What Is Visualization?

Torsten Möller
Graphics, Usability, and Visualization Lab
Simon Fraser University

Acknowledgements

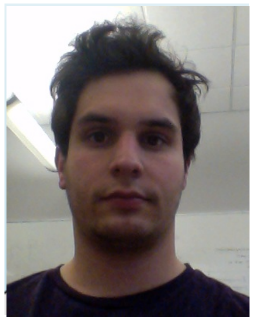
Melanie Tory
U Victoria

Hans-Christian Hege
Zuse I Berlin

Tamara Munzner
UBC

Maryam Booshehrian

Alireza Ghane

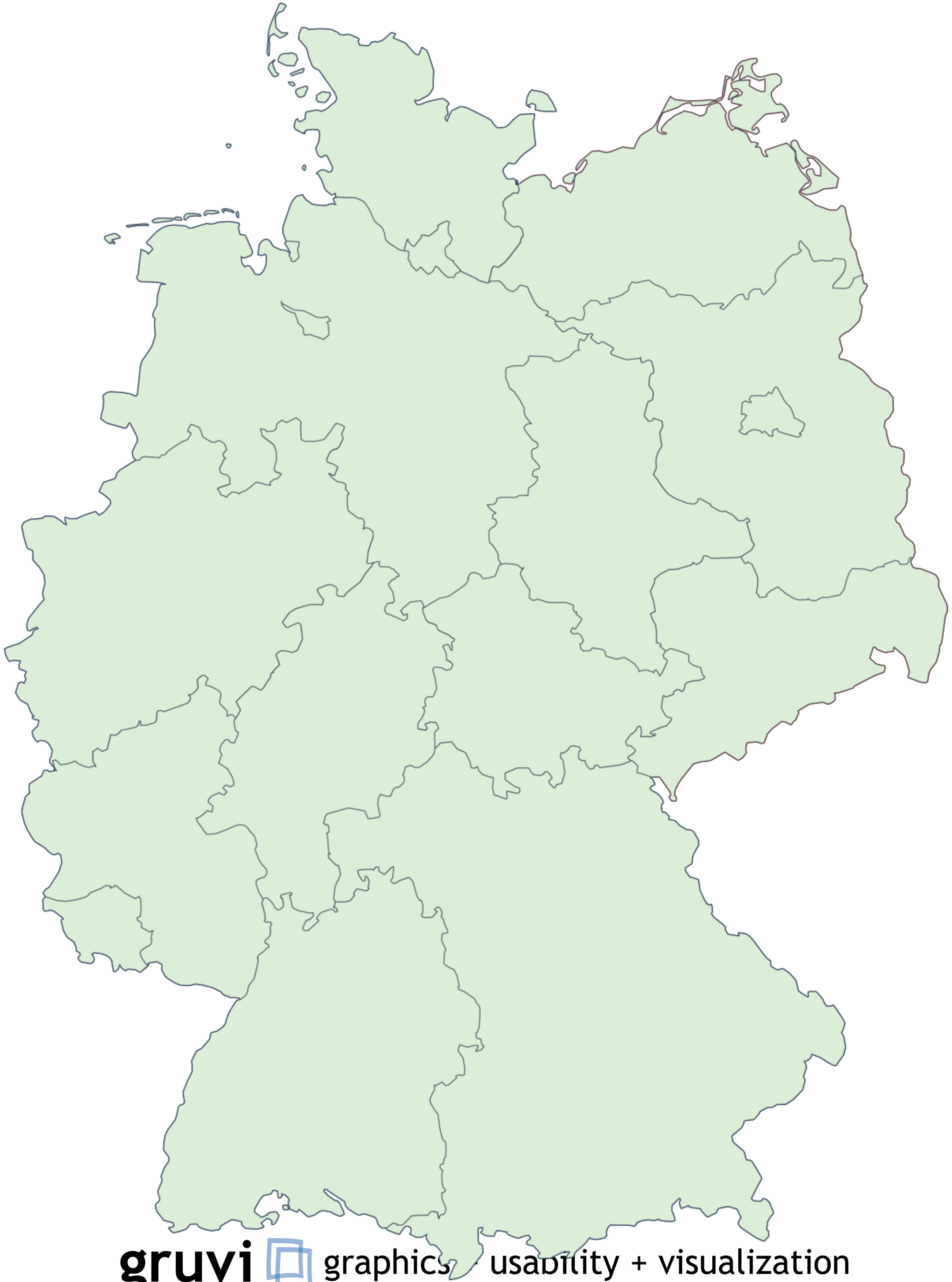


Joshua Horacsek

Mohsen Kamalzadeh

Mike Phillips

Thomas-Torsney Weir



Academic Definitions of Visualization

Vis timeline

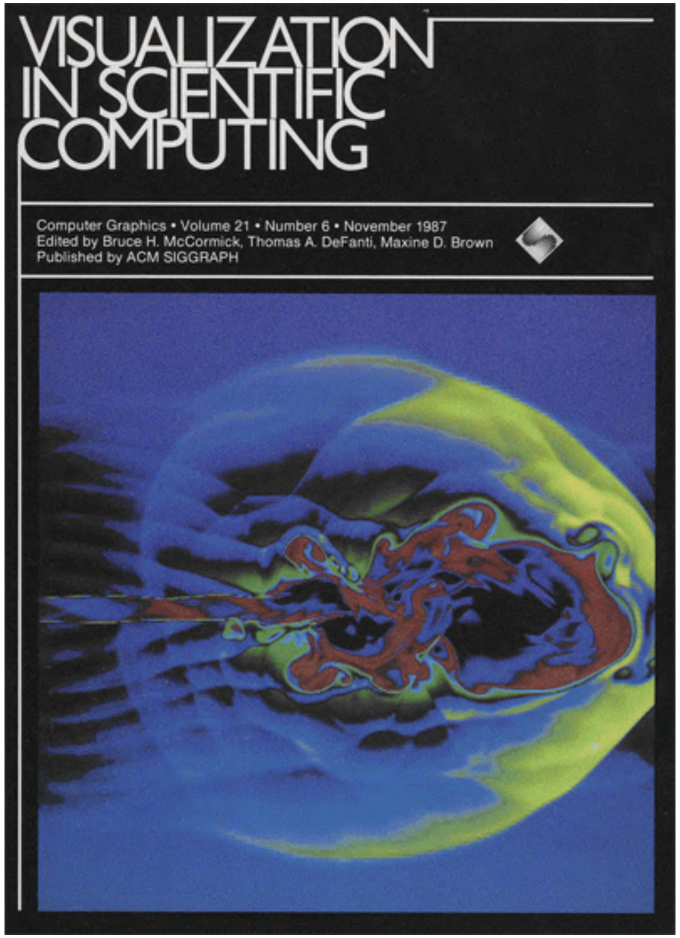
Early 1987

Bertin NSF
Tukey
Cleveland

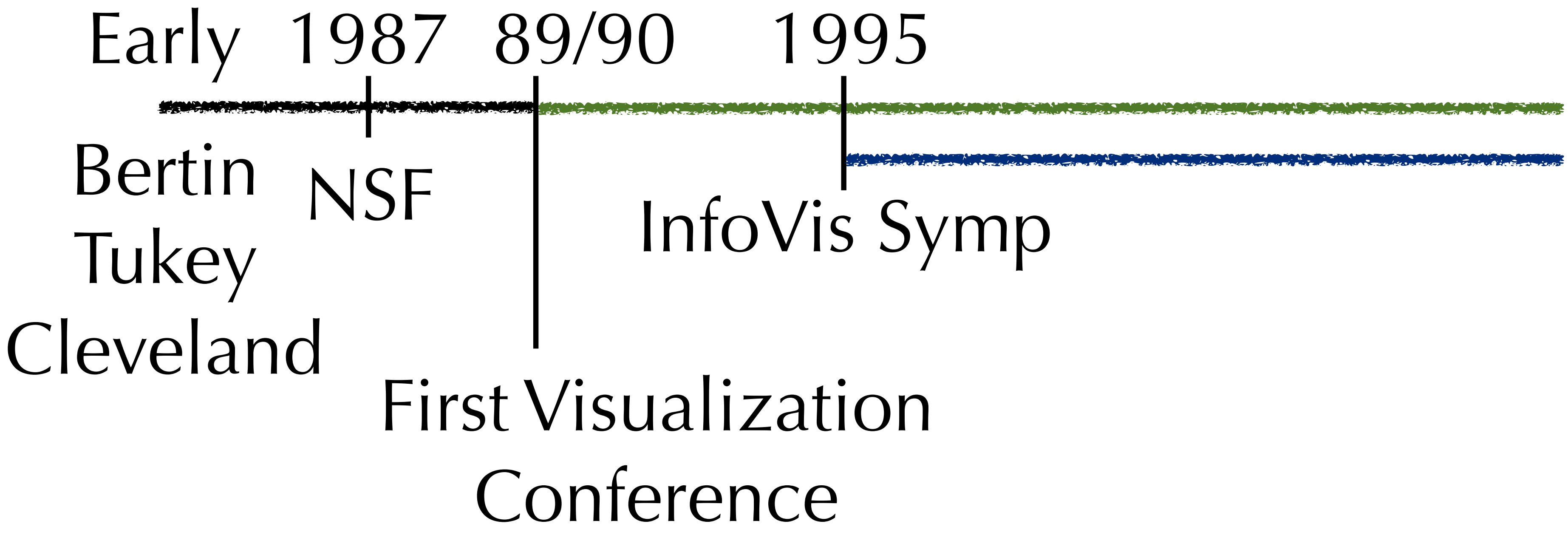
NSF Panel 1987

McCormick, DeFanti, Brown:

"Visualization is a method of computing. It **transforms the symbolic into the geometric**, enabling researchers to observe their simulations and computations. Visualization offers a method for **seeing the unseen**. ... It studies those mechanisms in **humans and computers** which allow them in concert to perceive, use and communicate visual information."

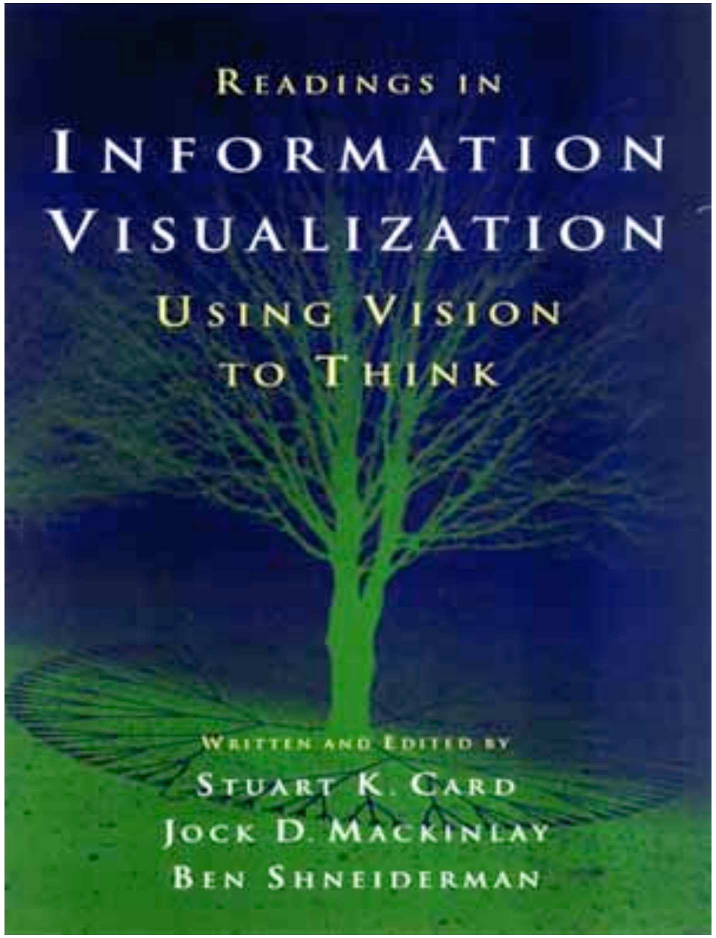


Vis timeline



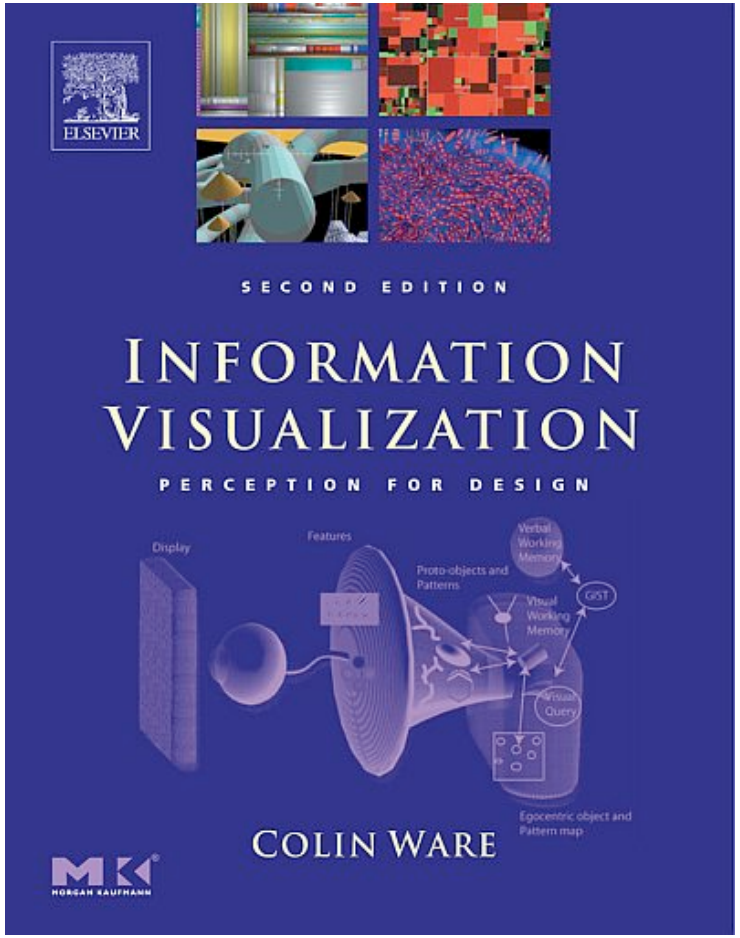
Card, MacKinlay, Shneiderman 1999

"[Information / Scientific] Visualization ... the use of computer-supported, interactive, visual representations of [abstract/scientific] data to amplify cognition."

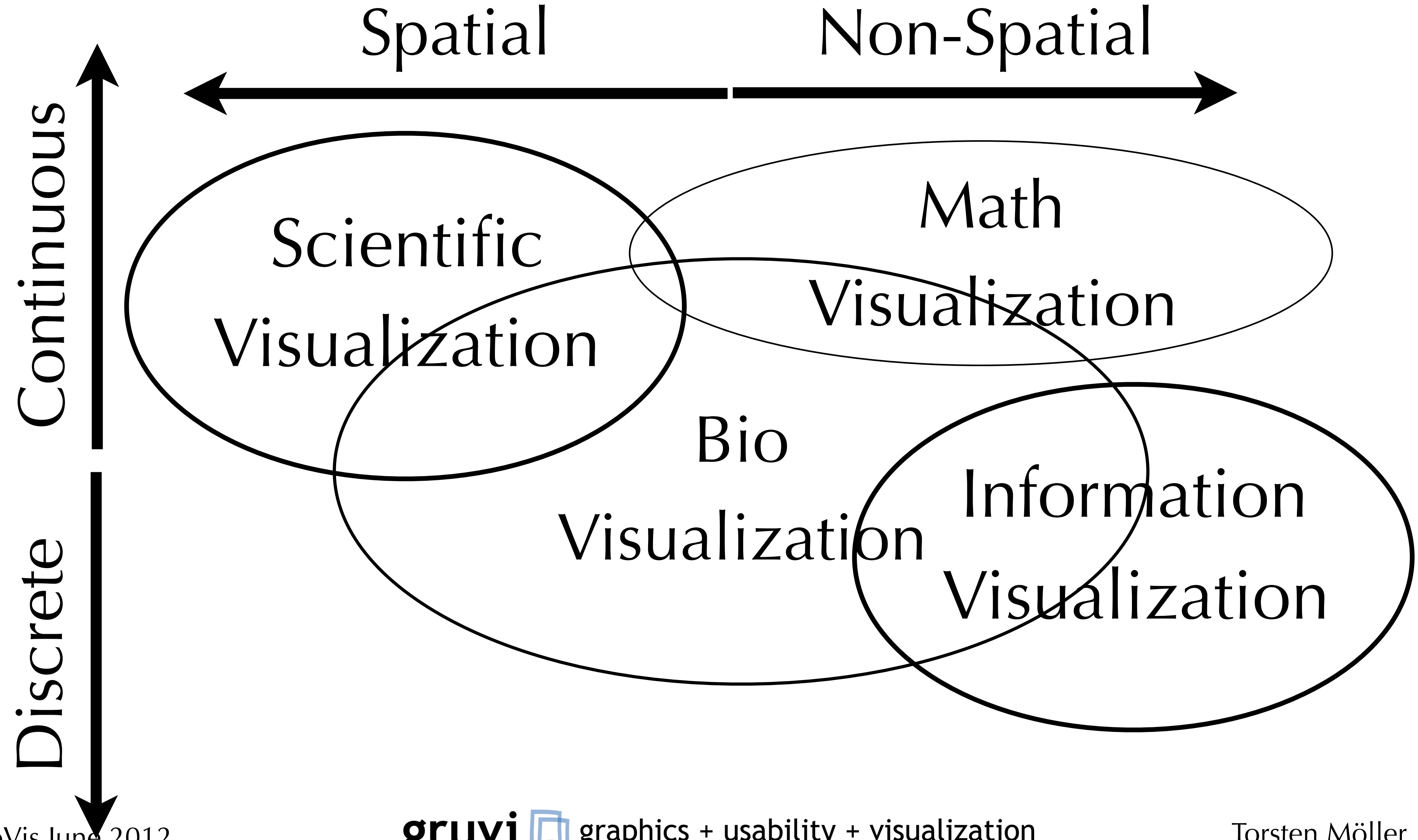


Ware 2004

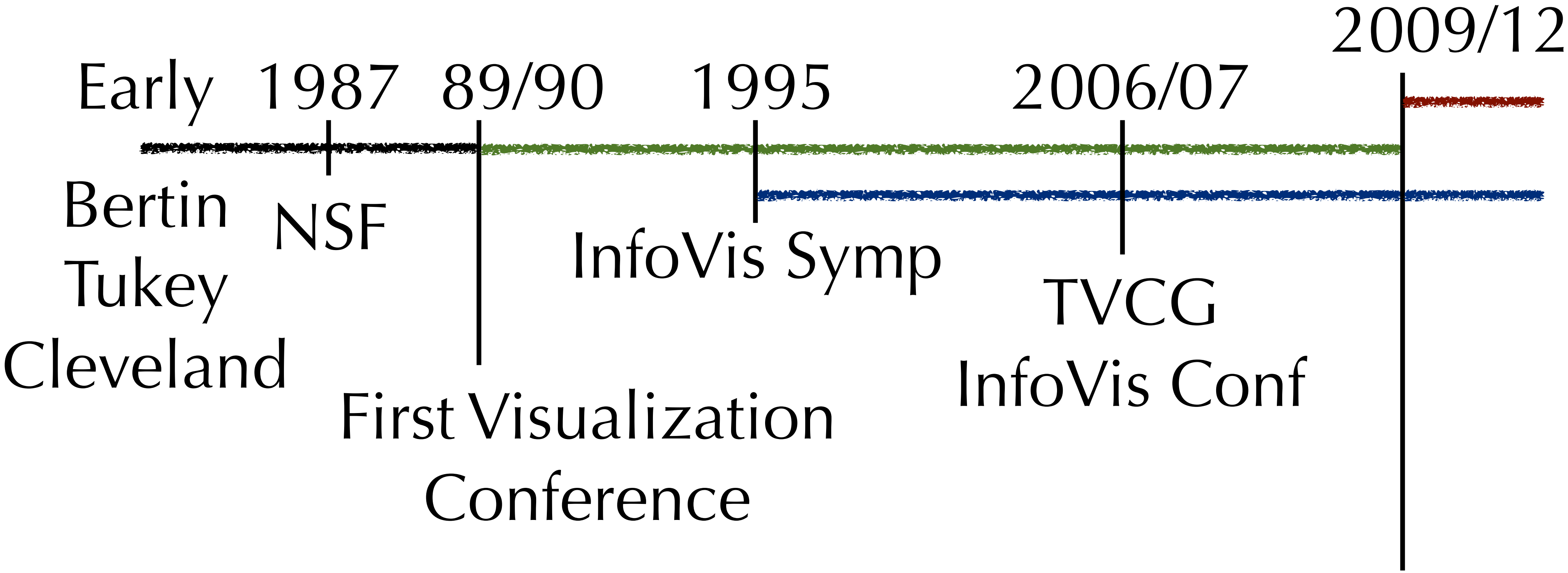
"**Information visualization** ... is the use of interactive visual representations of **abstract data** to amplify cognition"



Tory & Möller 2004



Vis timeline



2009 - CFP essentially the same, distinction on data type

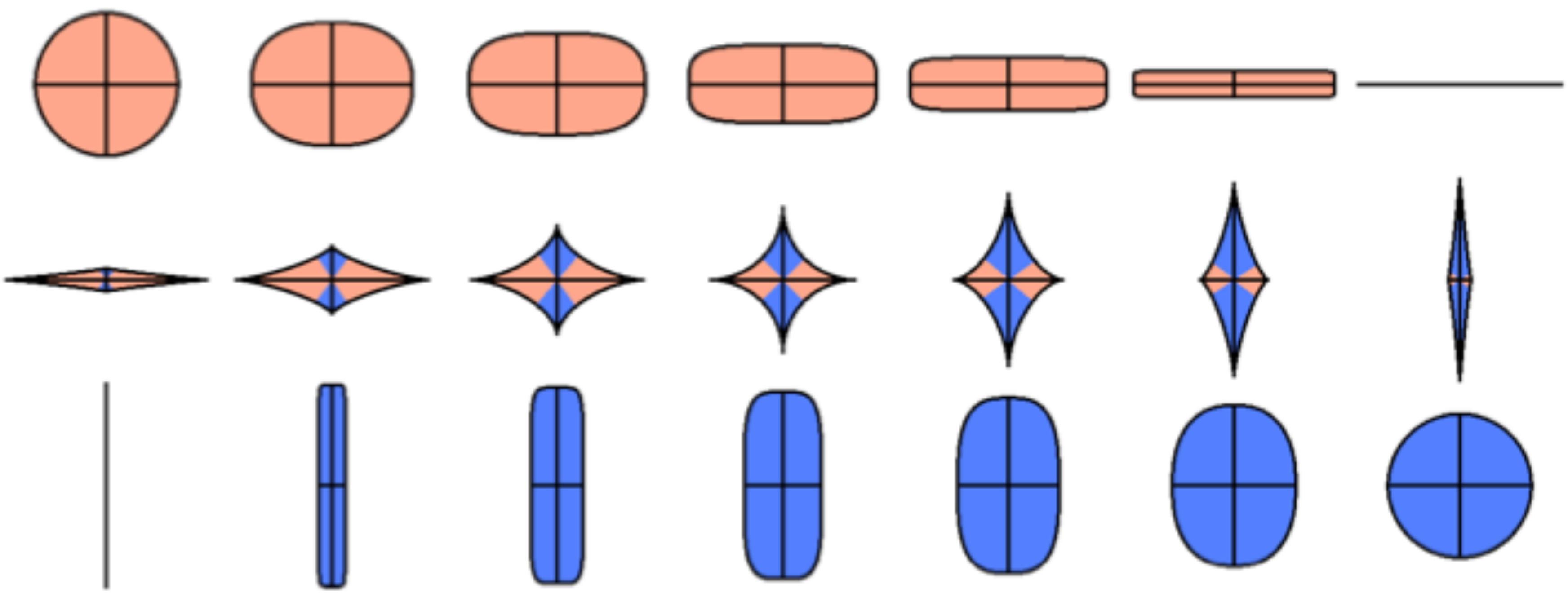
2012 - name SciVis / InfoVis

Thesis 1

The academic definitions of FooVis and BarVis do not accurately reflect their use inside or outside of our community.

Superquadric Glyphs for Symmetric Second-Order Tensors

Thomas Schultz and Gordon L. Kindlmann



1

In t… pla… ing all its degrees of freedom onto the shape and appearance of some base geometry [47]. Even though glyphs alone rarely provide a self-contained answer to a scientific question, they can help build understanding and intuition about scientific data and the patterns within it. When inspecting empirically measured data, glyphs allow one to visually evaluate data quality and detect measurement artifacts. Glyphs can also provide a useful reference point for understanding tensor data when creating new tensor visualization methods. Tensors also arise as ingredients in scalar and vector field analysis algorithms, where glyphs can help to monitor the progress and outcome of the analysis.

… alge- … ion 2, we aim to make it as transparent as possible what these constraints are and which additional design goals we follow. After reviewing previous work in Section 3, our new method is described in Section 4 and justified carefully with respect to these high-level goals. To confirm that our glyphs can be used in a wide variety of contexts, Section 5 presents results from various applications.

2 Tensor Algebra and Glyph Design

A symmetric second-order tensor $\mathbf{D}$ can be decomposed into real eigenvalues λ_i ($\lambda_1 \geq \lambda_2 \geq \lambda_3$) and corresponding orthonormal eigen-

Visual Exploration of High Dimensional Scalar Functions

Samuel Gerber, Peer-Timo Bremer, Valerio Pascucci, and Ross Whitaker

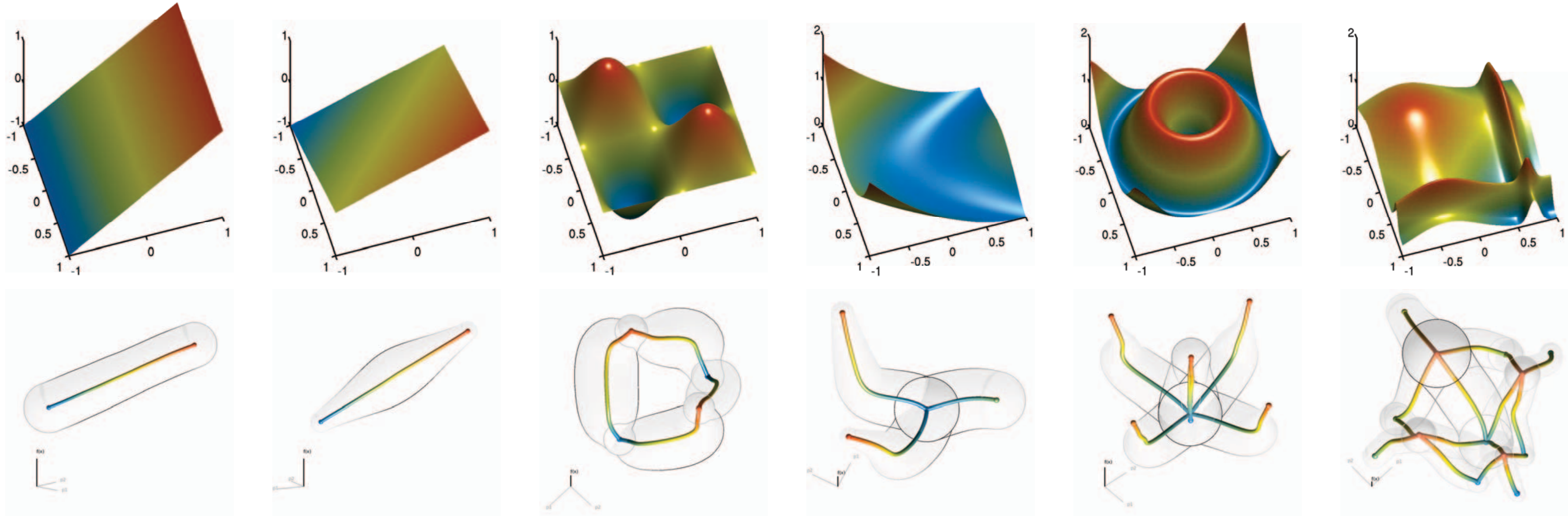


Fig. 1. The proposed visualization illustrated on several two-dimensional scalar fields. In the bottom row, each curve represents a monotonic region of the 2D domain, a geometric summary for each crystal of the Morse-Smale complex of the function above.

Abstract—An important goal of scientific data analysis is to understand the behavior of a system or process based on a sample of the system. In many instances it is possible to observe both input parameters and system outputs, and characterize the system as a high-dimensional function. Such data sets arise, for instance, in large numerical simulations, as energy landscapes in optimization problems, or in the analysis of image data relating to biological or medical parameters. This paper proposes an approach to analyze and visualizing such data sets. The proposed method combines topological and geometric techniques to provide interactive visualizations of discretely sampled high-dimensional scalar fields. The method relies on a segmentation of the parameter space using an approximate Morse-Smale complex on the cloud of point samples. For each crystal of the Morse-Smale complex, a regression of the system parameters with respect to the output yields a curve in the parameter space. The result is a simplified geometric representation of the Morse-Smale complex in the high dimensional input domain. Finally, the geometric representation is embedded in 2D, using dimension reduction, to provide a visualization platform. The geometric properties of the regression curves enable the visualization of additional information about each crystal such as local and global shape, width, length, and sampling densities. The method is illustrated on several synthetic examples of two dimensional functions. Two use cases, using data sets from the UCI machine learning repository, demonstrate the utility of the proposed approach on real data. Finally, in collaboration with domain experts the proposed method is applied to two scientific challenges. The analysis of parameters of climate simulations and their relationship to predicted

Evaluating Information Visualizations

Sheelagh Carpendale

Department of Computer Science, University of Calgary,
2500 University Dr. NW, Calgary, AB, Canada T2N 1N4
sheelagh@ucalgary.ca

1 Introduction

Information visualization research is becoming more established, and as a result, it is becoming increasingly important that research in this field is validated. With the general increase in information visualization research there has also been an increase, albeit disproportionately small, in the amount of empirical work directly focused on information visualization. The purpose of this paper is to increase awareness of empirical research in general, of its relationship to information visualization in particular; to emphasize its importance; and to encourage thoughtful application of a greater variety of evaluative research methodologies in information visualization.

One reason that it may be important to discuss the evaluation of information visualization, in general, is that it has been suggested that current evaluations are not convincing enough to encourage widespread adoption of information visualization tools

Eurographics/ IEEE-VGTC Symposium on Visualization 2008
A. Vilanova, A. Telea, G. Scheuermann, and T. Möller
(Guest Editors)

Volume 27 (*2008*), *Number 3*

Interactive Exploratory Visualization of 2D Vector Fields

Tobias Isenberg[1,2] Maarten H. Everts[1] Jens Grubert[2] Sheelagh Carpendale[2]

[1]University of Groningen, The Netherlands [2]University of Calgary, Canada

Abstract

In this paper we present several techniques to interactively explore representations of 2D vector fields. Through a set of simple hand postures used on large, touch-sensitive displays, our approach allows individuals to custom-design glyphs (arrows, lines, etc.) that best reveal patterns of the underlying dataset. Interactive exploration of vector fields is facilitated through freedom of glyph placement, glyph density control, and animation. The custom glyphs can be applied individually to probe specific areas of the data but can also be applied in groups to explore larger regions of a vector field. Re-positionable sources from which glyphs—animated according to the local vector field—continue to emerge are used to examine the vector field dynamically. The combination of these techniques results in an engaging visualization with which the user can rapidly explore and analyze varying types of 2D vector fields, using a virtually infinite number of custom-designed glyphs.

Categories and Subject Descriptors (according to ACM CCS): I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction techniques; I.3.m [Computer Graphics]: Miscellaneous—Visualization

1. Introduction

Vector field data arises in many scientific and technical

best able to reveal data properties and supports interactive distribution of these glyphs. This combination of custom-

Process and Pitfalls in Writing Information Visualization Research Papers

Tamara Munzner

University of British Columbia
tmm@cs.ubc.ca, http://www.cs.ubc.ca/~tmm

Abstract. The goal of this paper is to help authors recognize and avoid a set of pitfalls that recur in many rejected information visualization papers, using a chronological model of the research process. Selecting a target paper type in the initial stage can avert an inappropriate choice of validation methods. Pitfalls involving the design of a visual encoding may occur during the middle stages of a project. In a later stage when the bulk of the research is finished and the paper writeup begins, the possible pitfalls are strategic choices for the content and structure of the paper as a whole, tactical problems localized to specific sections, and unconvincing ways to present the results. Final-stage pitfalls of writing style can be checked after a full paper draft exists, and the last set of problems pertain to submission.

1 Introduction

Many rejected information visualization research papers have similar flaws. In this paper, I categorize these common pitfalls in the context of stages of the research process. My main goal is to help authors escape these pitfalls, especially graduate students or those new to the field of information visualization.

Example - PostDoc ad

Fellowship in **Information Visualisation** for the Biological Sciences, University of YVZ

We are looking for an exceptional Senior Research Fellow to oversee the creation and management of **3D visualisation** solutions across the 2020 Science research programme. ... The postholder will be expected to design and implement a visualisation strategy across the programme to determine where visualisation solutions would be most appropriate and the form they might take.

We will consider candidates from various **backgrounds**, but all must be able to give evidence of their ability to produce outstanding and novel **scientific visualisations** and communicate their work effectively to a diverse mix of academics and scientists. Applicants should have a degree or PhD in a relevant area (e.g. Information Design, **Computational Science**, **Mathematical or Computational Biology**, **Applied Mathematics**, or Computer Science) coupled with an excellent portfolio of research in visualisation or information design.

Thesis 2

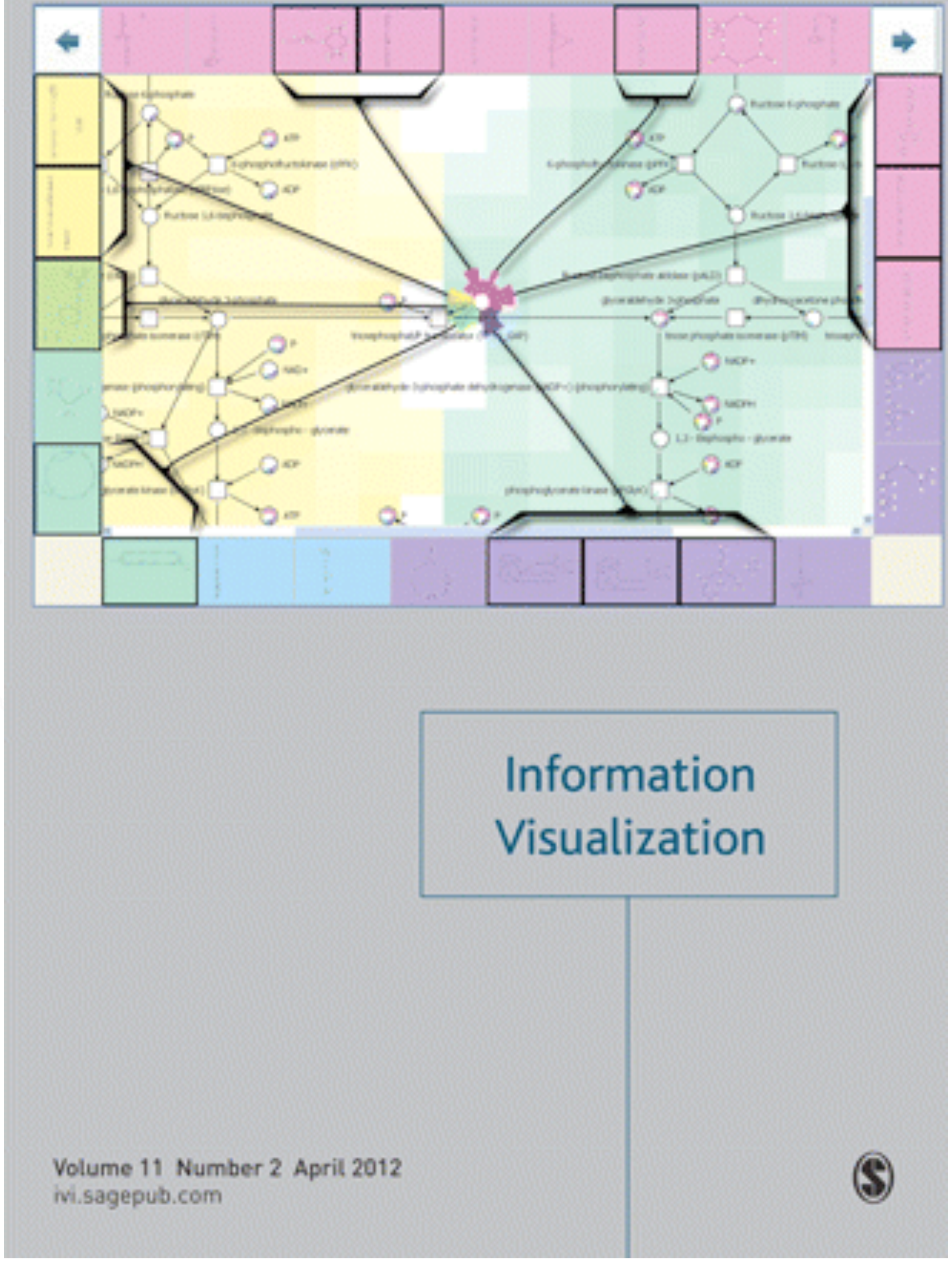
Our community enjoys a strong separation of FooVis and BarVis, and real animosities exist.


IEEE TRANSACTIONS ON
VISUALIZATION AND COMPUTER GRAPHICS
A publication of the IEEE Computer Society

NOVEMBER/DECEMBER 2004 VOLUME 10 NUMBER 6 ITVGEA (ISSN 1077-2626)

PAPERS

IEEE COMPUTER SOCIETY
http://www.computer.org
tvcg@computer.org
IEEE



SciVis Papers

CALL FOR PARTICIPATION: SciVis Papers

IEEE VisWeek 2012 is the premier forum for visualization advances for academia, government, and industry. This event brings together researchers and practitioners with a shared interest in visualization techniques, tools, and technology. The **IEEE Scientific Visualization Conference** solicits novel research ideas and innovative applications in all areas of visualization. Please carefully read the submission guidelines below, especially pertaining to submission

InfoVis Papers

CALL FOR PARTICIPATION: InfoVis Papers

IEEE VisWeek 2012 is the premier forum for visualization advances for academia, government, and industry. This event brings together researchers and practitioners with a shared interest in visualization techniques, tools, and technology. The **IEEE Information Visualization Conference** solicits novel research ideas and innovative applications in all areas of information visualization. Please carefully read the submission guidelines below, especially pertaining to

Seminar 14231, 01.06.14 - 06.06.14

DAG **Scientific Visualization**

Min Chen (University of Oxford, GB), Charles D. Hansen (University of Utah - Salt Lake City, US), Penny Rheingans (University of Maryland Baltimore County, US), Gerik Scheuermann (Universität Leipzig, DE)

Seminar 13201, 12.05.13 - 17.05.13

DAG **Information Visualization - Towards Multivariate Network Visualization**

Andreas Kerren (Linnaeus University - Växjö, SE), Helen C. Purchase (University of Glasgow, GB), Matthew Ward (Worcester Polytechnic Institute, US)

Sessions » Panels

» **Monday, 4:15PM - 5:55PM**

Grand Challenges for Information Visualization

Panelists: Georges Grinstein, Daniel Keim, Tamara Munzner

This panel will address the state of information visualization by providing a very brief history of the milestones. Various definitions of what a grand challenge is will be discussed. The results of the informal (not statistically valid) poll held to define and evolve a set of grand problems and challenges for information visualization will be presented. Well over 200 visualization researchers were contacted. This resulted in an overwhelming response with many enthused about the activity. The results have been sifted through, collated, organized, prioritized and

Panel 4

What Should We Teach in a Scientific Visualization Class?

Chair: Jon Genetti (University of Alaska Fairbanks)

Panelists:

Mike J. Bailey (Oregon State University)
Jon D. Genetti (University of Alaska Fairbanks)
David H. Laidlaw (Brown University)
Robert J. Moorhead (Mississippi State University)
Ross T. Whitaker (University of Utah)

Scientific Visualization has evolved past the point where one undergraduate course can

Political / Personalities

- Personal communication:
  - "BarVis is not a real science"
  - "FooVis is just a tiny niche area, not relevant for the bigger picture"
- Political power struggle about influence (steering committees, VGTC)

"Lieber das halbe Deutschland ganz als das ganze Deutschland halb."

"Better to control half of Germany fully than all of Germany partially."

Konrad Adenauer (1876-1967)
First (West) German Chancellor

What is so special about a data modality?

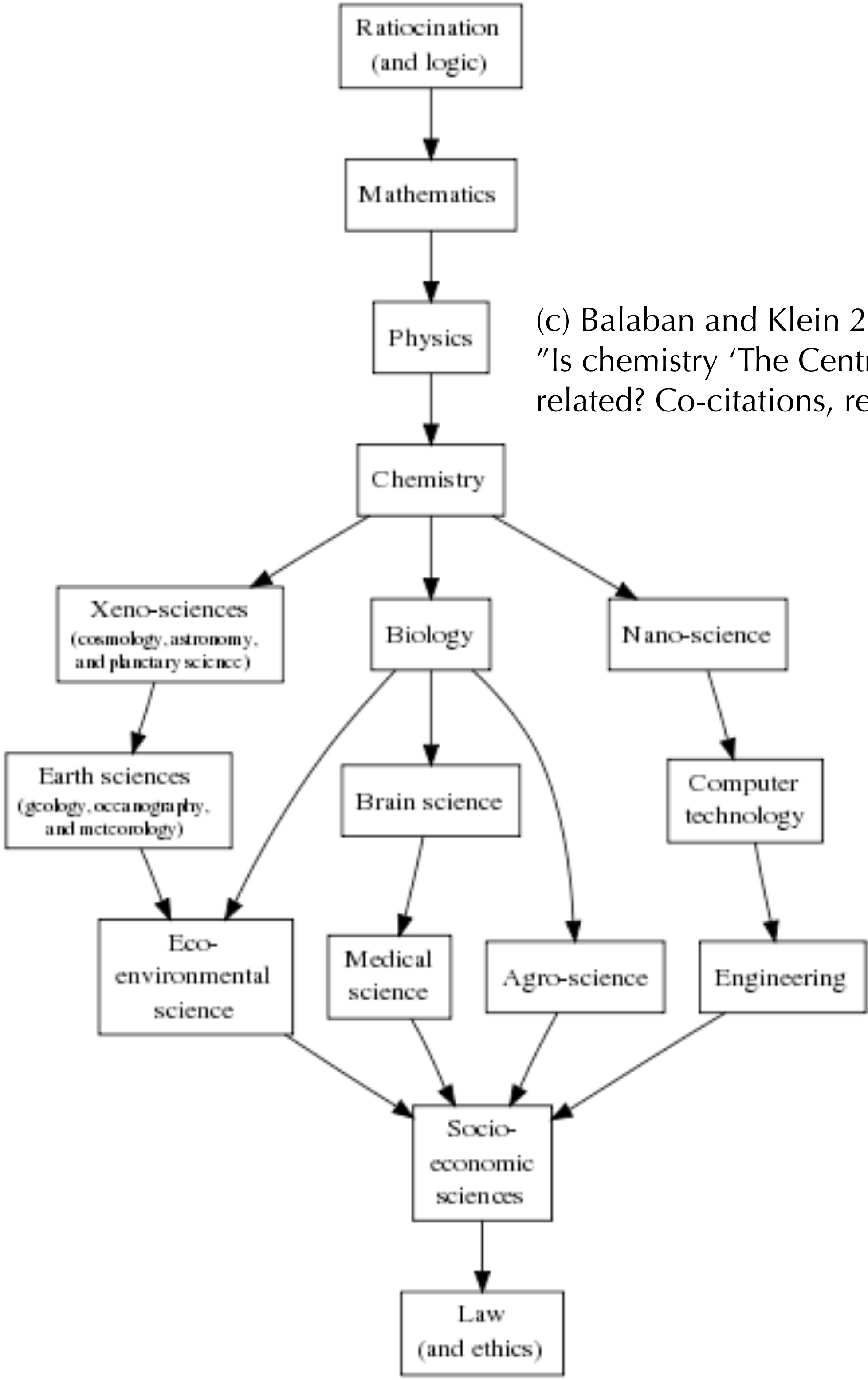
- Thesis 1: Academic definitions based on data modality do not reflect real use
- Thesis 2: There is a great ideological divide
- What is it about?

Main thesis

The difference of FooVis vs. BarVis is anchored in the different scientific approach being taken - one is about **mathematical modeling and reasoning** (based on natural/hard science) while the other is about an **human-centered modeling and reasoning** (based on social/ soft science).

Evidence 1
hard vs. soft sciences

Auguste Compte (1798 -- 1857)

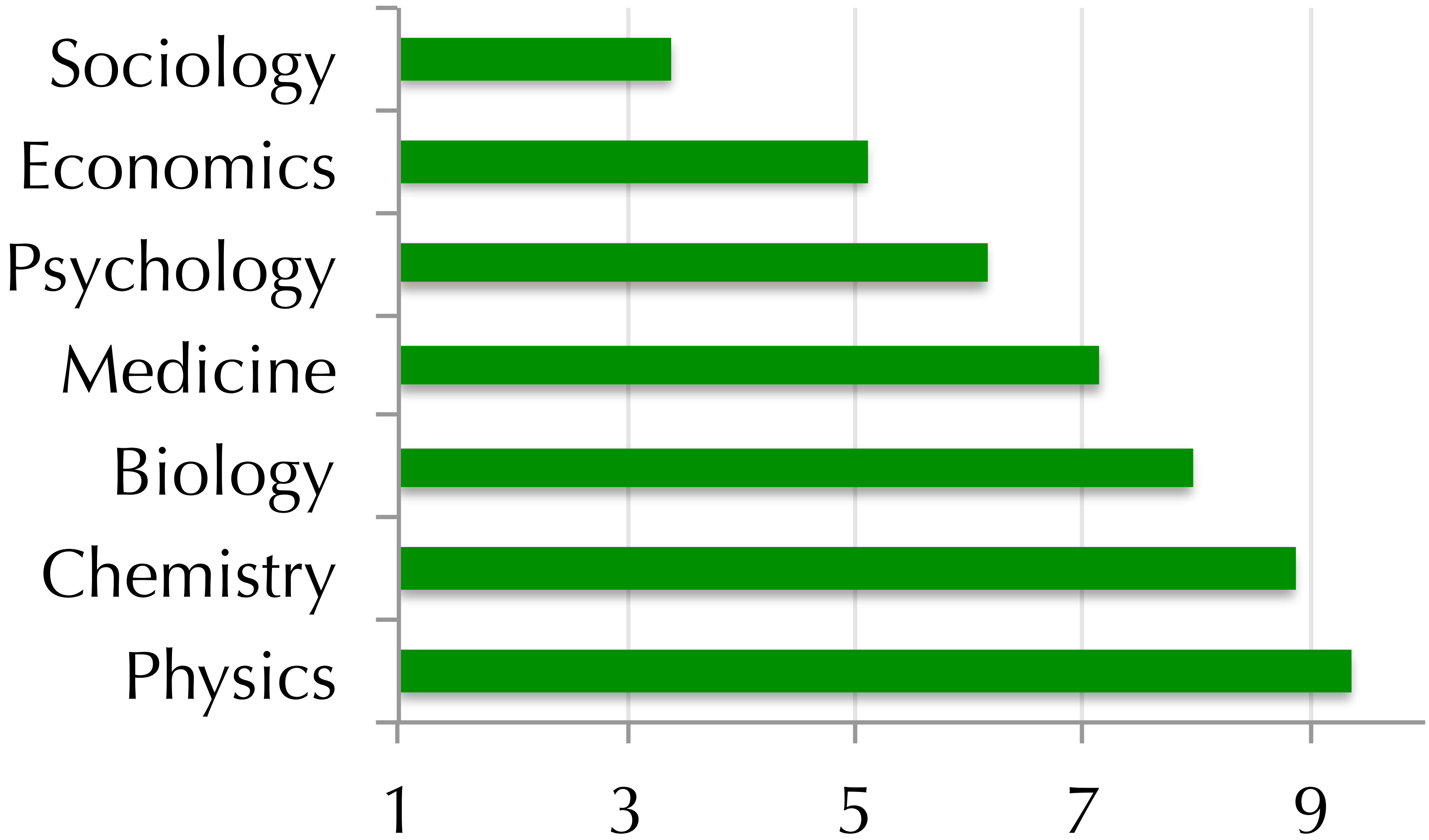


(c) Balaban and Klein 2006:
"Is chemistry 'The Central Science'? How are different sciences related? Co-citations, reductionism, emergence, and posets"

Hard vs. soft science

- Smith, et al. (2000), "Scientific Graphs and the Hierarchy of the Sciences":
  “It is commonly believed in our culture that a distinction can be drawn between the ‘hard’ sciences and the ‘soft’ sciences. Although these categories are not always clear-cut, most people have some sense of what the hard-soft distinction means. In the survey you are being asked to fill out, we are interested in your impressions of which areas of science can be considered relatively hard and which can be considered relatively soft.”

Hard vs. soft science



Graphism thesis

- Bruno Latour, 1990, “Drawing Things Together”:
  1. Graphs are immutable
  2. Graphs are readable
  3. Graphs are scalable
  4. Graphs are combinable

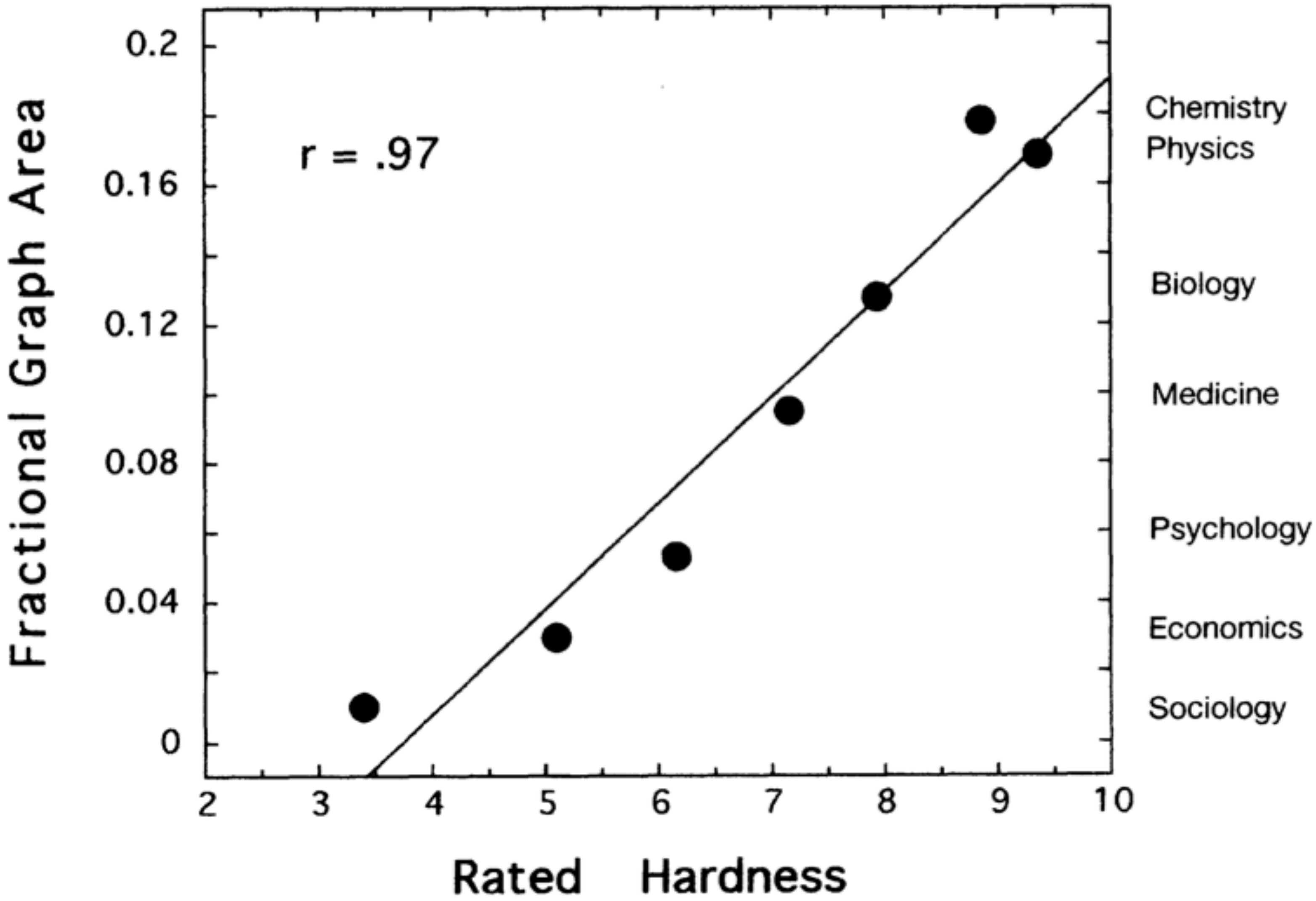
➡ Graphs are persuasive

➡ “Inscriptions allow Conscription”

Fractional Graph Area

- FGA: proportion of an article’s total page area that is devoted to graphs
  - Recorded for 50 articles
  - Randomly sampled from 4 (or in some cases 5) journals
  - In each of 7 disciplines
  - For the years 1980 and 1981.

Smith, Best, Stubbs, Johnston, Archibald (2000) "Scientific Graphs and the Hierarchy of the Sciences"

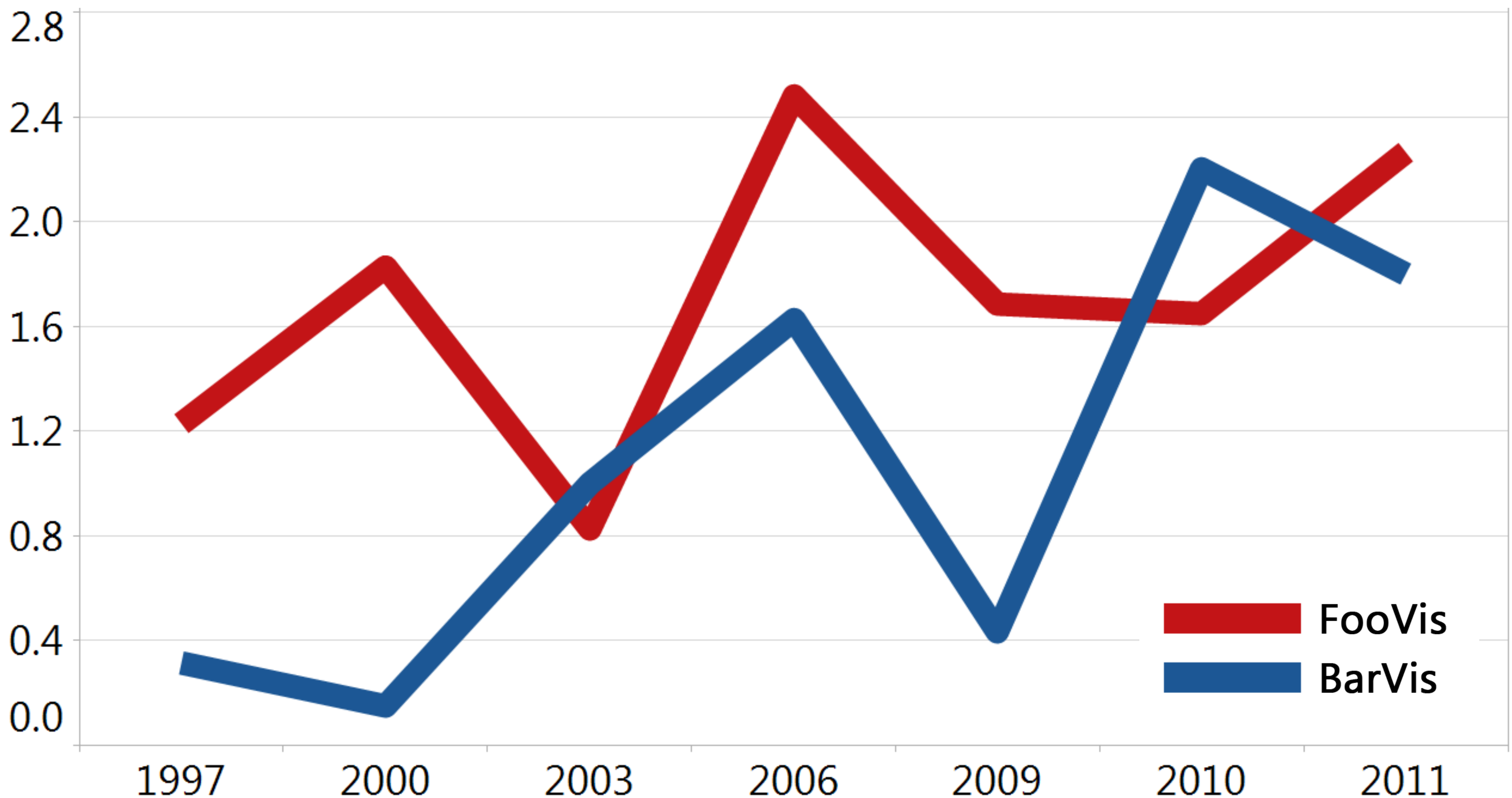


Hence ...

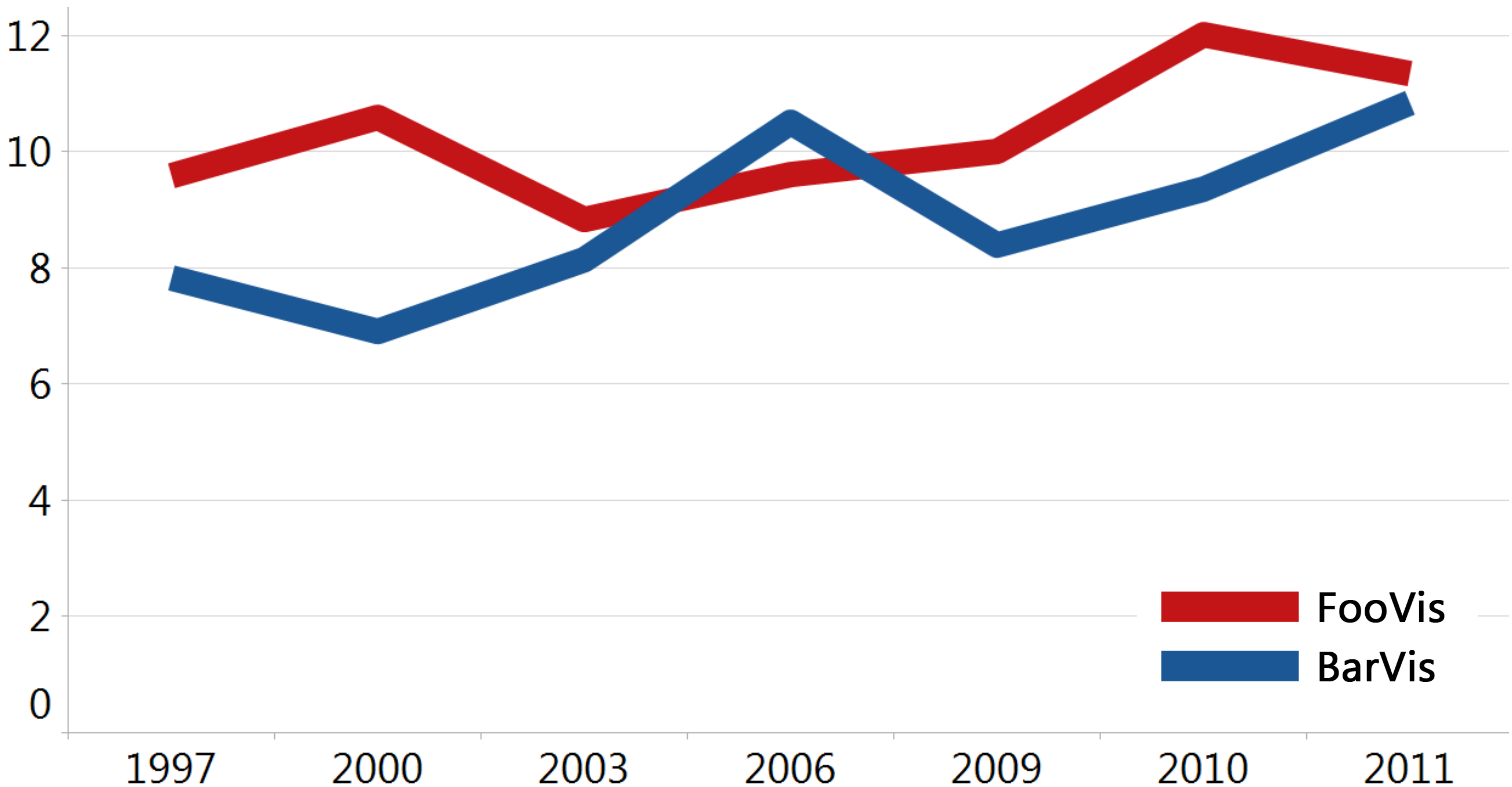
- Statistical measures to tell apart different scientific approaches
- What about our community?

Evidence 2
the data

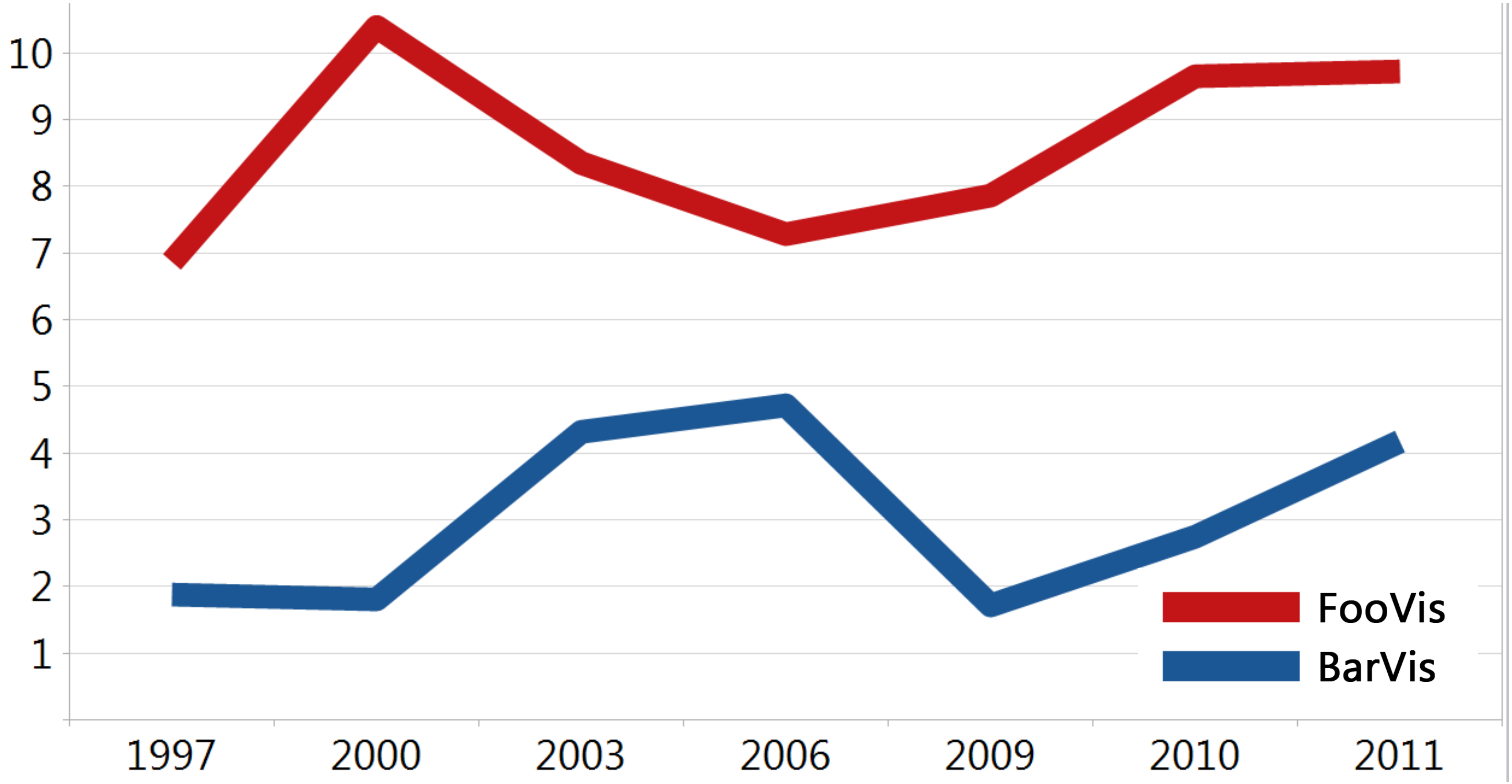
VisWeek: graphs



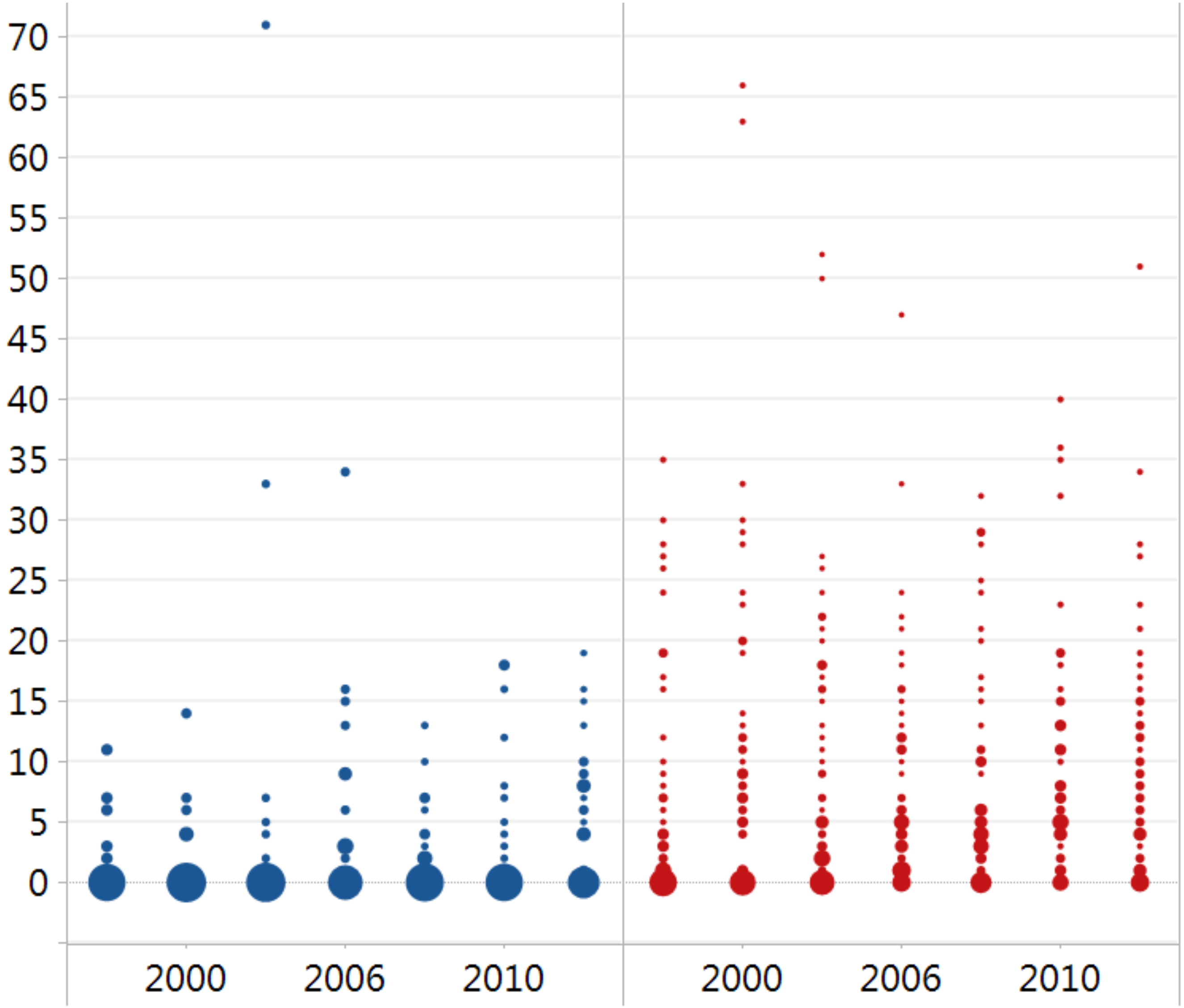
VisWeek: figures



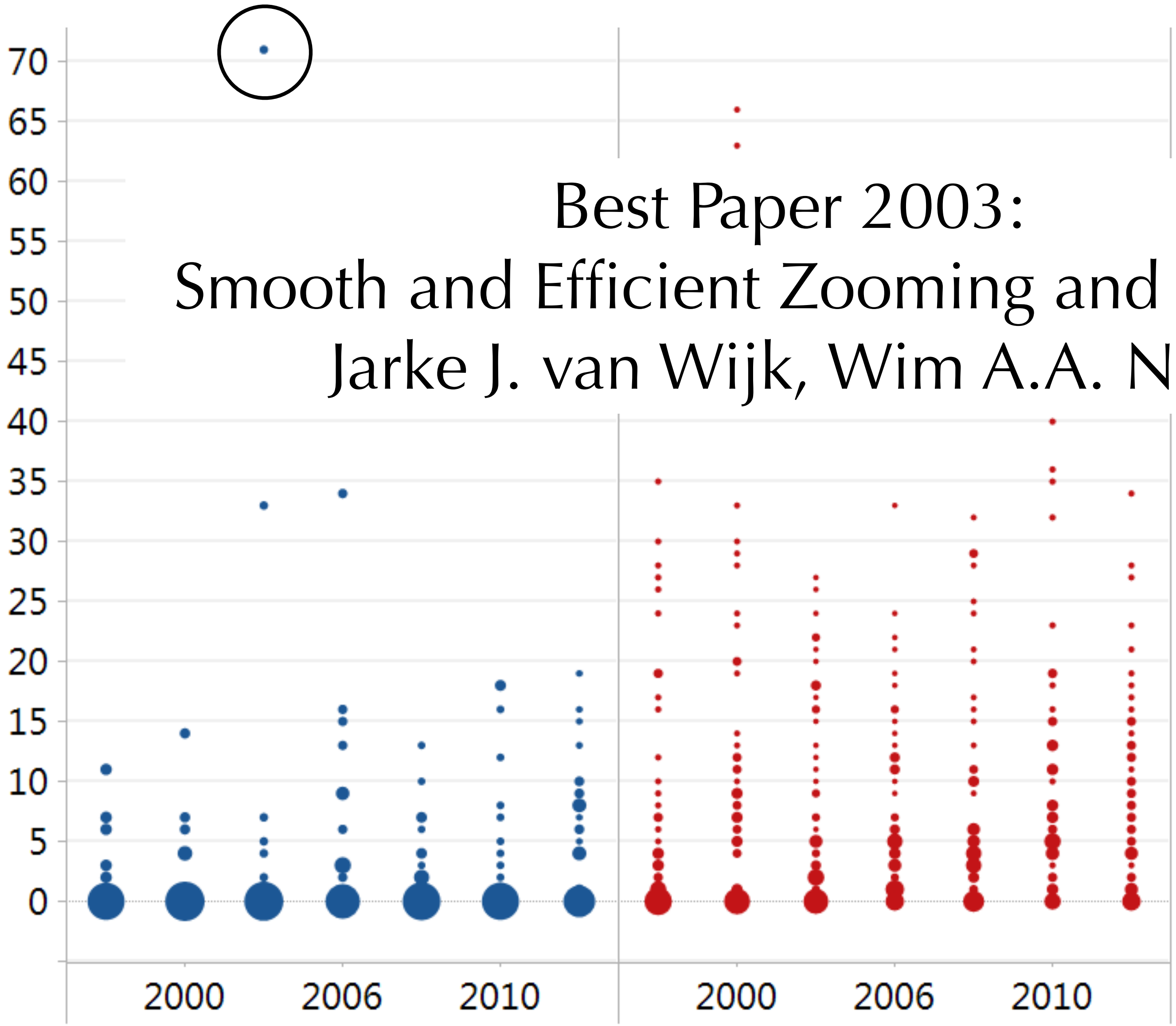
VisWeek: equations



VisWeek: equations



VisWeek: equations



Best Paper 2003:
Smooth and Efficient Zooming and Panning
Jarke J. van Wijk, Wim A.A. Nuij

FooVis vs. BarVis = Hard vs. Soft

- There is a gap in our approach to Visualization
- It is not about data modality!
- “Different” is not right or wrong
- Approaches are complementary

Two-State Solution Vs. Federal Republic

Recapture

- Academic definitions of FooVis vs. BarVis do not capture their general use and understanding
- FooVis vs. BarVis demarcates a strong ideological divide
- Let us not repeat a culture war!

C.P. Snow, 1956
The Two Cultures

- “Literary intellectuals” vs. “scientists”
- Our culture has become too fragmented
- Losing sight of the big picture

Two-state-solution vs. federal republic

- Two-state solution: necessary when ideological divide is unsurmountable or when the cultures are much too different

Wikipedia

"Freiheit ist immer die Freiheit des Andersdenkenden"

"Freedom is always the freedom of the one who thinks differently"

Wikipedia

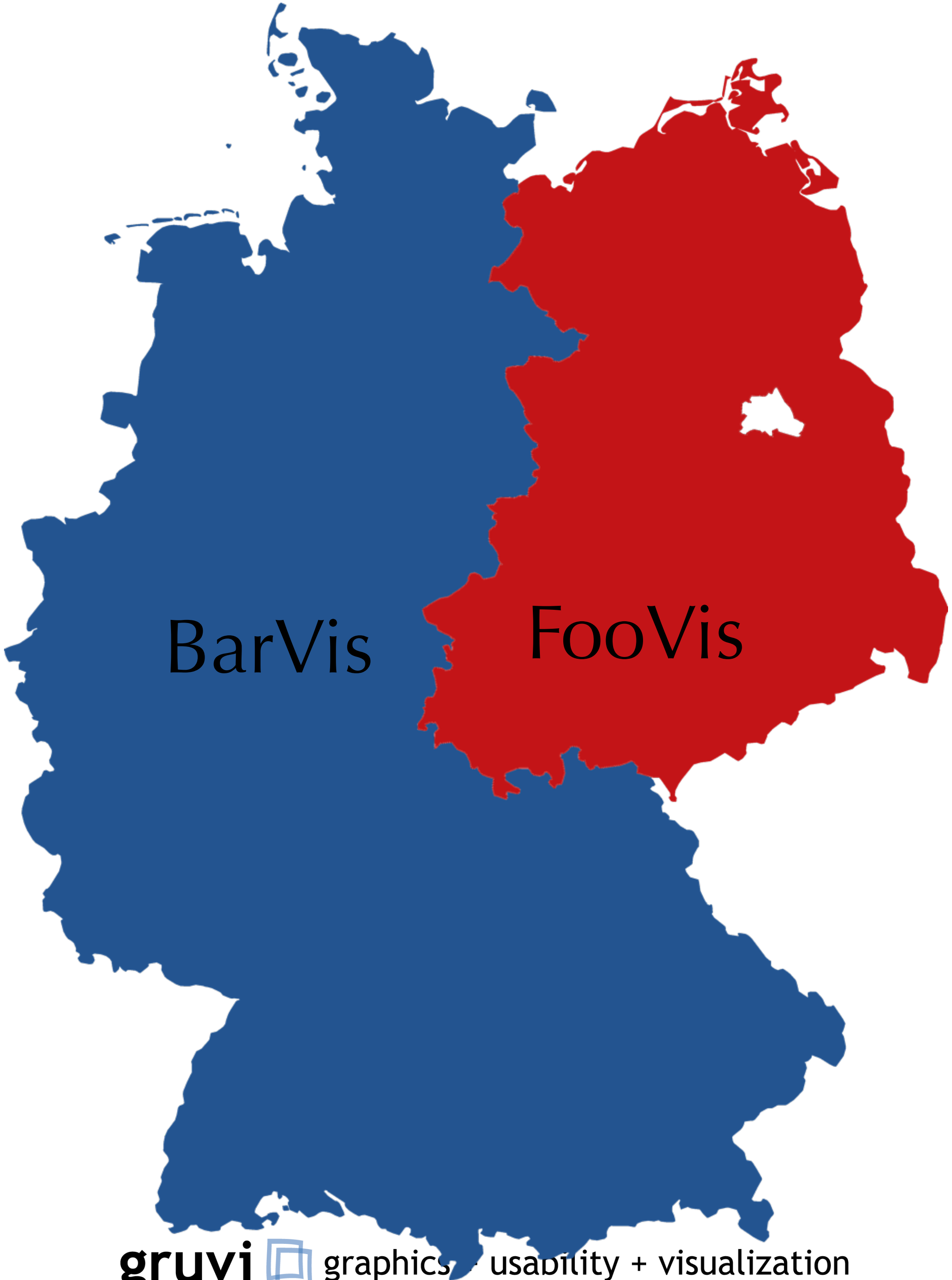
Rosa Luxemburg (1871-1919)

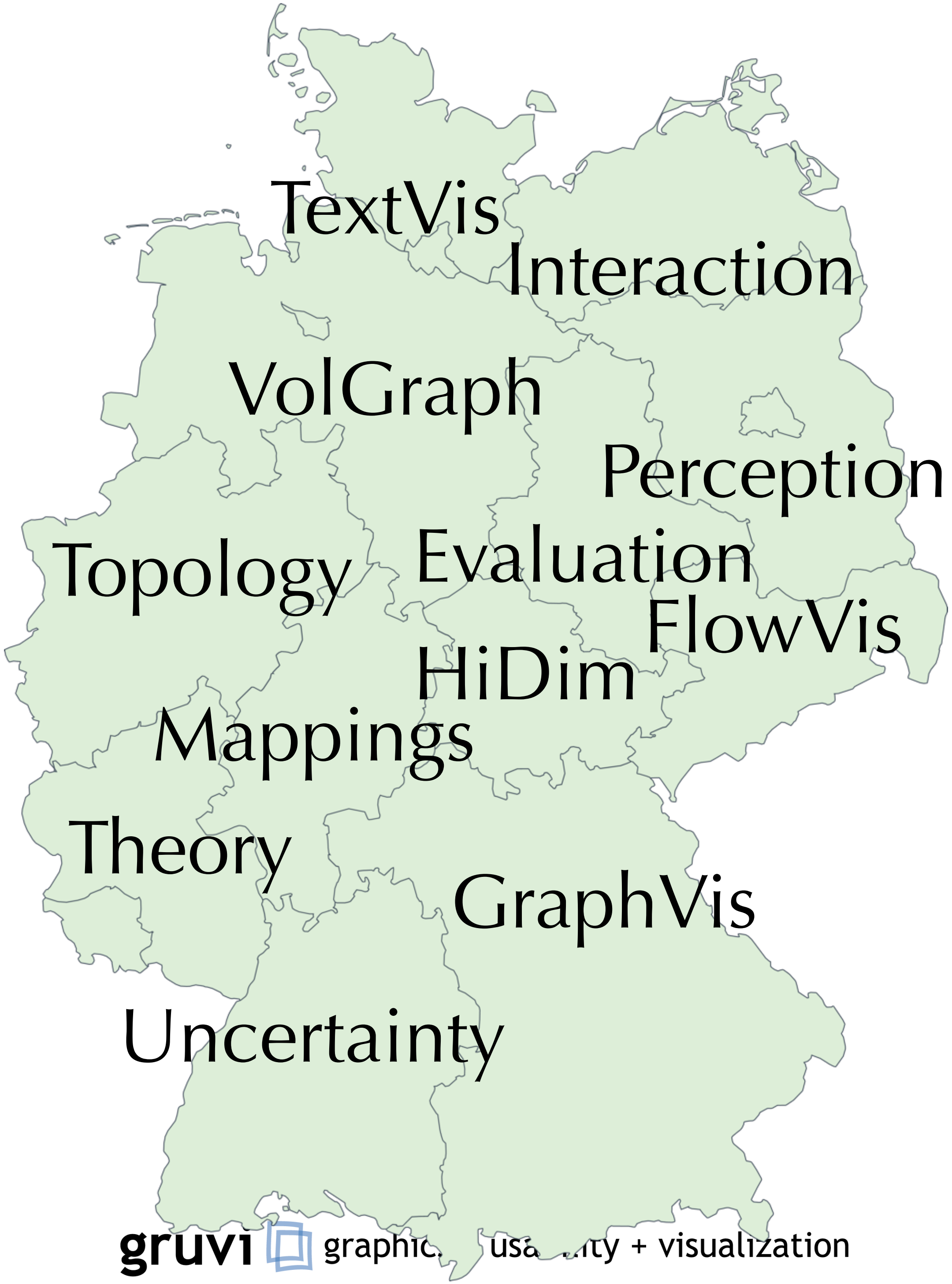
Interdisciplinary approach

Anders Karlqvist, 1999, "Going Beyond Disciplines"

more difficult ↓

1. Doing the same thing in different ways
2. Doing different things that can be combined
3. Doing different things that cannot be combined absent an additional framework
4. Doing things differently
5. Thinking differently


BarVis
FooVis


TextVis
Interaction
VolGraph
Perception
Topology
Evaluation
FlowVis
HiDim
Mappings
Theory
GraphVis
Uncertainty

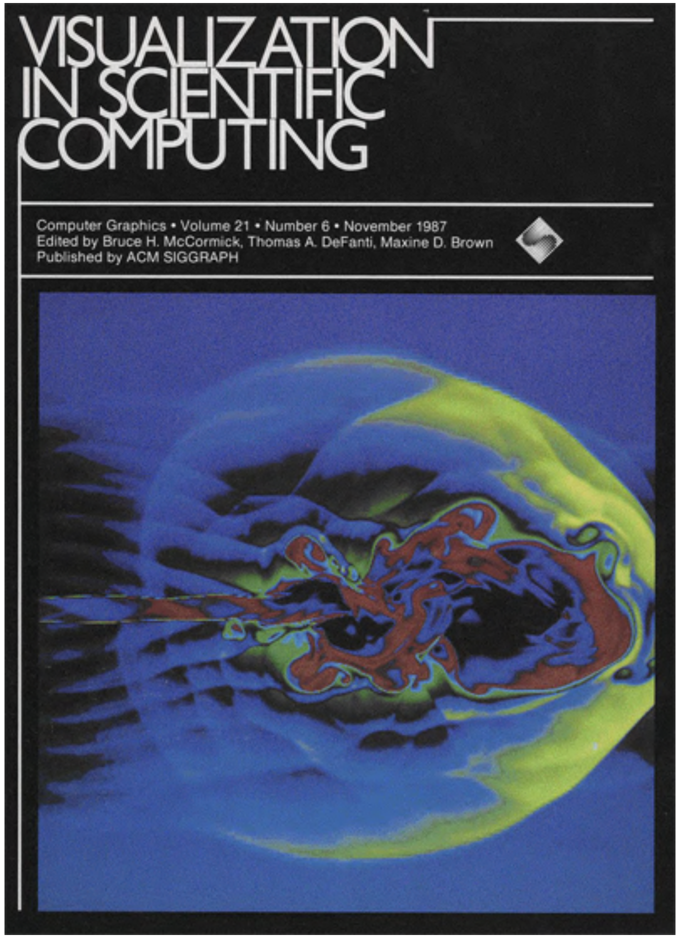
The Federal Republic of Visualization

- We have much to gain from creating a common visualization culture that embraces both world views - mathematical modeling as well as human-centered modeling
- Embrace diversity
- Create a stronger, better educated community
- Ability to create better tools for our users
- Increased reputation among the other sciences

What is Visualization?

McCormick, DeFanti, Brown:

"Visualization is a method of computing. It **transforms the symbolic into the geometric**, enabling researchers to observe their simulations and computations. Visualization offers a method for **seeing the unseen**. ... It studies those mechanisms in **humans and computers** which allow them in concert to perceive, use and communicate visual information."



What is Visualization?

Tamara Munzner 2011:

> "Computer-based visualization systems provide visual representations of datasets intended to help people carry out some task more effectively"

What is Visualization?

Tamara Munzner 2011:

> "**Computer-based** visualization systems provide visual representations of datasets intended to **help people** carry out some task more effectively"

What is Visualization?

Tamara Munzner 2011:

> "Computer-based visualization systems provide **visual representations** of datasets intended to help people carry out some task more effectively"

What is Visualization?

Tamara Munzner 2011:

> "Computer-based visualization systems provide visual representations of **datasets** intended to help people carry out some **task** more effectively"

What is Visualization?

Tamara Munzner 2011:

> "Computer-based visualization systems provide visual representations of datasets intended to help people carry out some task **more effectively**"

F.R.V.: A constitution

- Visualization 101: strike a balance between
  - mathematical and human-centered
  - algorithmic and empirical
  - programming and design

F.R.V.: The provinces

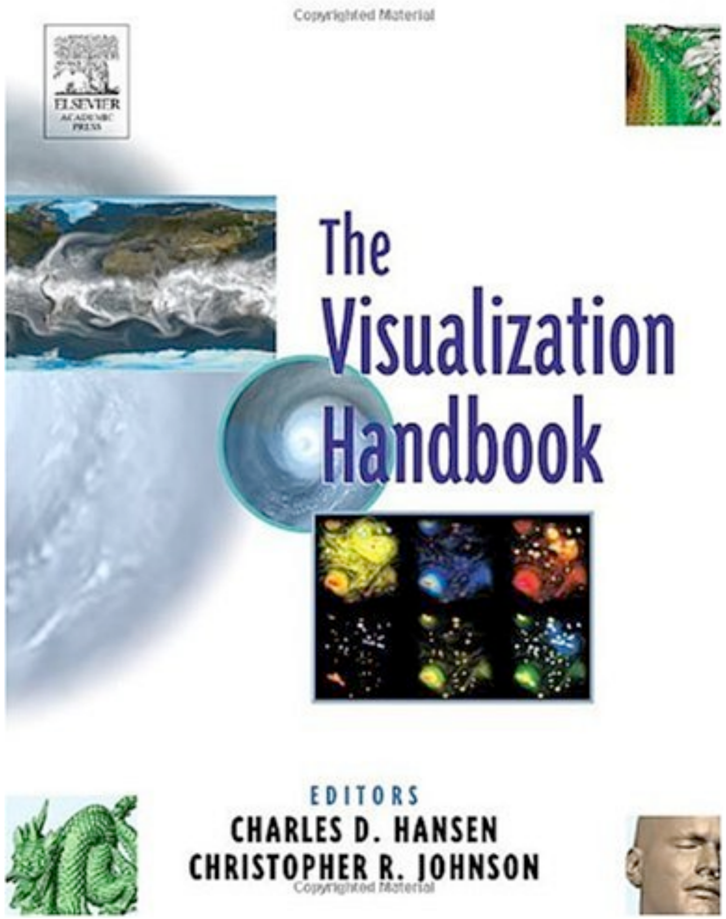
- Data (GraphVis, VolVis, TextVis, etc.)
- Methods (Evaluation, Interaction, etc.)
- Applications (BioVis, SoftVis, VisSec, MathVis, etc.)

Visualization - The good news

- EuroVis!
- TVCG
- some encouraging books

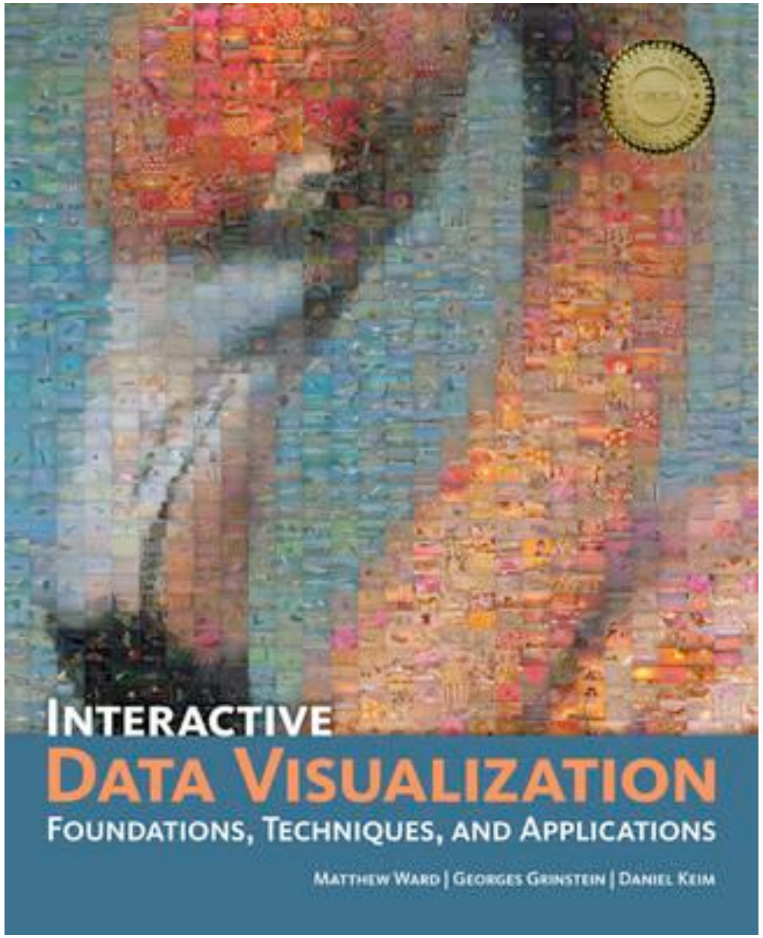
Hansen & Johnson 2005

- Offer McCormick's definition
- Focuses on rendering and analysis of 3D volumetric data (volume graphics)



Ward, Grinstein, Keim, 2010

Visualization ... the communication of information using graphical representations.



http://www.idvbook.com/

Swords into Plowshares
Schwerter zu Pflugscharen

Clarity

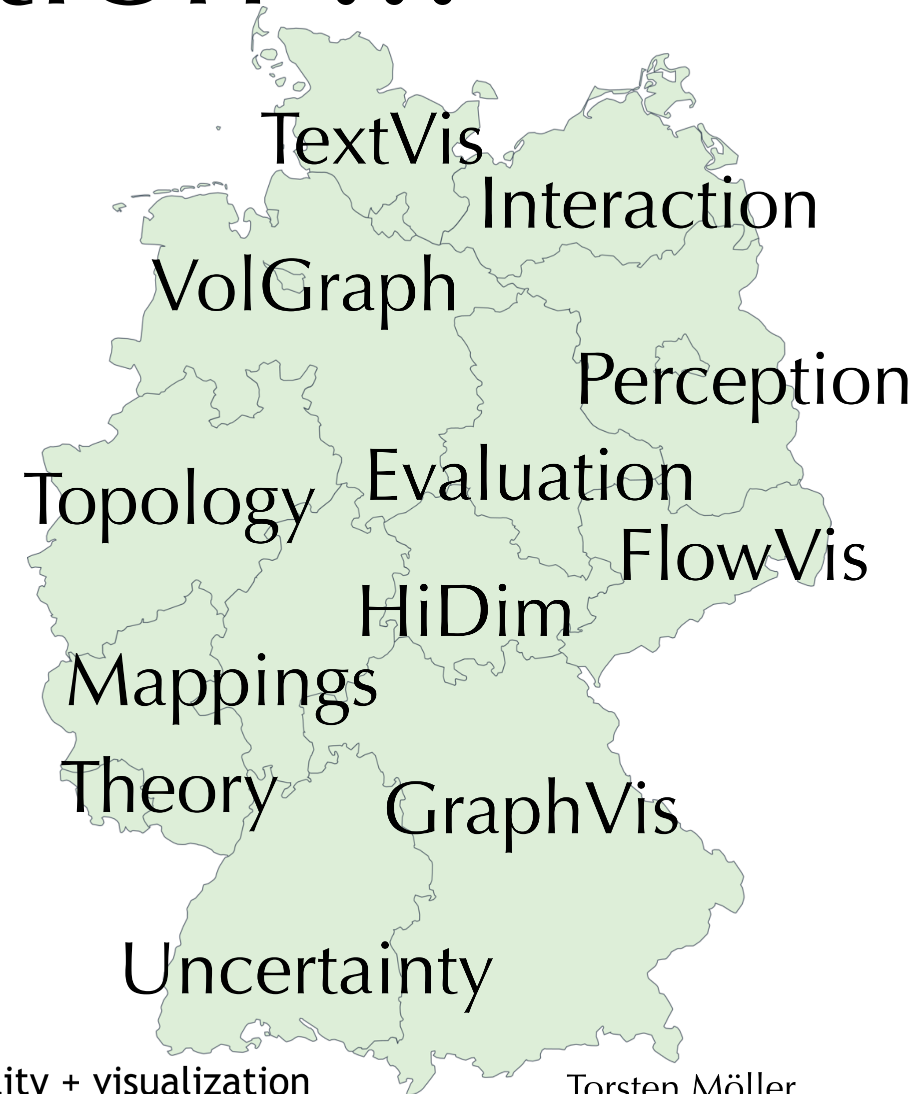
- Let's embrace "Visualization" as the broad term of our community and our research
- FooVis vs. BarVis: imprecise, re-enacts ideological borders
- Visualization = GraphVis, Volume Graphics, Topology, Interaction, Evaluation, FlowVis, Visual Mappings, etc.

Clarity

- Instead of “we need a reviewer with expertise in BarVis”
- Let’s say “we need a reviewer with expertise in GraphVis”
- Instead of “Have a look at the FooVis wiki”
- Let’s say “Have a look at the Vis wiki”

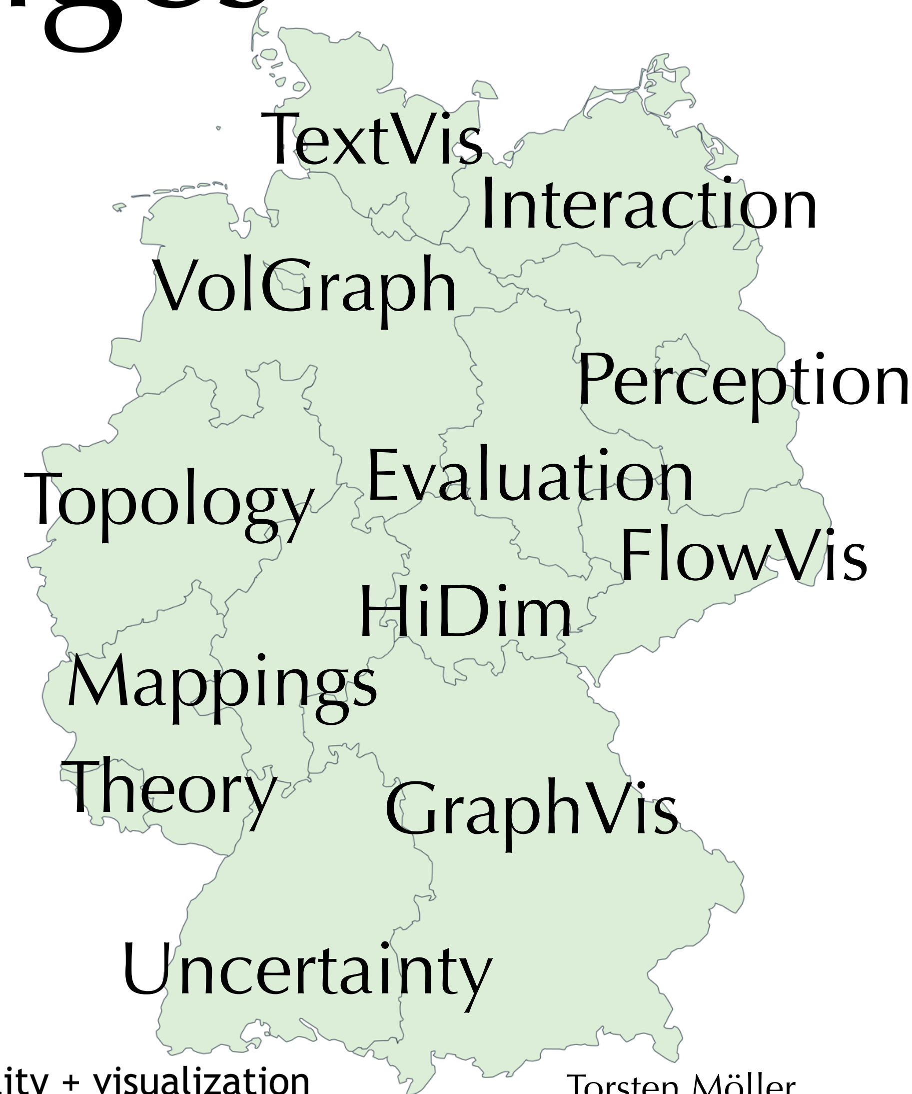
Let's talk about Visualization ...

- Challenges
- Teaching
- Textbooks
- Research
- Solutions



Visualization challenges

- Scalability
- Quantify Effectiveness vs. Feature detection
- Multifield / High-Dim Visualization
- Integrated Problem Solving Environments
- Theory of Visualization



Scalability

Daniel Keim, Dagstuhl 2009

- Big Data
- Independent of data modality
- Technical challenges (engineering, modeling)
- Cognitive challenges

Quantify effectiveness vs. Feature detection

- Evaluation is difficult
- Qualitative and quantitative approaches

- Sophisticated analysis algorithms
- State-of-the-art in math, stats, and engineering

Multi-field / High-dim

- Appears in all application domains
- Model building in both “hard” and “soft” sciences
- Simulation is a driving force for computational science

Lots of work both FooVis and BarVis

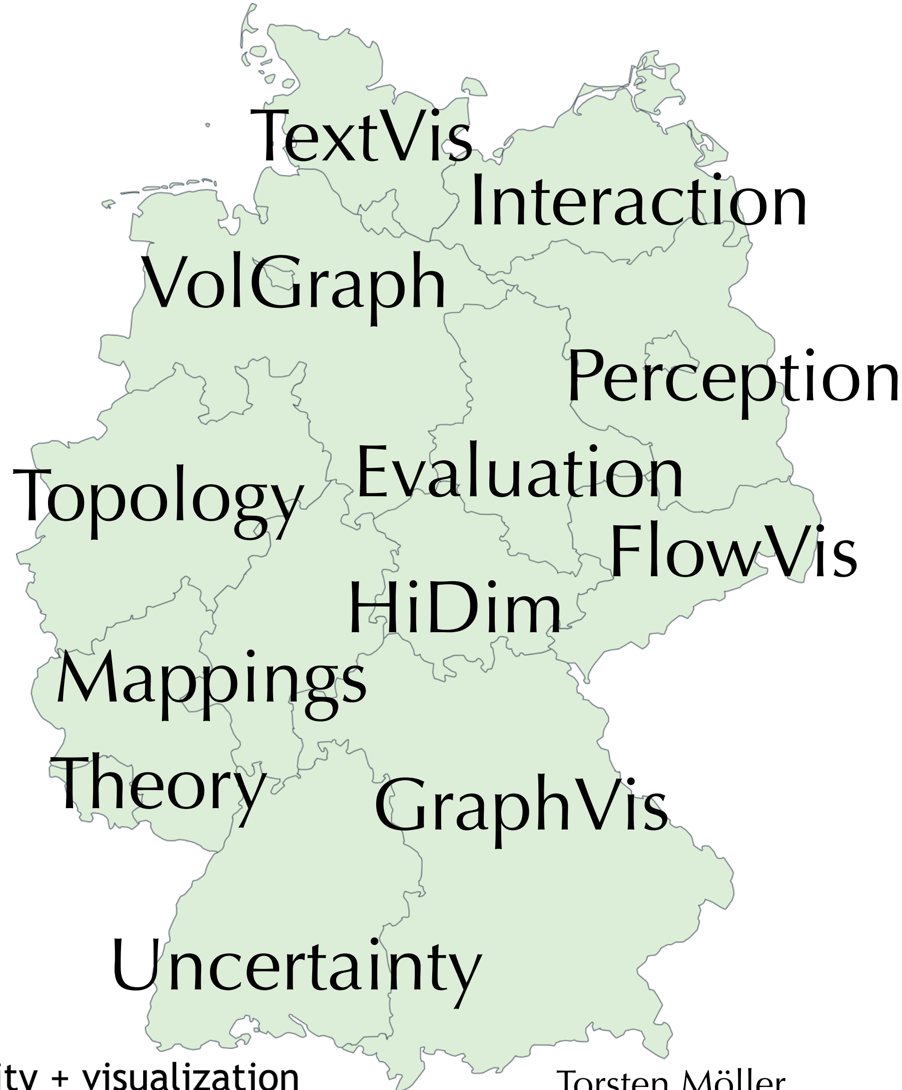
- HyperSlice (1993)
- Visplore (2010)
- Tuner (2011)
- FluidExplorer (2011)
- Prosection Matrix (1998)
- Paramorama (2011)
- Vismon (2012)

Multi-field / High-dim

- Sampling
- Rendering / Display
- Features
- Cognition
- Design
- Ethnography
- Computing uncertainty
- Conveying sensitivity

Visualization theories / Visualization education

- Mathematics
- Statistics
- Design Principles
- Perception
- Interaction
- Evaluation



My wish list

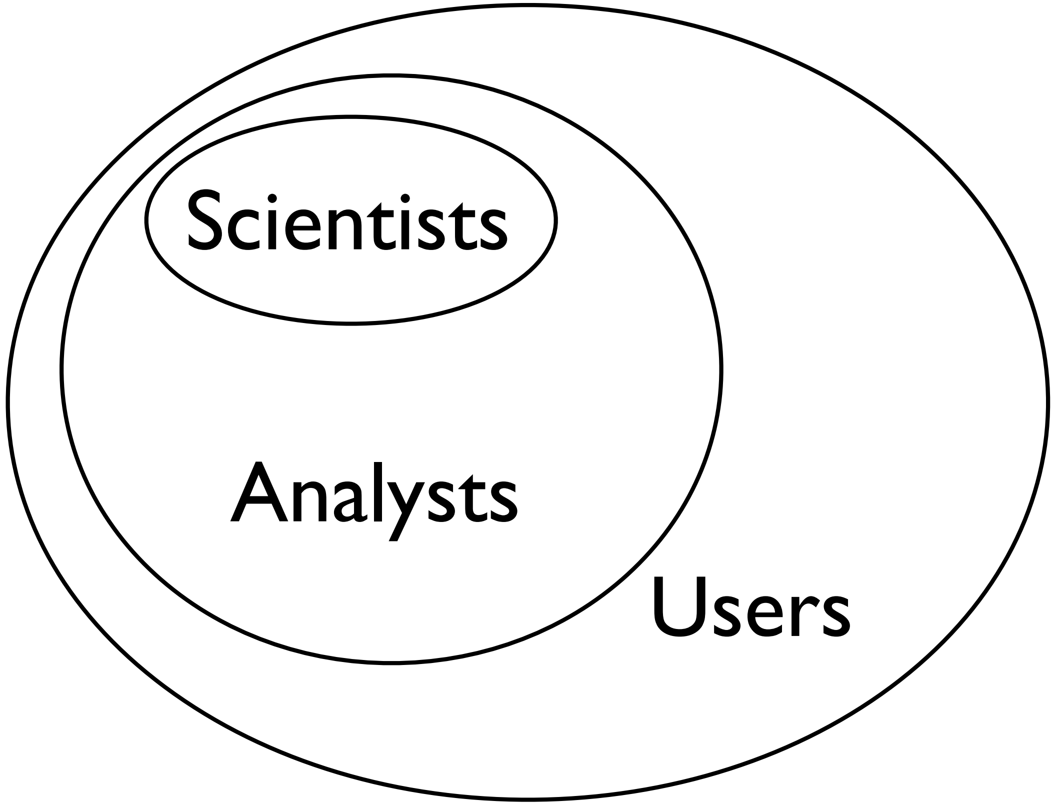
- Clarity in our language
- Unified community
- Extend your horizon
  - Read up on design studies
  - Understand clustering, segmentation and rendering techniques
  - Collaborate with real users
- Visualization 101

AP

But what about VA ...?

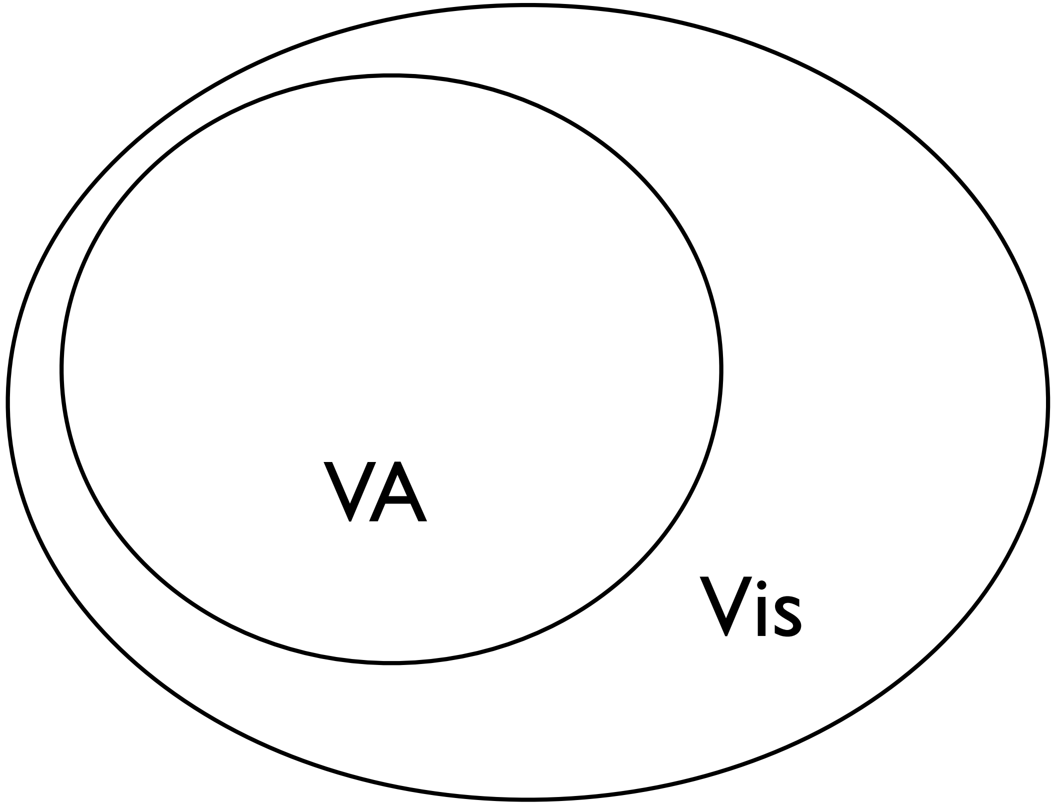
Human-centric

- 1987 - the focus was on **scientists**, hence “scientific visualization”
- mid-90ies: influence of HCI terminology: focus broadened to **users**
- VA focuses on **analysts**



Mathematics

- a focus on algorithms for analysis is welcome
- VA constraints itself to statistical analysis
- Vis includes tools in signal processing, numerics, topology, etc.



Math+Humans