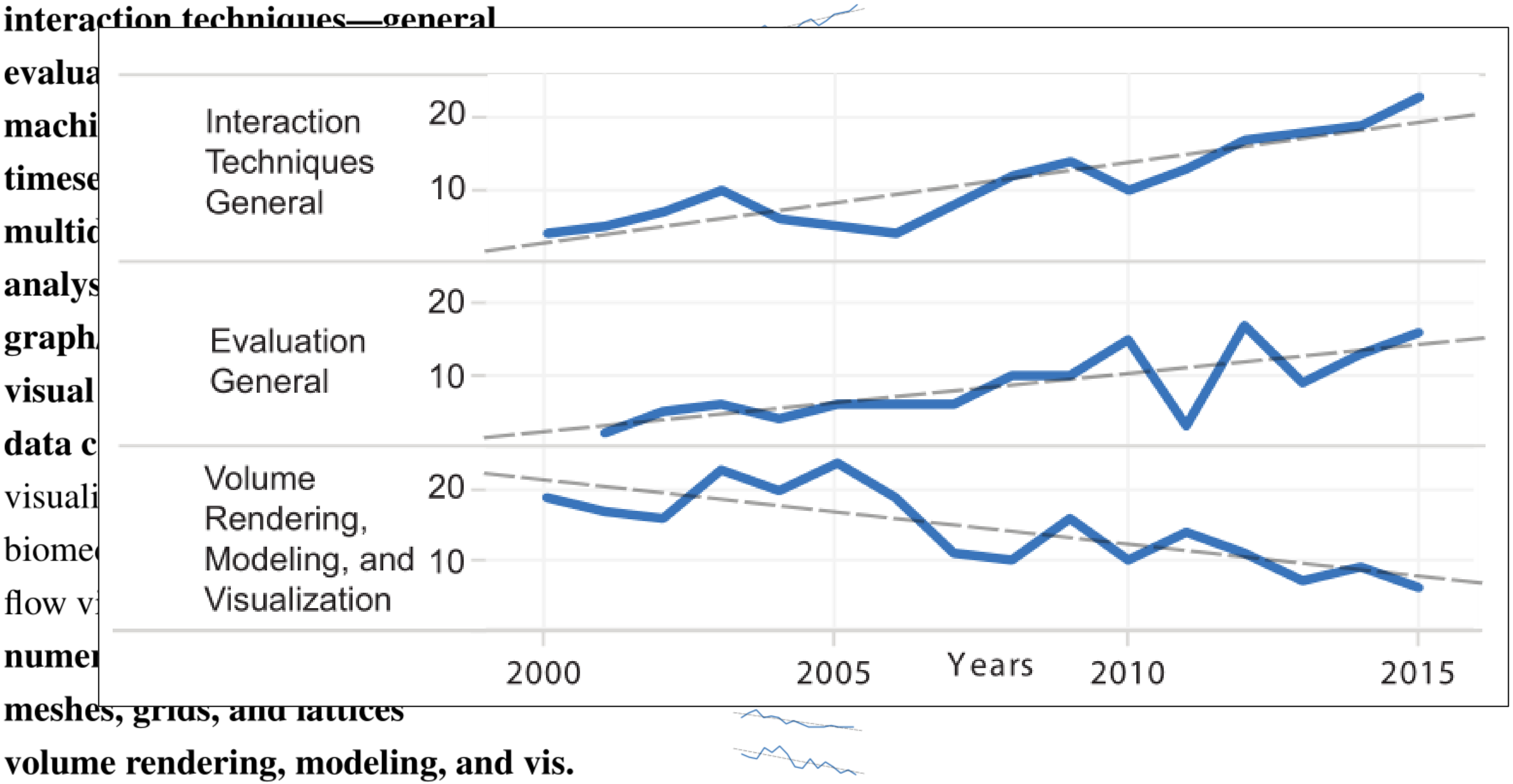
SHOULD WE ADD AND REMOVE KEYWORDS?

if yes, when and how should they be chosen?

SHOULD WE LOOK AT TRENDS?

2000-2007	2008-2015
volume rendering, modeling & vis	interaction techniques – general
meshes, grids & lattices	evaluation – general
flow vis, data, & techniques	**volume rendering, modeling & vis**
biomedical science & medicine	graph/network data & techniques
numerical methods / mathematics	multidim./-var./.-field data & techn

SIGNIFICANT TEMPORAL TRENDS



SUMMARY OF TAXONOMY CHALLENGES

objectivity – how to avoid overemphasis & underspecification based on "believes"

Perceptual Cognition	1.5%
Color Perception	1.3%
Cognitive and Perceptual Skill	1.3%
Cognition Theory	1.3%
Perception Theory	1.2%
Scene Perception	1.1%
Motion Perception	<1%
Attention and Blindness	<1%
Texture Perception	<1%
Distributed Cognition	<1%
Embodied / Enactive Cognition	<1%

SUMMARY OF TAXONOMY CHALLENGES

objectivity – how to avoid overemphasis & underspecification based on "believes"

clarity – how to avoid ambiguity of keywords

multi-dimensional data
vs.
high-dimensional data

SUMMARY OF TAXONOMY CHALLENGES

objectivity – how to avoid overemphasis & underspecification based on "believes"

clarity – how to avoid ambiguity of keywords

higher-level categories – what to do with keywords that fit in many?

multi-dimensional data
(large data visualization)
vs.
high-dimensional data
(non-spatial data and techniques)

SUMMARY OF TAXONOMY CHALLENGES

objectivity – how to avoid overemphasis & underspecification based on "believes"

clarity – how to avoid ambiguity of keywords

higher-level categories – what to do with keywords that fit in many?

naming

collaborative and distributed visualization

FINALLY

LIMITATIONS

- we are not social scientists
- the dataset is rich but limited
  - our work can / should be complemented by other approaches

http://vispubdata.org

http://keyvis.org

http://tinyurl.com/keyvis

LETS FIND ANSWERS TOGETHER

- how should we establish and maintain a VIS taxonomy ?
- do we need more than one taxonomy ?

- what is our accumulated knowledge ?
- do we build enough on previous work ?
- do we rely too much on external factors (data, applications, …) ?
- …

Visualization as Seen Through its Research Paper Keywords

Petra Isenberg, Tobias Isenberg, Michael Sedlmair, Jian Chen, Torsten Möller

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

Additional Slides

most common topics

2008-2015	PCS
interaction techniques – general	visual knowledge discovery
evaluation – general	**graph/network data**
volume rendering, modeling & vis	coordinated and multiple views
graph/network data & techniques	user interfaces
multidim./-var./.-field data & techn	biomedical and medical vis

Co-Word Analysis

1. Build co-occurrence matrix

Keywords →

vector field visualization

Keywords ↓

	user interfa	user study	vector field	vector field	vector field	virtual realit	visual analy	visual data	visual explo	visual know
distance field	0	0	0	0	0	0	0	0	0	0
evaluation	0	5	0	0	0	2	0	0	0	0
experiment	0	2	0	0	0	1	0	0	0	0
exploratory data ana	1	0	0	0	0	0	0	0	0	0
feature extraction	1	0	0	1	1	0	0	0	0	0
flow visualization	0	2	2	5	3	0	0	0	0	0
[illegible]	[illegible]	0	0	0	0	0	1	0	0	0
[illegible]	[illegible]	0	0	0	0	0	0	0	0	0
focus+context visual	0	0	0	0	0	0	0	0	0	0
framework	0	0	0	0	0	0	0	0	0	0
geovisualization	0	0	0	0	0	0	0	0	0	0
glyph	0	0	0	0	0	0	0	0	0	0
gpu	0	0	0	0	1	0	0	0	0	0
graph	0	0	0	0	0	0	0	0	0	0
graph drawing	0	0	0	0	0	0	0	0	0	0
graph layout	0	1	0	0	0	0	0	0	0	0
graph visualization	0	0	0	0	0	1	0	0	0	0
graphics hardware	0	0	0	0	1	0	0	0	0	0
hardware acceleratic	0	0	0	0	0	0	0	0	0	0
hierarchy	0	0	0	0	0	0	0	0	0	0
high-dimensional da	2	0	1	0	0	0	0	2	0	2
human-computer int	1	0	0	0	0	0	0	0	0	1

flow visualization

5

Co-Word Analysis

2. Build correlation matrix

Keywords →

Keywords ↓

vector field visualization

flow visualization

0.2

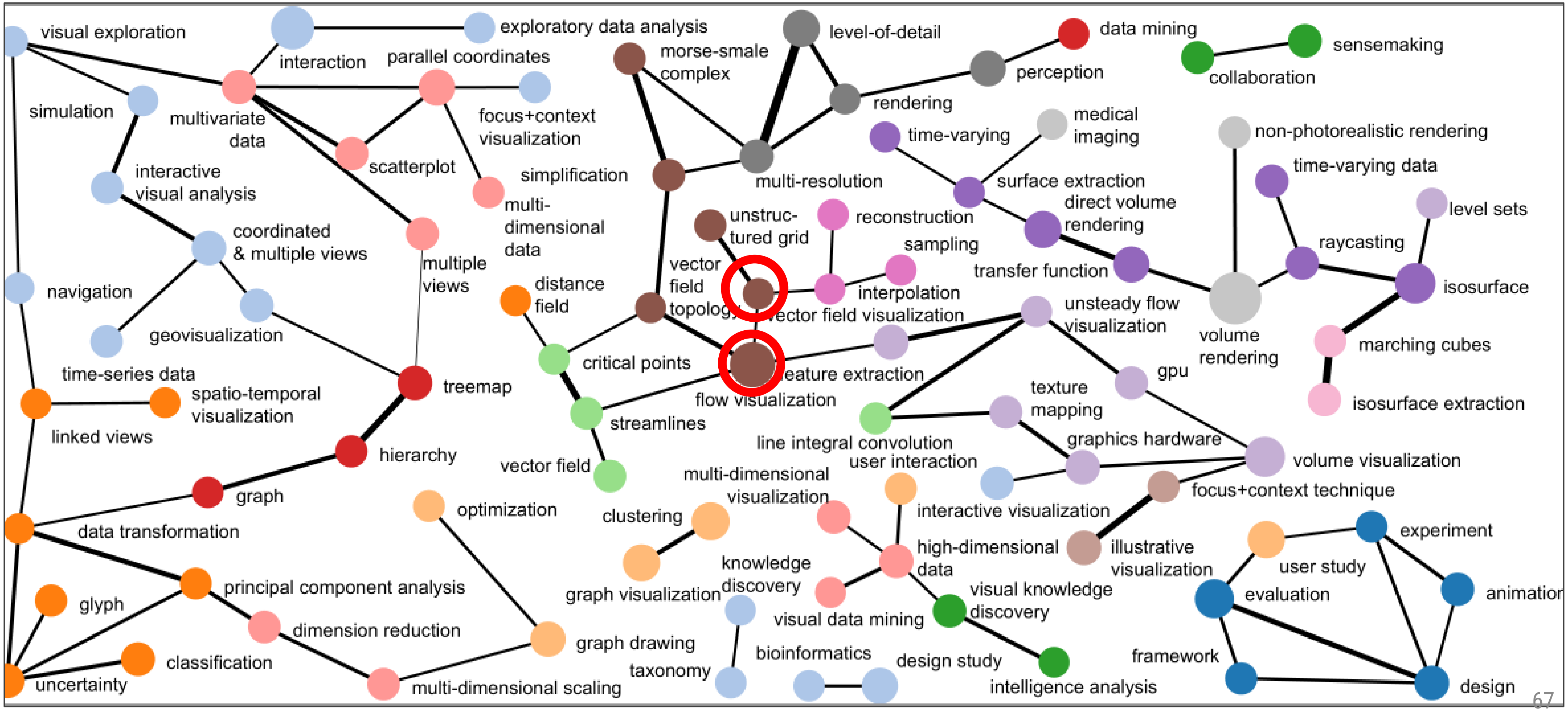
	user interfa	user study	vector field	vector field	vector field	virtual realit	visual analy	visual data i	visual explo	visual know
distance fie	-0.00777	-0.00842	-0.00582	[illegible]	-0.00484	-0.00604	-0.00582	-0.00456	-0.00456	-0.00626
evaluation	-0.01637	0.147804	-0.01227	[illegible]	-0.0102	0.078886	-0.01227	-0.00961	-0.00961	-0.01319
experiment	-0.00869	0.113584	-0.00651	[illegible]	-0.00541	0.078334	-0.00651	-0.0051	-0.0051	-0.007
exploratory	0.061902	-0.00894	-0.00618	[illegible]	-0.00513	-0.00641	-0.00618	-0.00484	-0.00484	-0.00664
feature extr	0.034879	-0.01337	-0.00924	[illegible]	0.067477	-0.00959	-0.00924	-0.00724	-0.00724	-0.00993
flow visuali	[illegible]	[illegible]	[illegible]	[illegible]	0.110634	-0.01779	-0.01714	-0.01343	-0.01343	-0.01842
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.00842	-0.01052	0.047084	-0.00794	-0.00794	-0.01089
[illegible]	[illegible]	[illegible]	[illegible]	-0.00535	-0.00568	-0.00709	-0.00683	-0.00535	-0.00535	-0.00734
focus+conte	-0.00869	-0.00942	-0.00651	-0.0051	-0.00541	-0.00676	-0.00651	-0.0051	-0.0051	-0.007
framework	-0.00912	-0.00989	-0.00683	-0.00535	-0.00568	-0.00709	-0.00683	-0.00535	-0.00535	-0.00734
geovisualiza	-0.01066	-0.01156	-0.00799	-0.00626	-0.00664	-0.00829	-0.00799	-0.00626	-0.00626	-0.00859
glyph	-0.00912	-0.00989	-0.00683	-0.00535	-0.00568	-0.00709	-0.00683	-0.00535	-0.00535	-0.00734
gpu	-0.01029	-0.01116	-0.00772	-0.00604	0.08326	-0.00801	-0.00772	-0.00604	-0.00604	-0.00829
graph	-0.00824	-0.00894	-0.00618	-0.00484	-0.00513	-0.00641	-0.00618	-0.00484	-0.00484	-0.00664
graph draw	-0.01232	-0.01337	-0.00924	-0.00724	-0.00768	-0.00959	-0.00924	-0.00724	-0.00724	-0.00993
graph layou	-0.00912	0.048772	-0.00683	-0.00535	-0.00568	-0.00709	-0.00683	-0.00535	-0.00535	-0.00734
graph visua	-0.01435	-0.01556	-0.01075	-0.00842	-0.00894	0.040876	-0.01075	-0.00842	-0.00842	-0.01156
graphics ha	-0.01168	-0.01267	-0.00876	-0.00686	0.071895	-0.00909	-0.00876	-0.00686	-0.00686	-0.00941
hardware a	-0.00912	-0.00989	-0.00683	-0.00535	-0.00568	-0.00709	-0.00683	-0.00535	-0.00535	-0.00734
hierarchy	-0.00912	-0.00989	-0.00683	-0.00535	-0.00568	-0.00709	-0.00683	-0.00535	-0.00535	-0.00734
high-dimen	0.090955	-0.01231	0.059335	-0.00667	-0.00707	-0.00883	-0.00851	0.166059	-0.00667	0.117247
human-con	0.046027	-0.01116	-0.00772	-0.00604	-0.00641	-0.00801	-0.00772	-0.00604	-0.00604	0.061287

Co-Word Analysis

3. Clustering (filtered)

Co-Word Analysis

4. Keyword Network (filtered)

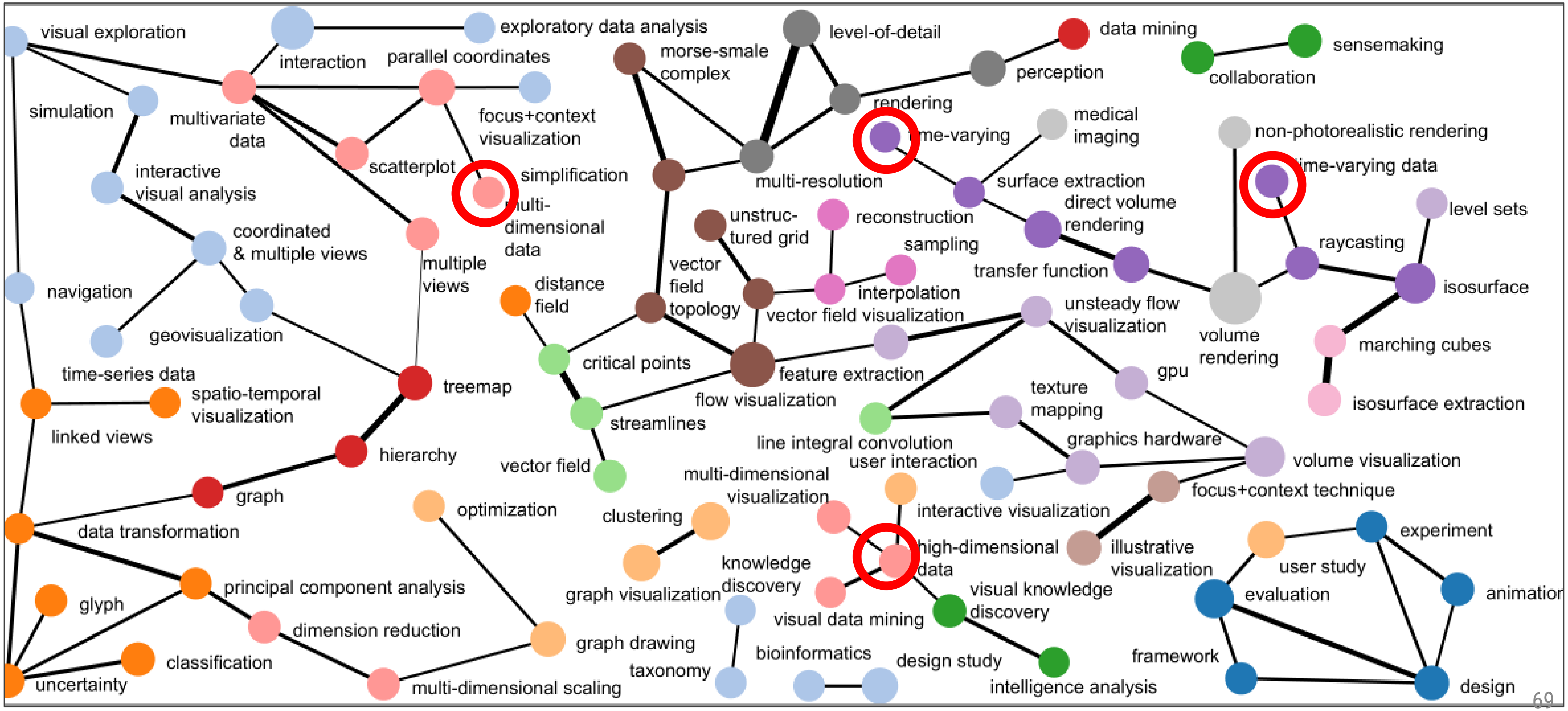


why topic coding?

ID	Keywords	Size	F	CW-F	Cohesion	Centr.	Density
B1	***mobile phone***, **sustainability**, ***ethnography***, online communities, HCI4D/ICTD, health, persuasive technology, motivation, *user-centered design*, behavior change, community	11	30.09	30.27	0.358	0.899	1.036
B2	***ubiquitous computing***, ***privacy***, **mobile**, *augmented reality*, wearable computing, *field study*, *mobile computing*, context-aware, *navigation*, *haptic*, large displays, human-robot interaction, music, computer vision, GPS, feedback, mobile interaction	17	26.94	28.58	0.416	1.064	0.654
B3	***visualization***, ***collaboration***, ***user interface***, wikis, *social computing*, tagging, *annotation*, personal information management	8	30.62	35.5	0.516	0.866	1.393
B4	***mobile/handheld devices***, ***gestures***, ***Fitts' Law***, touch screens, text entry, pointing, touch	7	36	43.71	0.470	0.631	3.619
B5	***computer-mediated communication***, ***computer supported cooperative work***, ***eye tracking***, communication, *empirical study*, *trust*, *videoconferencing*	7	30.71	36	0.496	0.722	2.048
B6	***user studies***, ***interaction techniques***, **web search**, *input devices*, personalization	5	26.4	28.2	0.442	0.642	1.500
B7	***design***, **games**, ***usability***, user experience, older adults, accessibility, memory	7	30.14	32.14	0.368	0.790	1.476
B8	***children***, ***tangible user interface***, **multi-touch**, *education*, tabletop, *learning*	6	34	44.16	0.551	0.748	3.333
B9	***evaluation***, ***information visualization***, ***interaction design***, *participatory design*, assistive technology, *Methodology*, design methods, creativity, *prototypes*, Security, *end-user programming*	11	25.63	27	0.419	0.842	0.855
B10	**social networks**, **SNS**, **social media**, twitter, Facebook	5	25.6	34	0.705	0.453	3.700
B11	**crowdsourcing**, **human computation**	2	23	25.5	0.533	0.268	7.000
B12	***awareness***, ***video***, **families**, coordination	4	19	23.5	0.690	0.449	2.167
B13	**multitasking**, **attention**, **interruption**	3	25.33	31	0.656	0.293	9.000
B14	**emotion**, **affect**	2	18	24.5	0.792	0.236	6.000

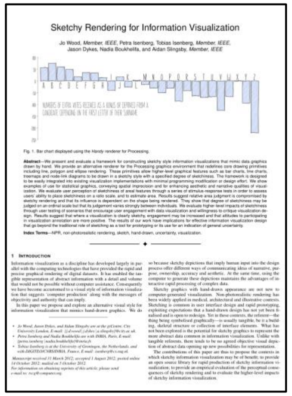
Table 2. Major research themes in HCI during 2004-2013 (size, frequency (F), co-word frequency (CW-F), cohesion, centrality (Centr.), density)

why topic coding?



Topic Coding

1. Initial coding: 2004-2013 data (10 years), freely evolving code-set, 5 coders
2. Clustering: refining of topics with automatic and manual clustering
   → 156 unique topics
3. Consolidation: 2-day workshop, PCS keywords vs. our topics, higher-level category coding
   → 210 unique topics
4. Refining: Assign all 3952 keywords a topic, collection of problems, ambiguities etc.
5. Re-coding: all keywords recoded with new code-set, 2 coders per keyword
6. Fine-tuning: remote meeting, looking at frequencies
   → 180 topics, 14 categories



authors

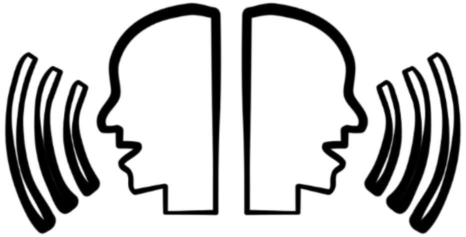
situate

taxonomy of key terms in visualization

rank expertise

reviewers

communication



RESEARCH METHODS

RESEARCH CONTRIBUTIONS

APPLICATIONS

HISTORY

TAXONOMIES

Assumptions

- keywords come from a somewhat finite and codified repository of domain terms
- used together to propose non-trivial relationships
- the proposal of the same relationship by different authors is informative

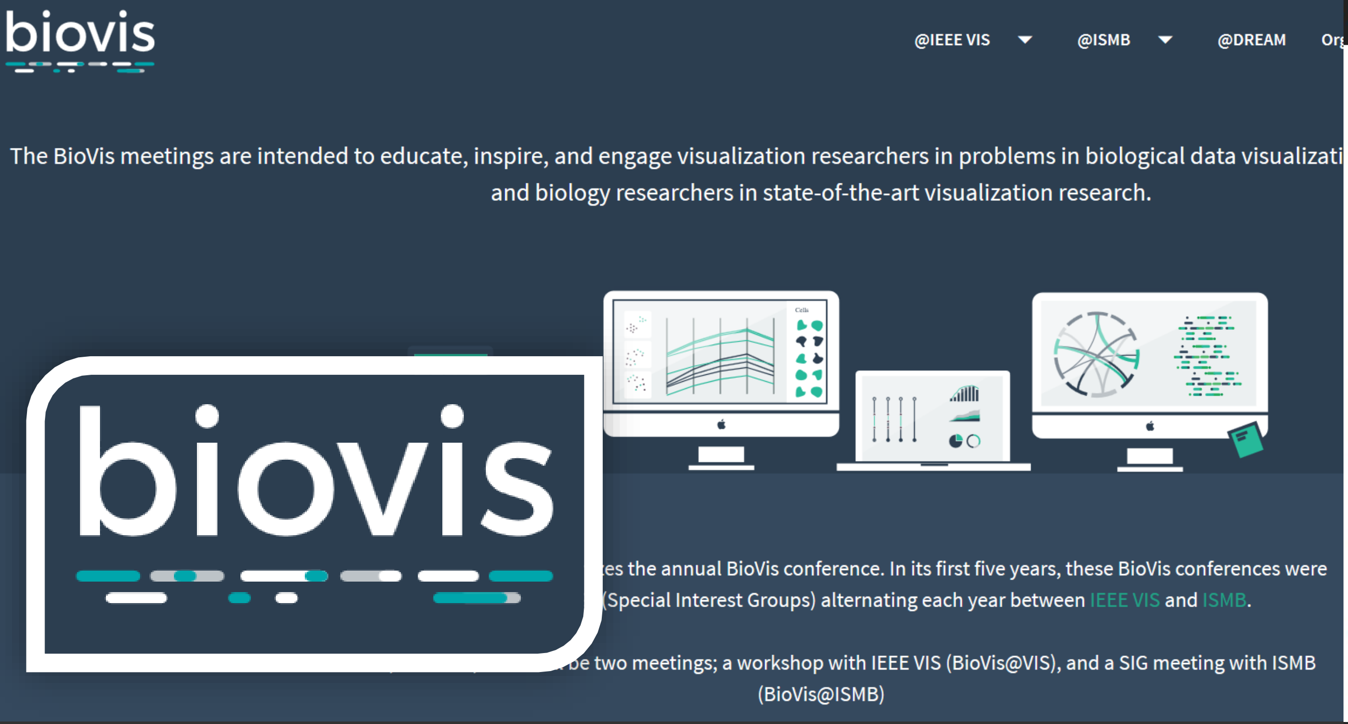
author keywords

author topics

PCS keywords

CO-WORD ANALYSIS

(analyze correlations between keywords)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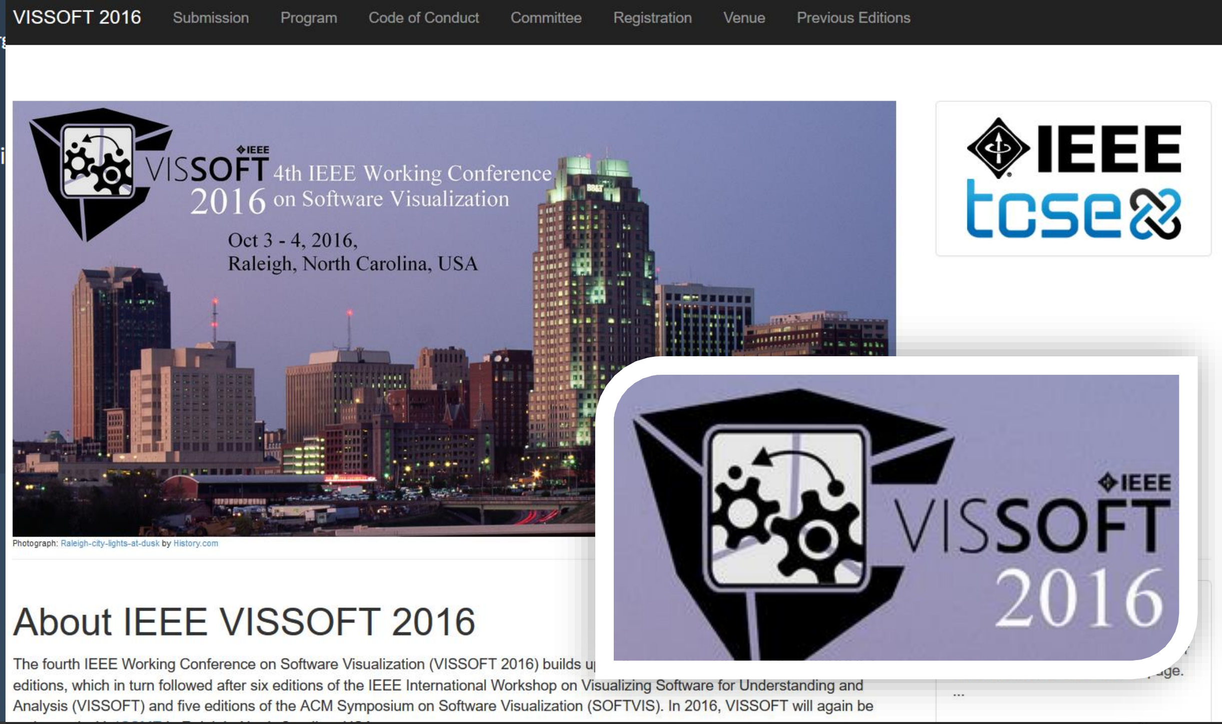
@IEEE VIS
@ISMB
@DREAM
The BioVis meetings are intended to educate, inspire, and engage visualization researchers in problems in biological data visualizati
and biology researchers in state-of-the-art visualization research.
biovis
es the annual BioVis conference. In its first five years, these BioVis conferences were
(Special Interest Groups) alternating each year between IEEE VIS and ISMB.
be two meetings; a workshop with IEEE VIS (BioVis@VIS), and a SIG meeting with ISMB
(BioVis@ISMB)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2016
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editions, which in turn followed after six editions of the IEEE International Workshop on Visualizing Software for Understanding and
Analysis (VISSOFT) and five editions of the ACM Symposium on Software Visualization (SOFTVIS). In 2016, VISSOFT will again be


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Guide for contributors
Image Contest
Welcome to VCBM & MedViz 2016!
In Sept. 2016, the annual MedViz conference and the Eurographics Workshop on Visual Computing for Biology and Medicine (EG VCBM) are coming together and form a joint, interdisciplinary meeting of experts from technology, medicine, biology, and related fields.
MedViz has one impressive decade of exciting experiences from annually assembling more than 100 technologists and physicians from Bergen, Norway, and from abroad for the MedViz conference. During Sept. 7-9, the MedViz Conference comes together with the 6th edition of the Eurographics Workshop on Visual Computing for Biology and Medicine (VCBM). VCBM was first organized in 2008 in Delft, The Netherlands, then becoming a very successful series of events, happening again in 2010 in Leipzig, Germany, then in 2012 in Norrköping, Sweden, and then in 2014 in Vienna, Austria. Due to its increased success, VCBM was then improved into an annual event—organized in 2015 in Chester, UK, before then coming to Bergen, Norway, in 2016.
VCBM & MEDVIZ
2016

SPECIFIC NAMING VS. GENERALITY

IEEE terms

rendering (CG)
computer graphics
visual analytics
computational modeling
data mining

INSPEC controlled

rendering (CG)
data analysis
computational geometry
interactive systems
medical image processing