

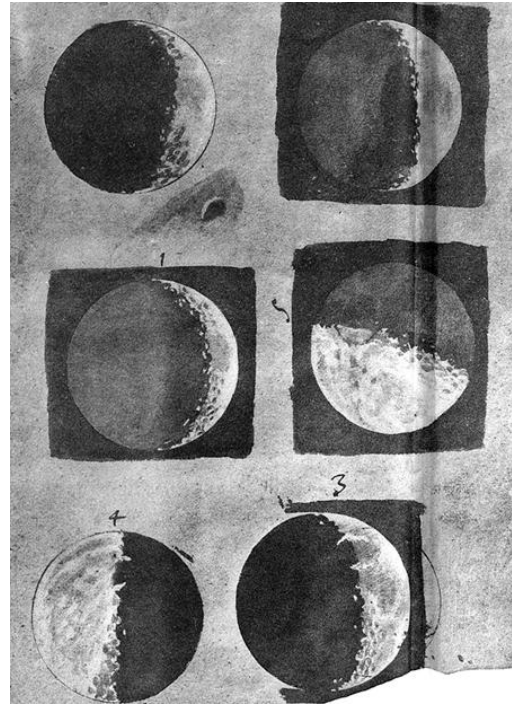
Introduction to Visualization

Yunhai Wang

cloudseawang@gmail.com

<http://web.siat.ac.cn/~yunhai/>

Visualization

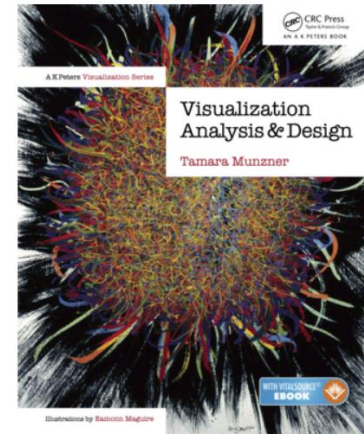


$$\begin{array}{r} 13 \\ \times 11 \\ \hline 13 \\ 13 \\ \hline 143 \end{array}$$



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”

Comparison

Input	Output	Research Area
Image	Image	Image Processing
Image	3D Model	Computer Vision
3D Model	Image	Computer Graphics
Data	Image	Visualization

Vis timeline

Early

Bertin

Tukey

Cleveland

Vis timeline

Early 1987



Bertin NSF

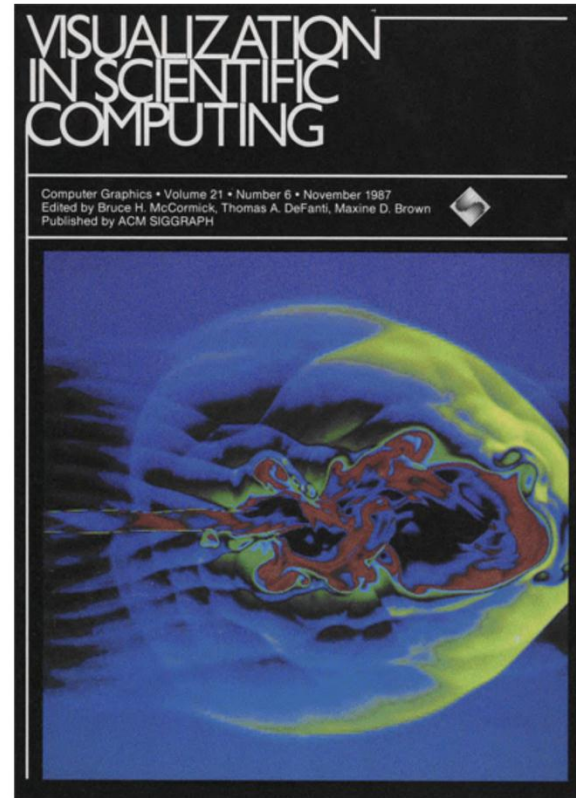
Tukey

Cleveland

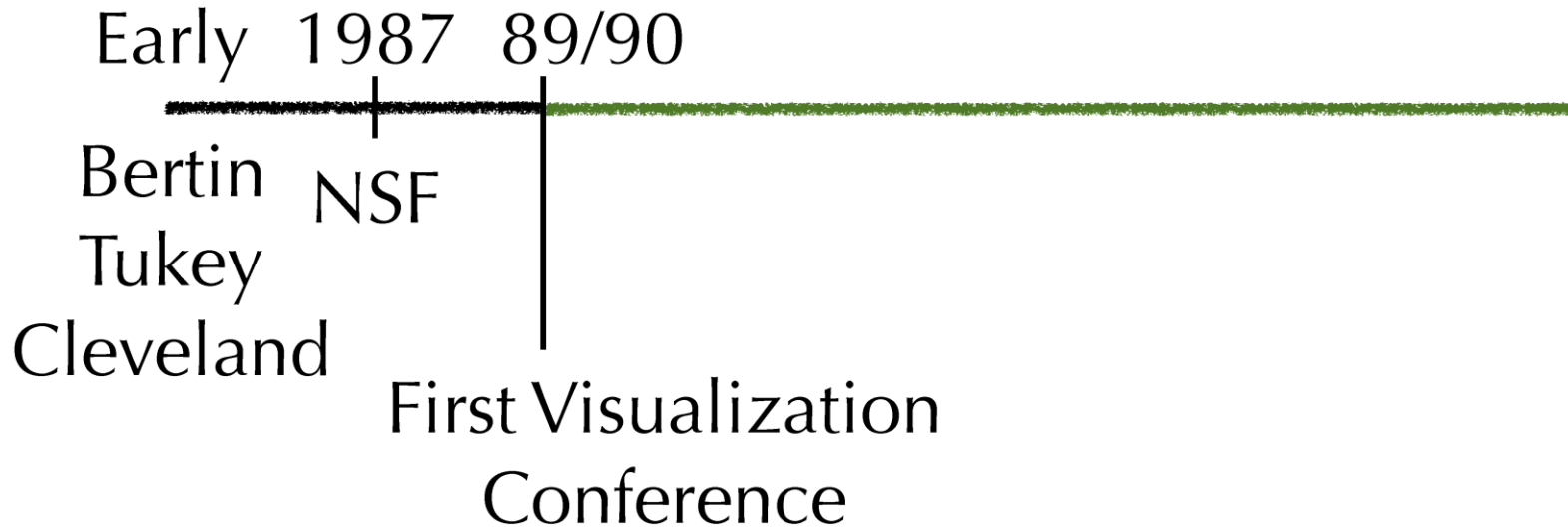
NSF Panel 1987

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.”

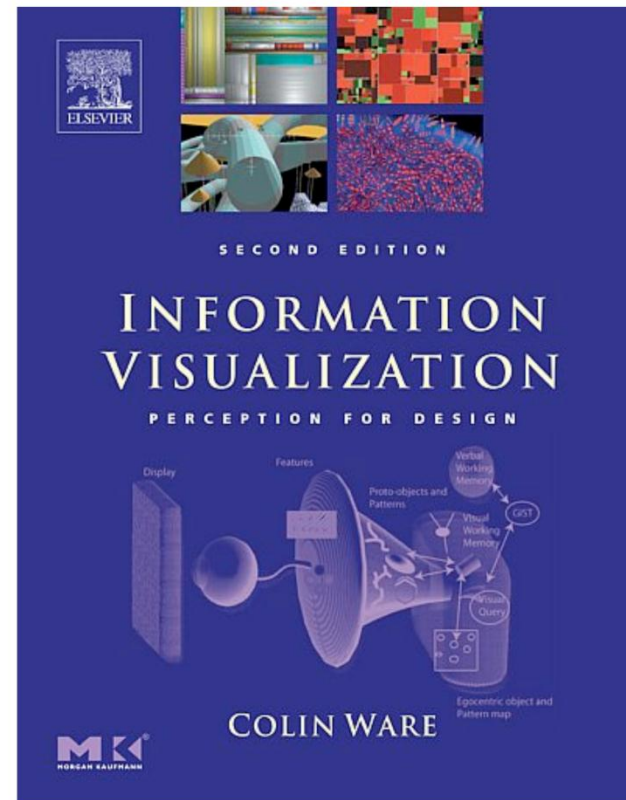


Vis timeline

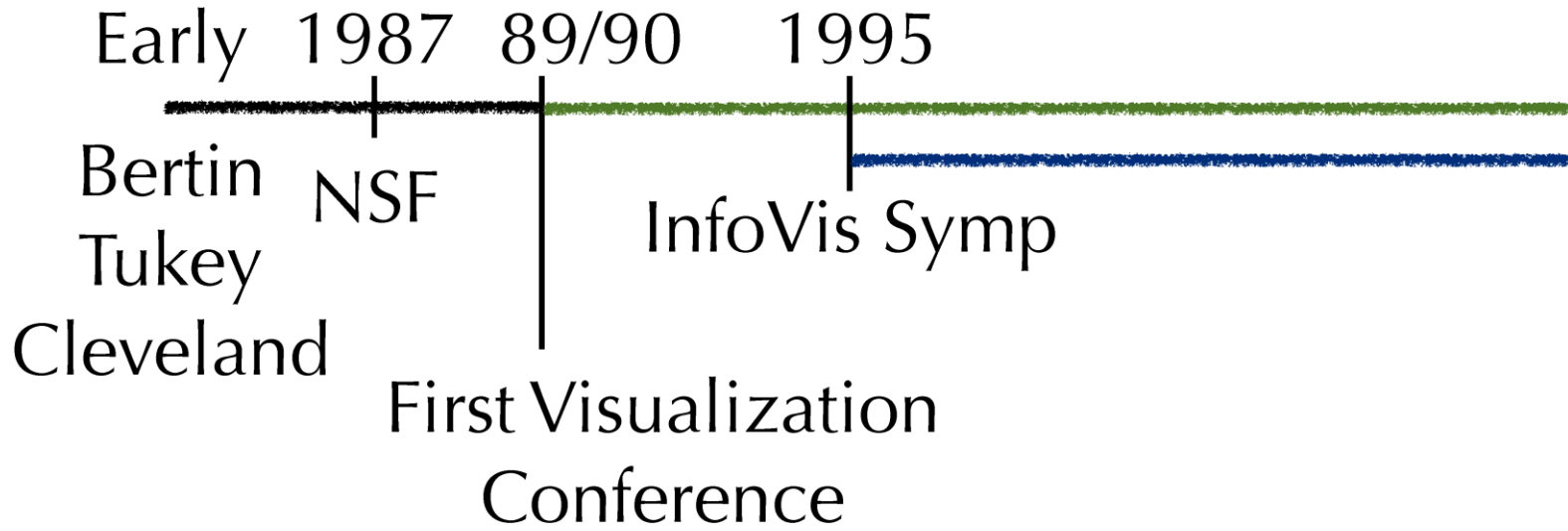


Ware 2004

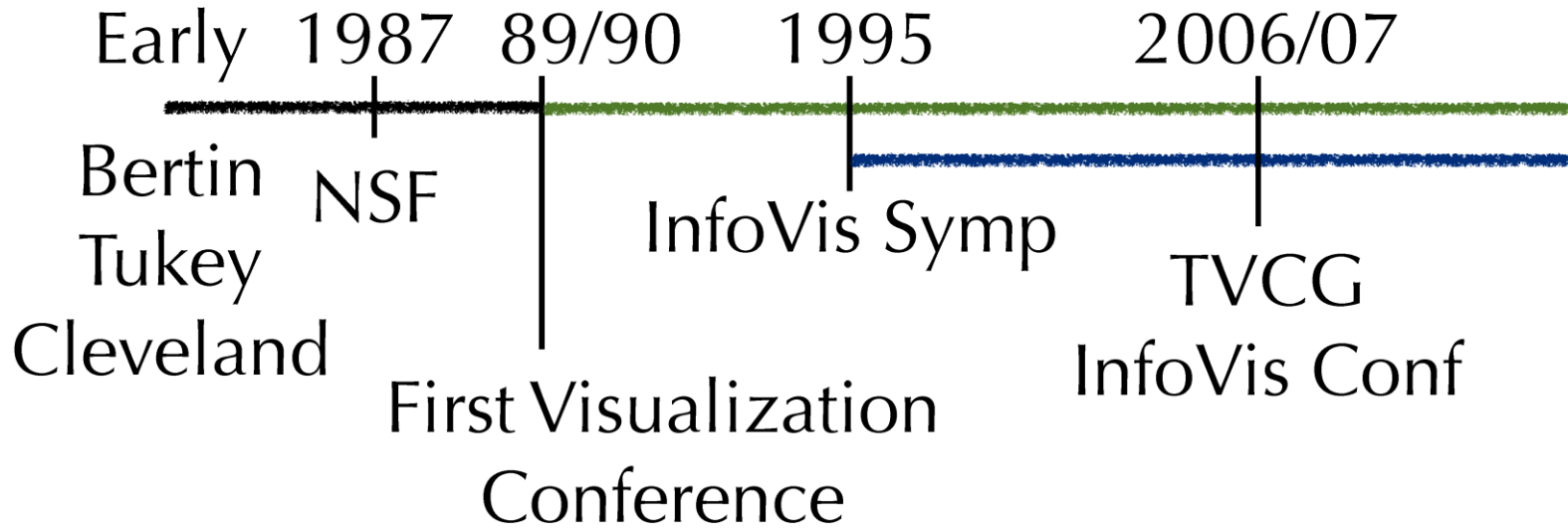
“**Information visualization** ... is the use of interactive visual representations of **abstract data** to amplify cognition”



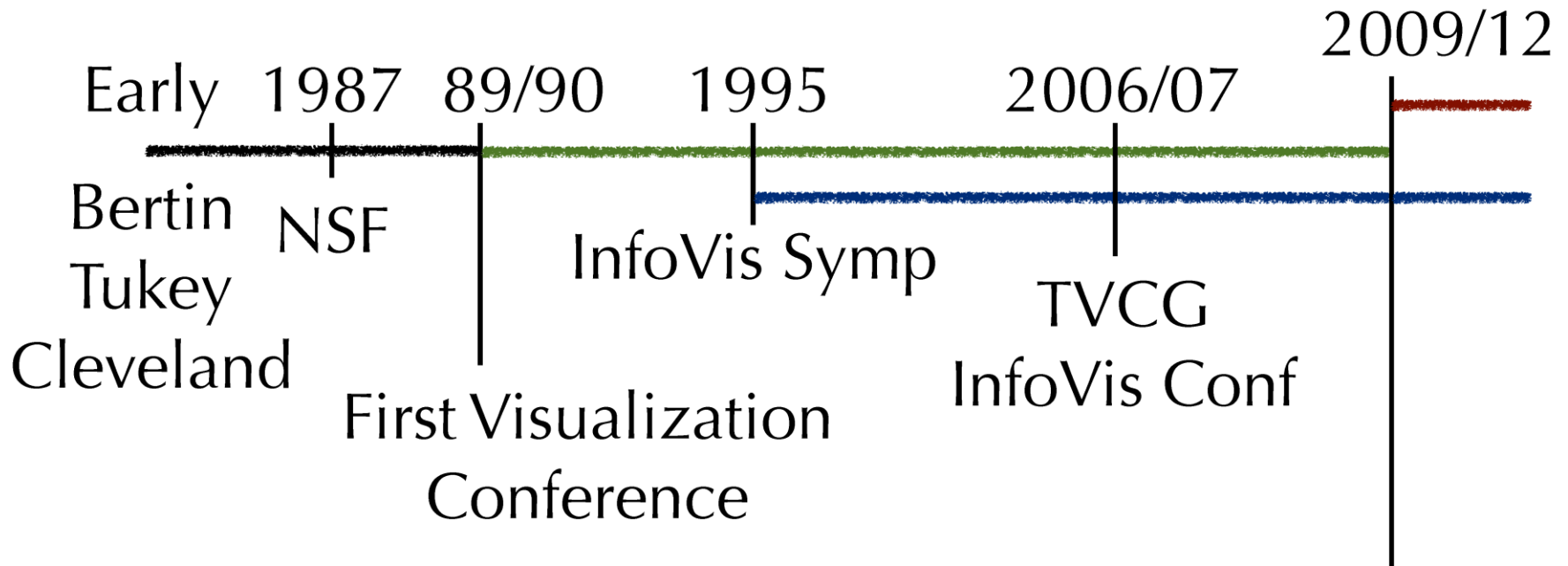
Vis timeline



Vis timeline



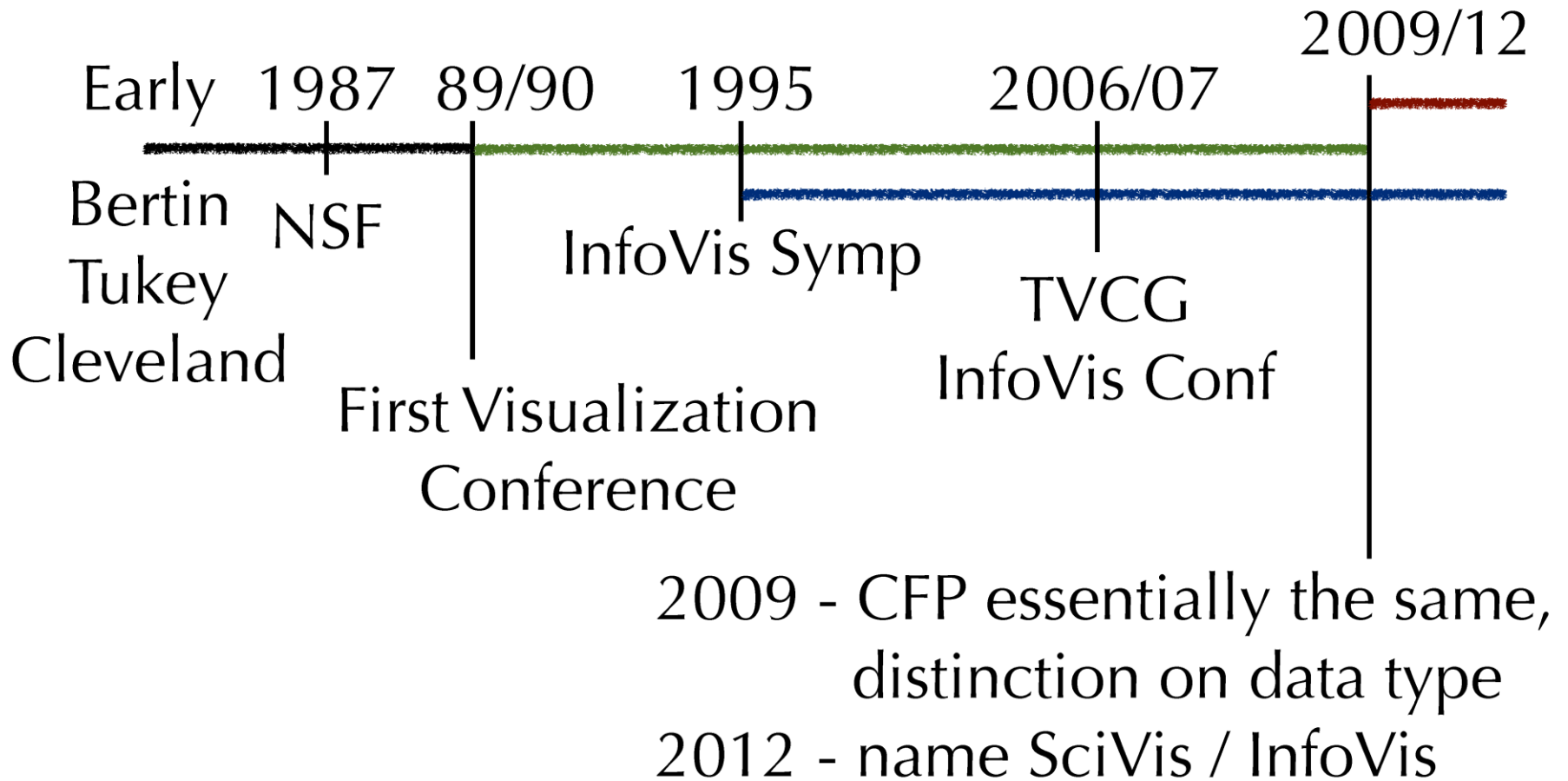
Vis timeline



2009 - CFP essentially the same,
distinction on data type

2012 - name SciVis / InfoVis

Vis timeline



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

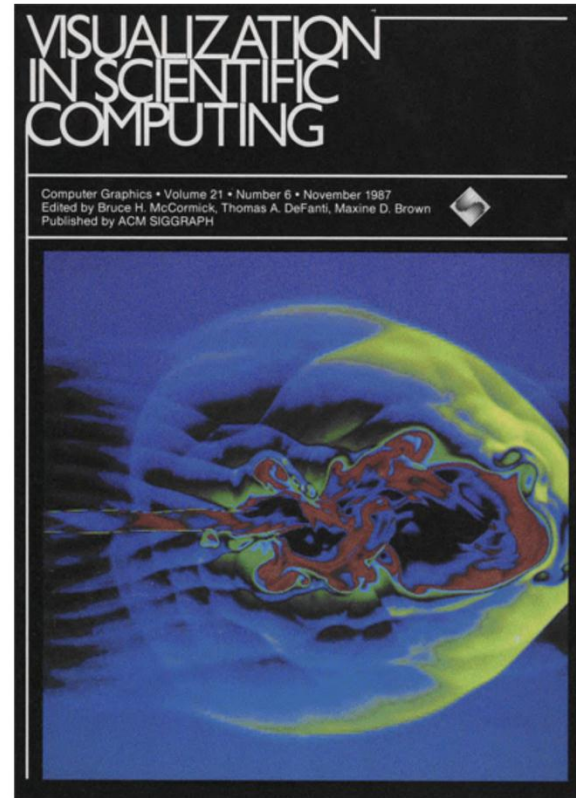
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What is Visualization?

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?

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

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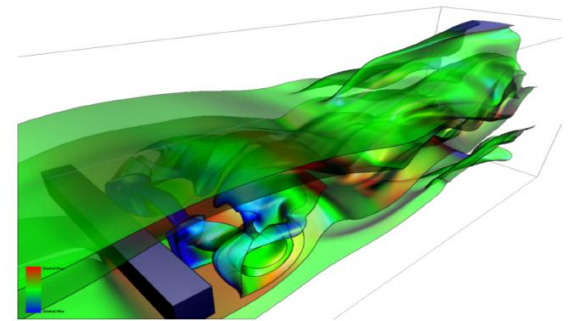
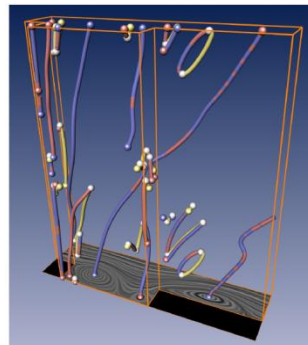
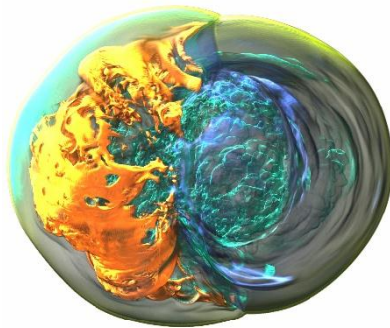
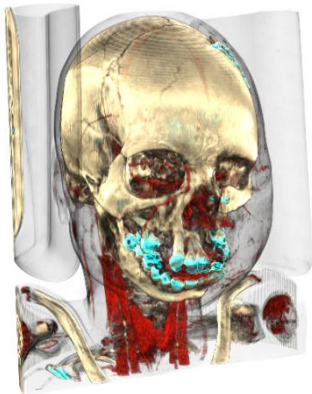
Three minimal criteria

Robert Kosara 2011:

- Based on (non-visual) data
- Produce an image
- The result must be readable and recognizable

Scientific Visualization

- Scientific visualization focuses on the use of **computer graphics** to create visual **images** which aid in understanding of complex, often massive numerical representation of scientific concepts or results.

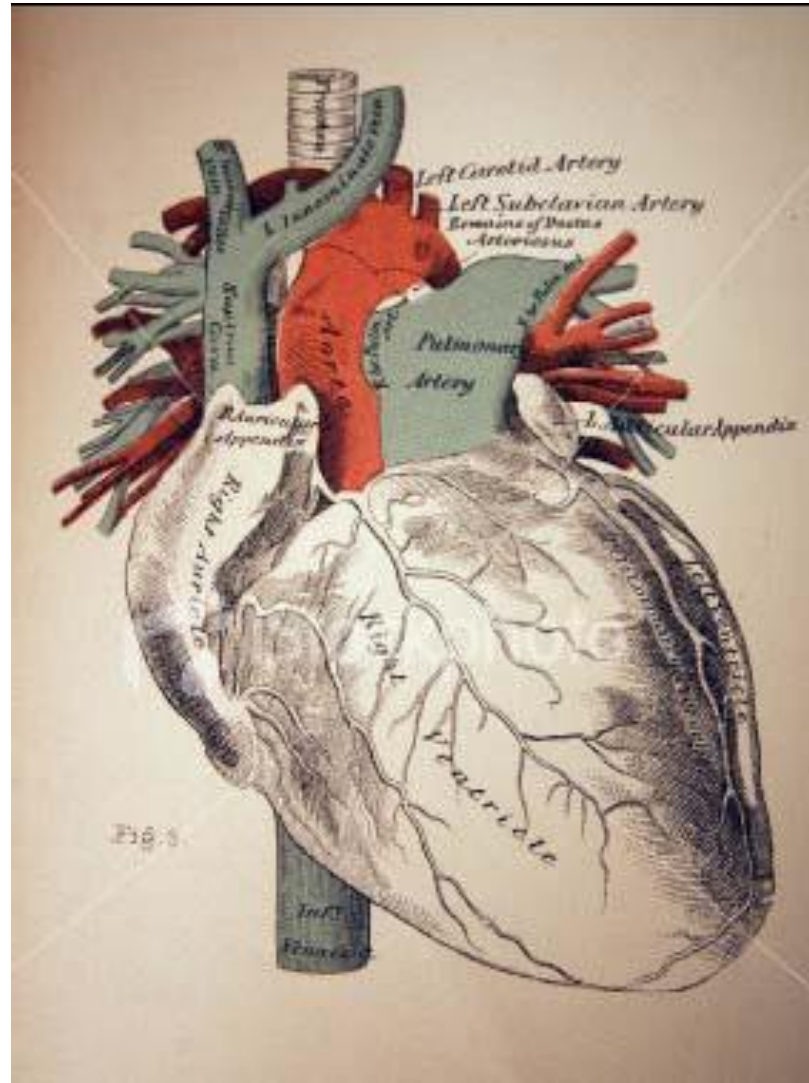


Examples



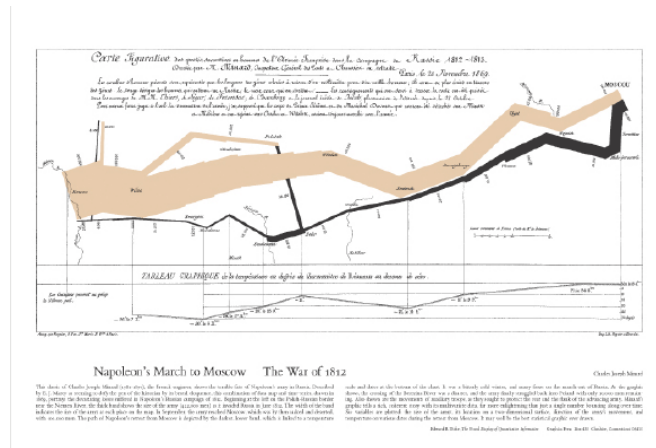
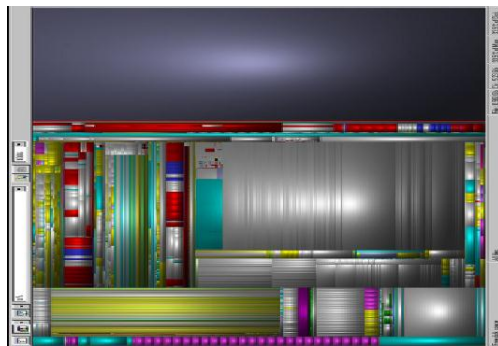
Kevin Hulse Illustration, INC.

Examples



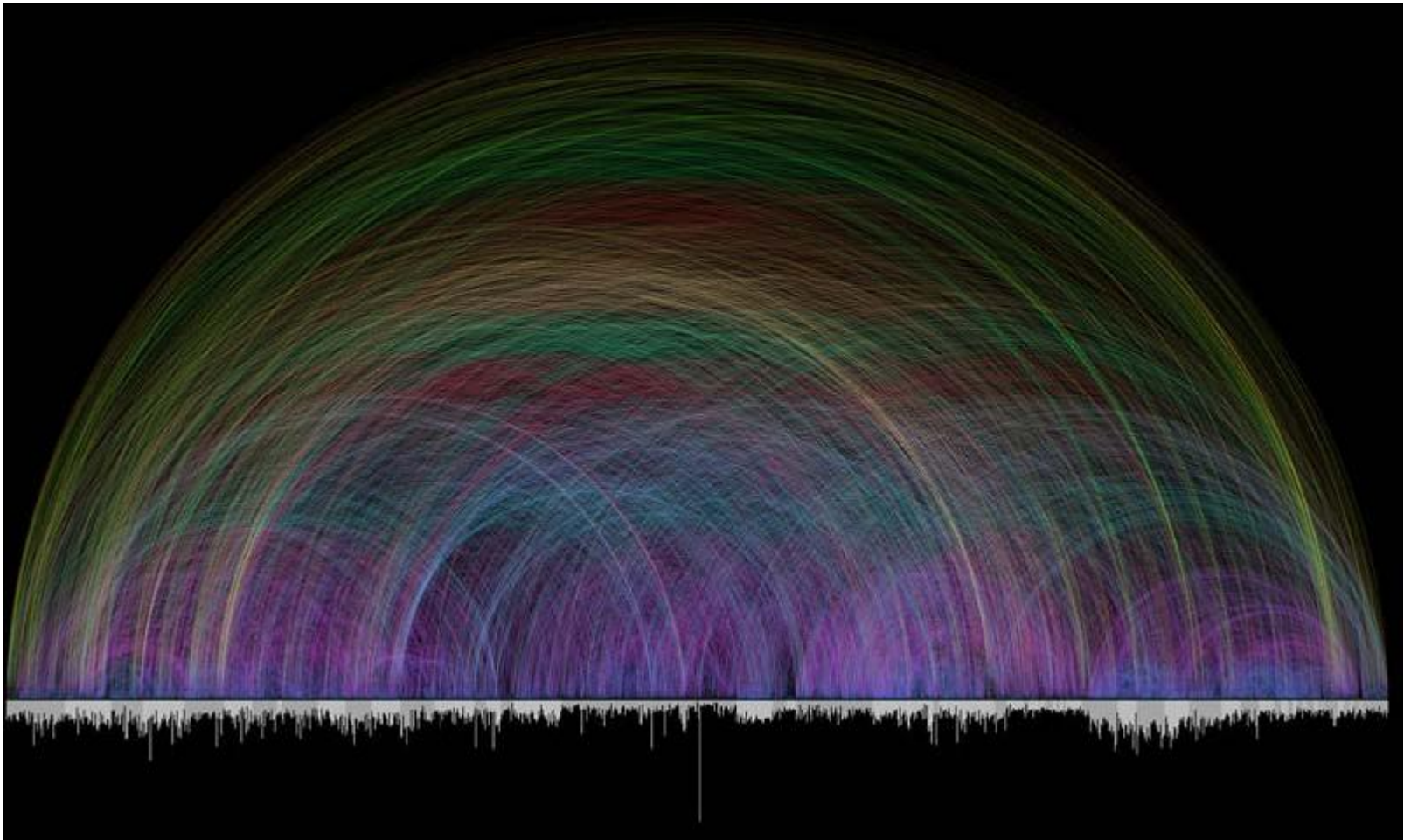
Information Visualization

- **Information visualization** is the communication of **abstract data** through the use of **interactive visual interfaces**. [Keim et al., 2006]

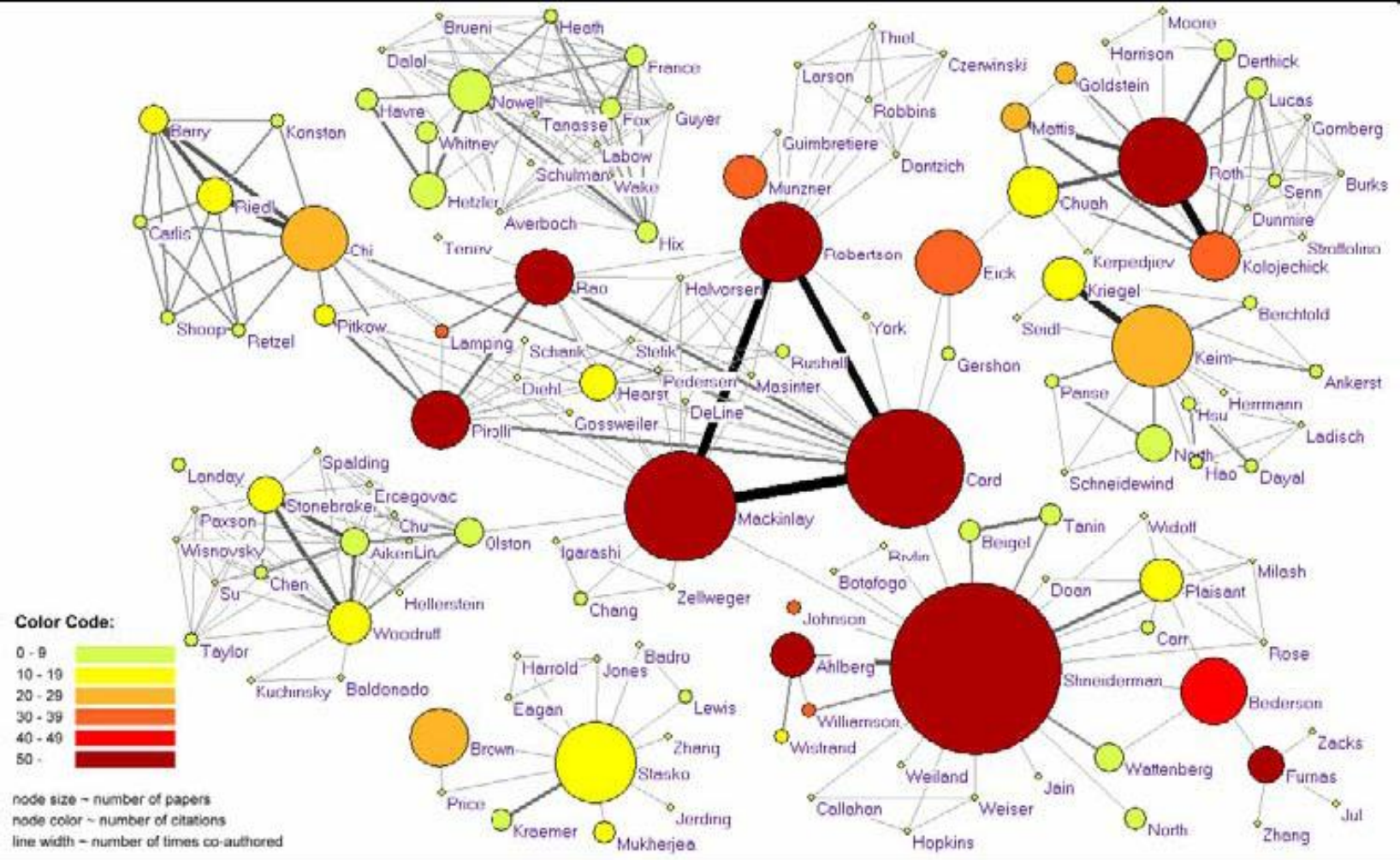


Napoleon's March to Moscow

Examples



Examples

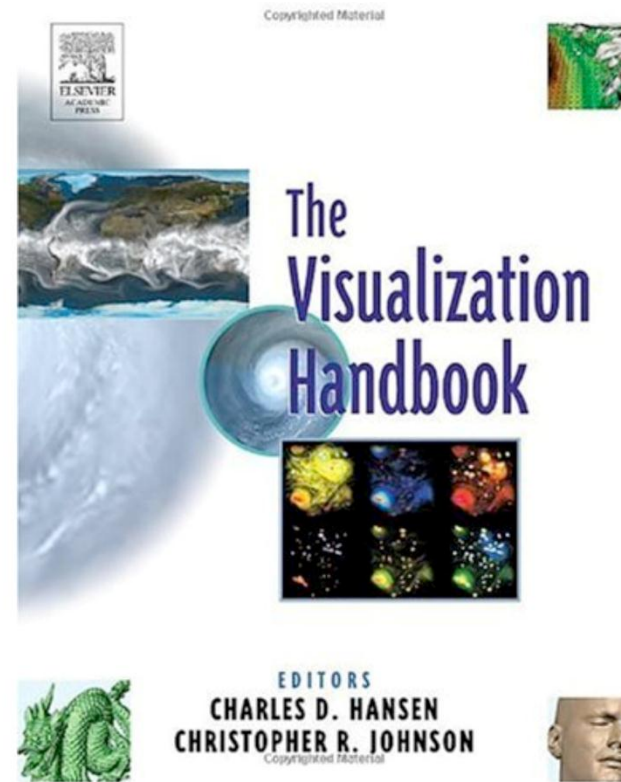


Visualization - Research

- Journal
 - TVCG/IEEE CG&A/CGF
- Conference
 - SciVis/ Infovis (TVCG)
 - Eurovis (CGF)
 - PacificVis
- Some encouraging books

Hansen & Johnson 2005

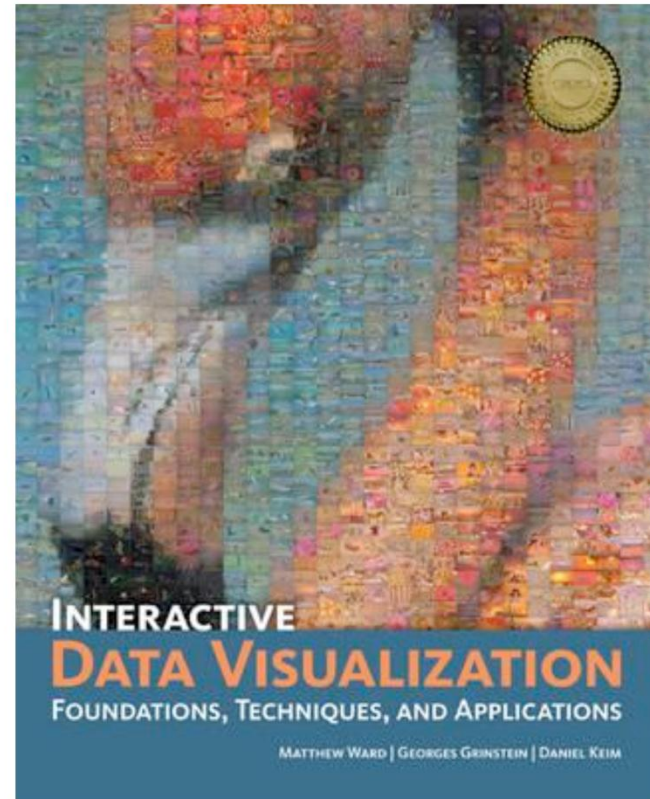
- Offer McCormick's definition
- Focuses on rendering and analysis of 3D volumetric data (volume graphics)



Ward, Grinstein, Keim, 2010

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

<http://www.idvbook.com/>



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

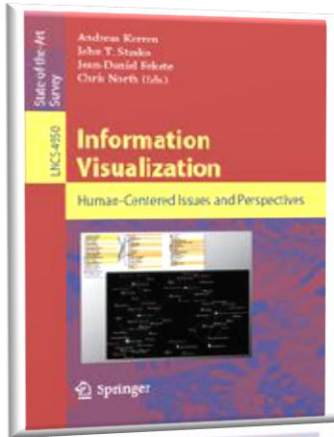
- Appears in all application domains
- Model building in both “hard” and “soft” sciences
- Simulation is a driving force for computational science

Multi-field / High-dim

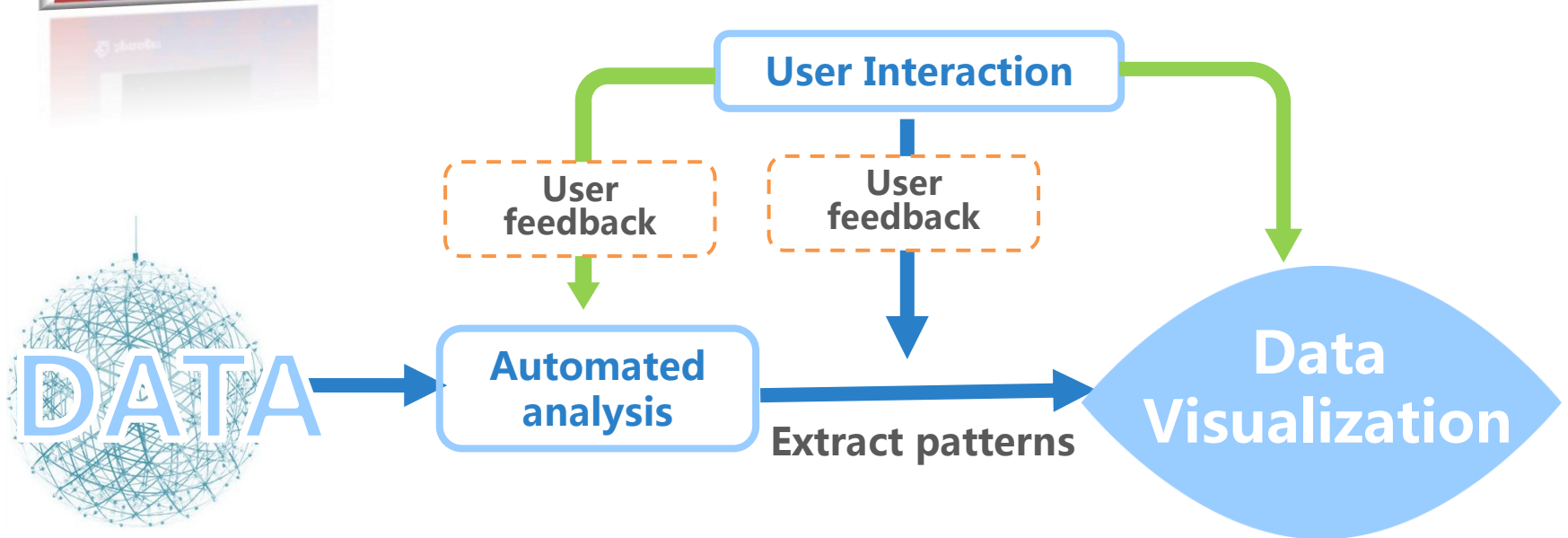
- Sampling
- Rendering / Display
- Features
- Computing uncertainty
- Cognition
- Design
- Ethnography
- Conveying sensitivity

What about *Visual Analytics*?

What is Visual Analytics?

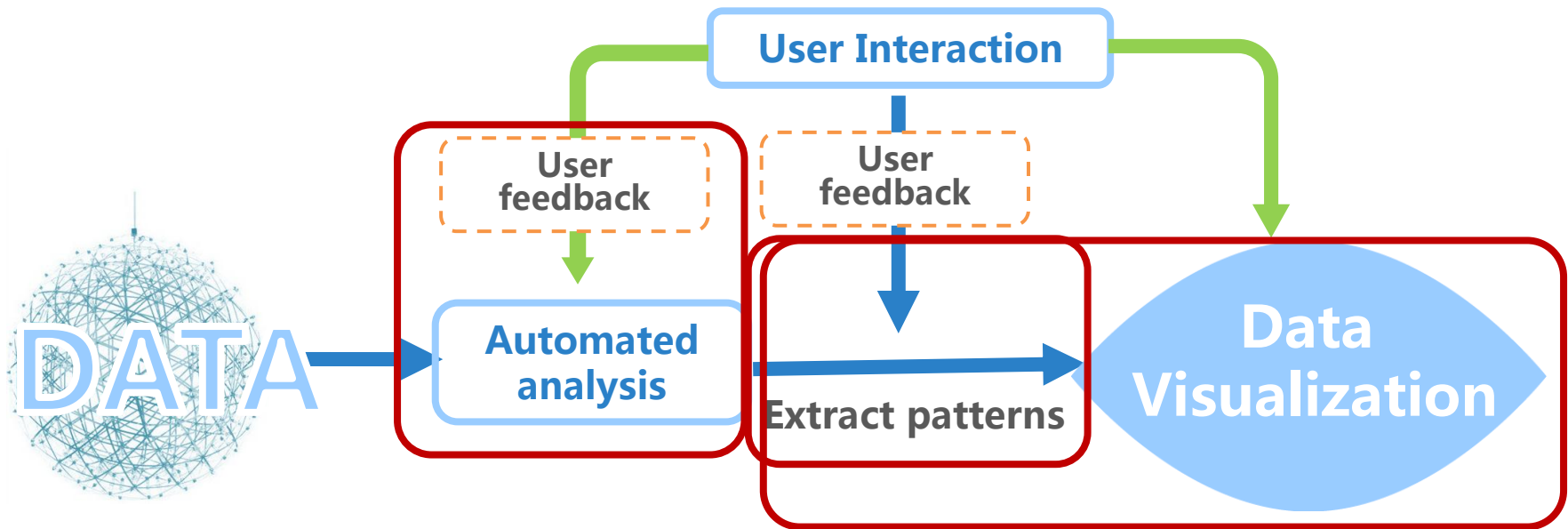


Visual analytics combines **automated analysis** techniques with **interactive visualizations** for an effective understanding, reasoning and decision making on the basis of very large and complex dataset



Challenges in Visual Analysis

- ◆ Visualization might not encode all pattern information
- ◆ Patterns might not be interactable
- ◆ User feedback might not be incorporated into the automated analysis



History of Visual Analytics

- 1963 – Ivan Sutherland developed SketchPad
- 1968 – Ray Tracer developed by Appel
- **1969 – Andy van Dam founded ACM SIGGRAPH**
- 1975 – Phong Shading and Scatterplot Matrix introduced
- 1979 – Volume Rendering introduced
- 1982 – TRON Released by Disney; SGI founded
- 1987 – Special Issue on Visualization in Scientific Computing
- **1990 – First IEEE Visualization Conference**
- 1992 – OpenGL released by SGI
- 1993 – Doom and Myst Released
- **1995 – First IEEE Information Visualization Symposium**
- 1996 – Founding of Spotfire; First generation GPUs released (ATI Rage, nVidia TNT2, 3dfx Voodoo3)
- 2003 – Founding of Tableau Software
- 2005 – Thomas and Cook published *Illuminating the Path*
- **2006 – First IEEE Visual Analytics Science and Technology Symposium**
- **2012 – renamed as the IEEE Conference on Visual Analytics Science and Technology**

ACM SIGGRAPH

IEEE Visualization

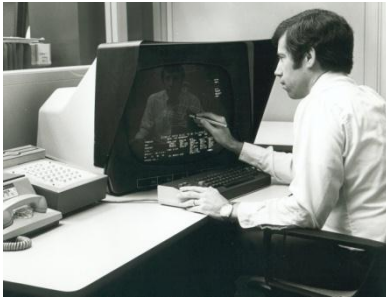
IEEE Information
Visualization

IEEE Visual
Analytics

History of Visual Analytics

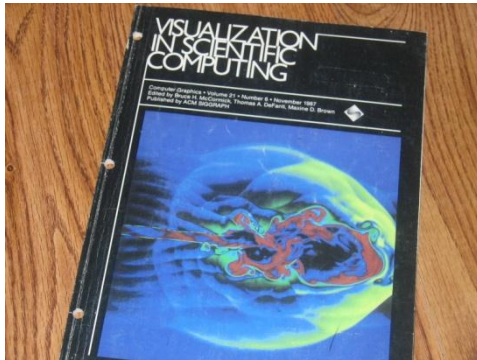
- **70s to 80s**

- CAD/CAM Manufacturing, cars, planes, and chips
- 3D, education, animation, medicine, etc.



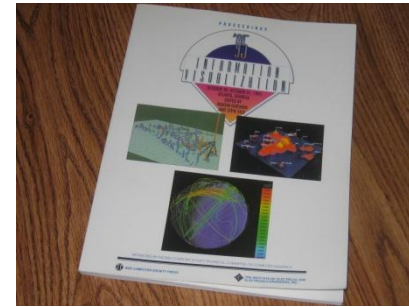
- **80s to 90s**

- Scientific visualization
- Realism, entertainment



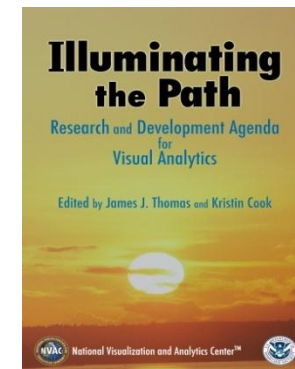
- **90s to 2000s**

- Information visualization
- Web and Virtual environments



- **2000s to 2010s**

- Visual Analytics
- Visual/audio appliances



Why Visual Analytics?

The growth of data is exceeding our ability to analyze them.

The amount of digital information generated is growing exponentially...

2002: 22 EB (exabytes, 10^{18})

2006: 161 EB

2010: 988 EB (almost 1 ZB)



"... and what's more, my databank has more data than you databank!"

Why Visual Analytics?

The data is often complex, ambiguous, noisy. Analysis of which requires human understanding.

About 2 GB of data is being produced per person per year

95% of the Digital Universe's information is unstructured

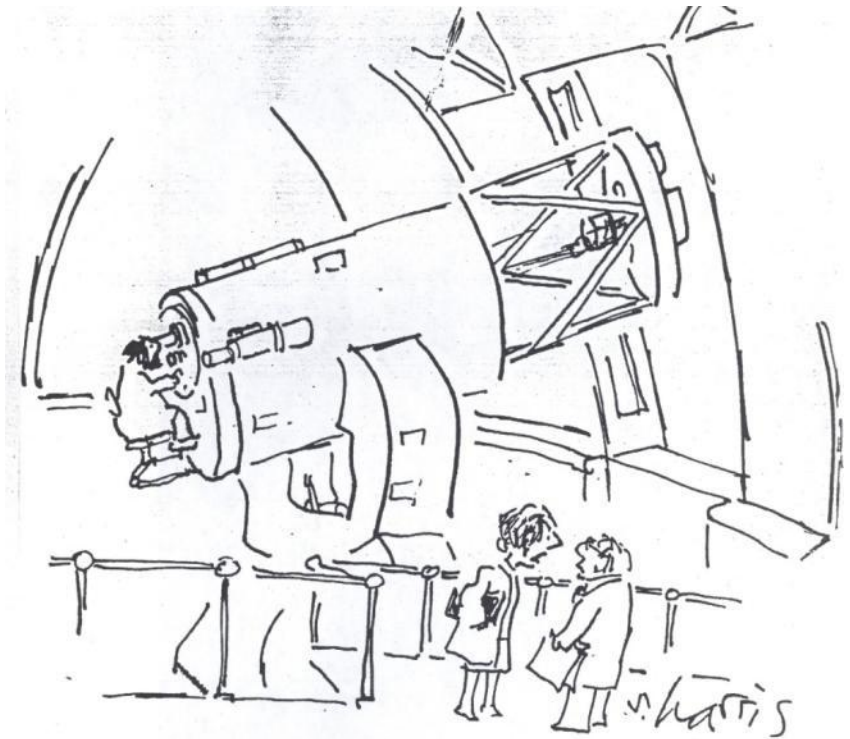
There isn't enough man-power to analyze and visualize all the data, and the problem is getting worse!

Solution: help the user

Find patterns

Filter out noise

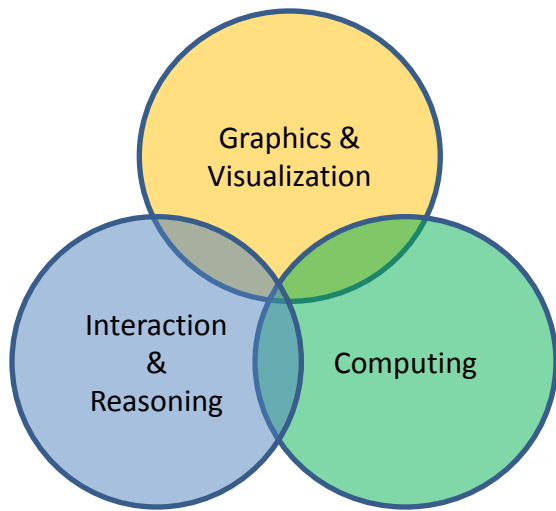
Focus on the important stuff



"THE REASON HE'S NEVER SEEN A CONSTELLATION IS HE'S CONVINCED THERE REALLY ARE WHITE LINES CONNECTING THE STARS."

Why Visual Analytics?

- **“The sexy job in the next 10 years will be statisticians,”** said Hal Varian, chief economist at Google. “And I’m not kidding.”
- Yet data is merely the raw material of knowledge. “We’re rapidly entering a world where everything can be monitored and measured,” said Erik Brynjolfsson, an economist and director of the Massachusetts Institute of Technology’s Center for Digital Business. **“But the big problem is going to be the ability of humans to use, analyze and make sense of the data.”**
- “The key is to **let computers do what they are good at**, which is trawling these massive data sets for something that is mathematically odd,” said Daniel Gruhl, an I.B.M. researcher whose recent work includes mining medical data to improve treatment. “And that **makes it easier for humans to do what they are good at** — explain those anomalies.”¹



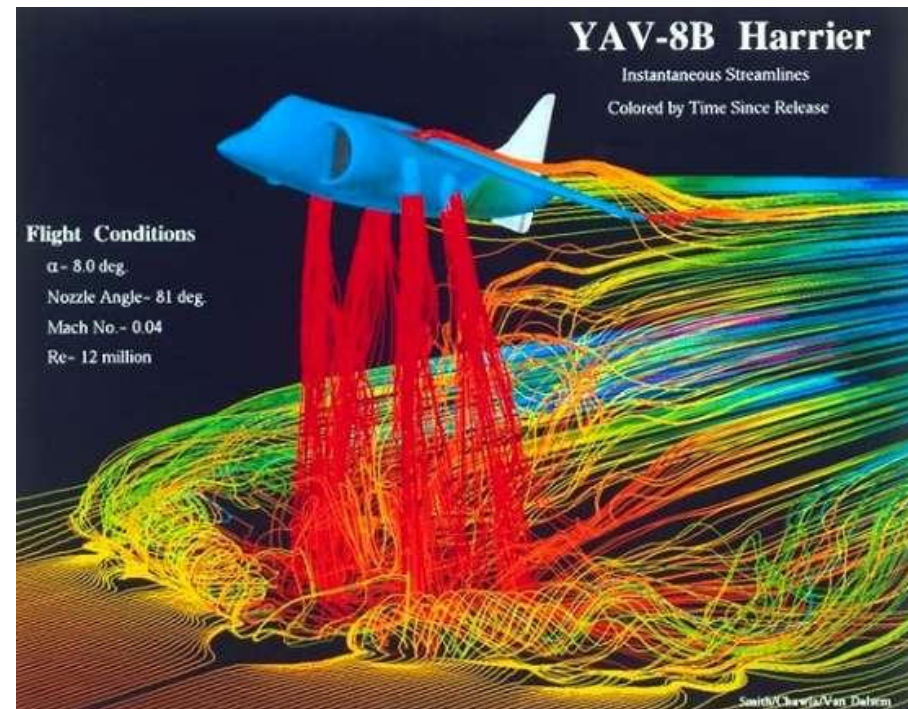
What is Visual Analytics?

The goal of visualization is to:

Ease understanding of the data by providing an effective visual representation

Amplify Perception

*Detect the Expected,
Discover the Unexpected™*



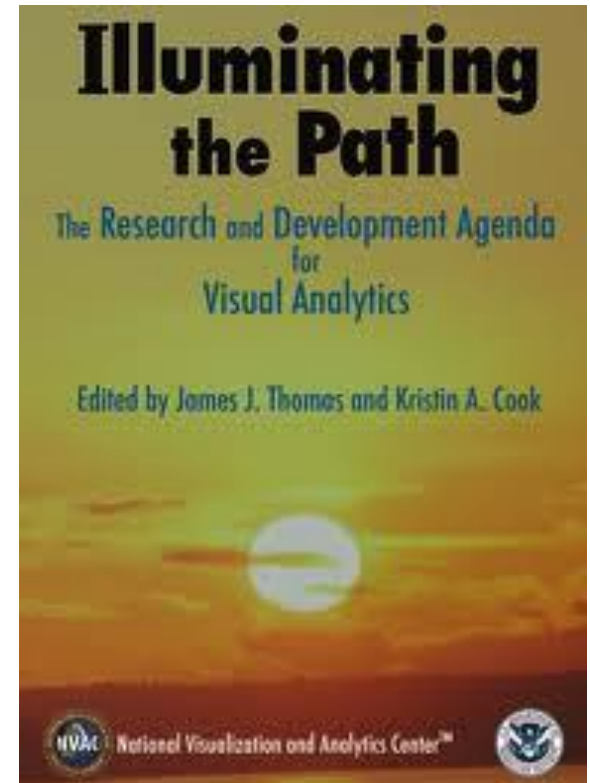
What is Visual Analytics?

- Visualization plus...
 - data representation
 - interaction & analysis
 - dissemination & story telling
 - a scientific approach
 - (evaluation)
- *Visual Analytics is the science of the science of analytical reasoning facilitated by visual interactive interfaces*
- *Congress: Visual analytics provides the last 12 inches between the masses of information and the human mind to make decisions*



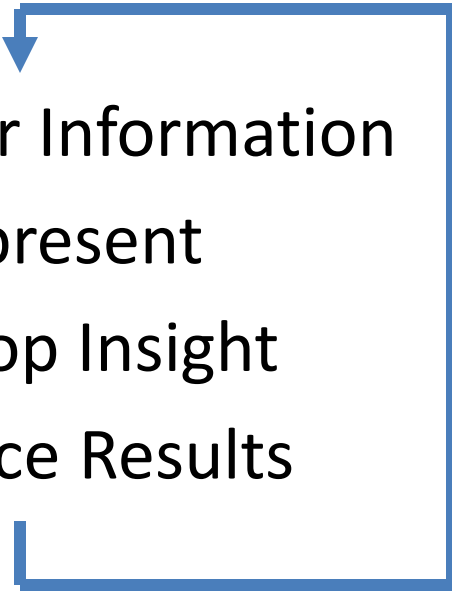
Illuminating the Path

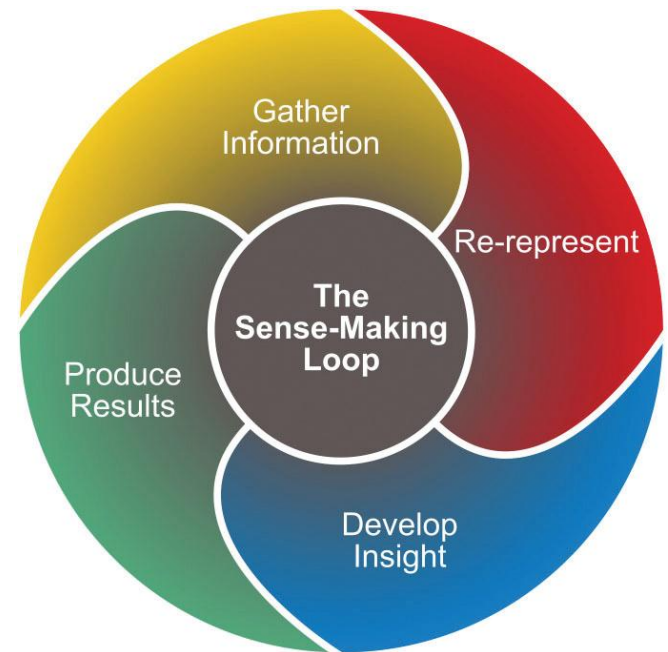
- The text book that we'll be using in this class is called "*Illuminating the Path: The Research and Development Agenda for Visual Analytics*"
- Video:
<http://nvac.pnl.gov/agenda.stm>



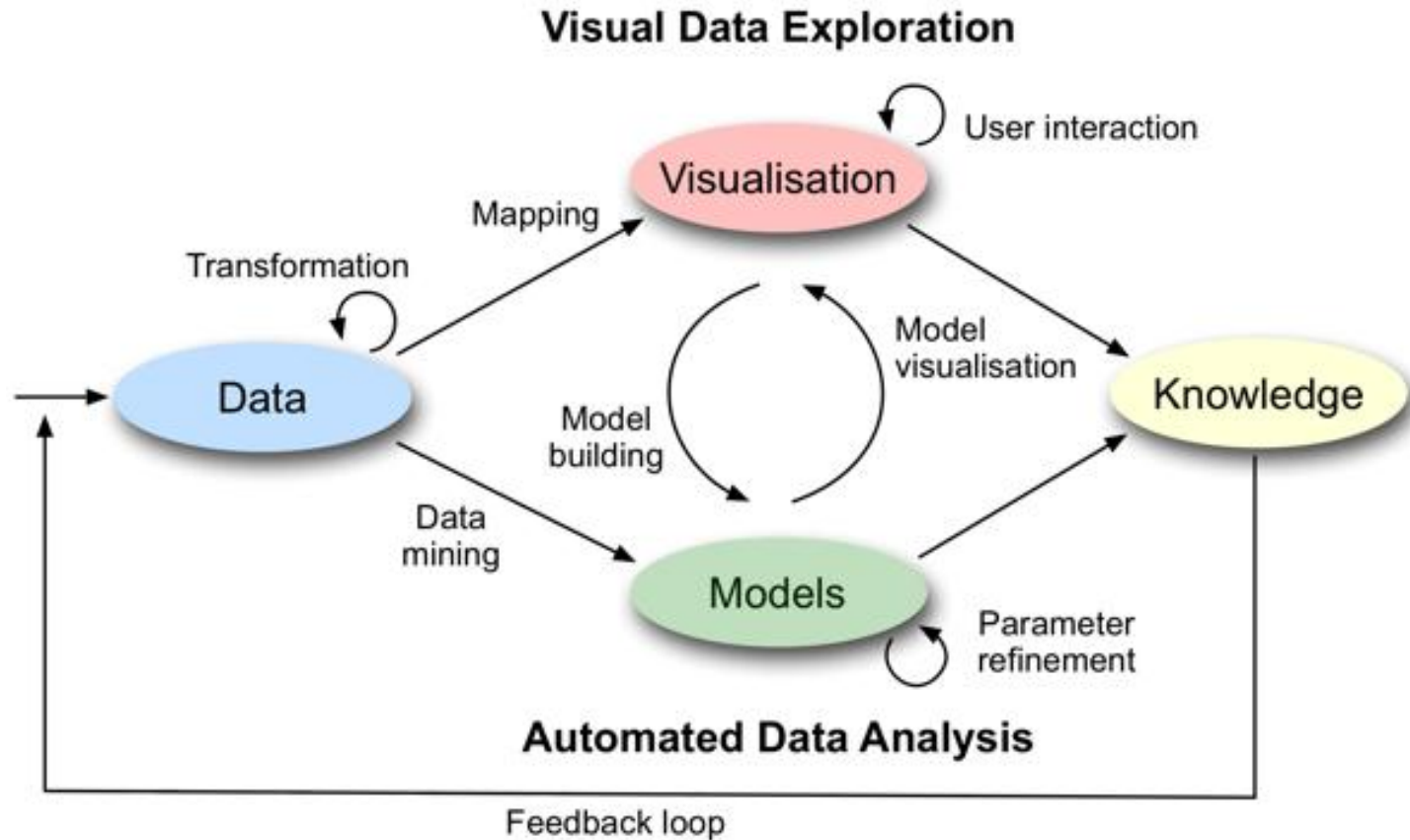
The Analytical Reasoning Process

- The Sense-Making Loop:

- 
- Gather Information
 - Re-represent
 - Develop Insight
 - Produce Results

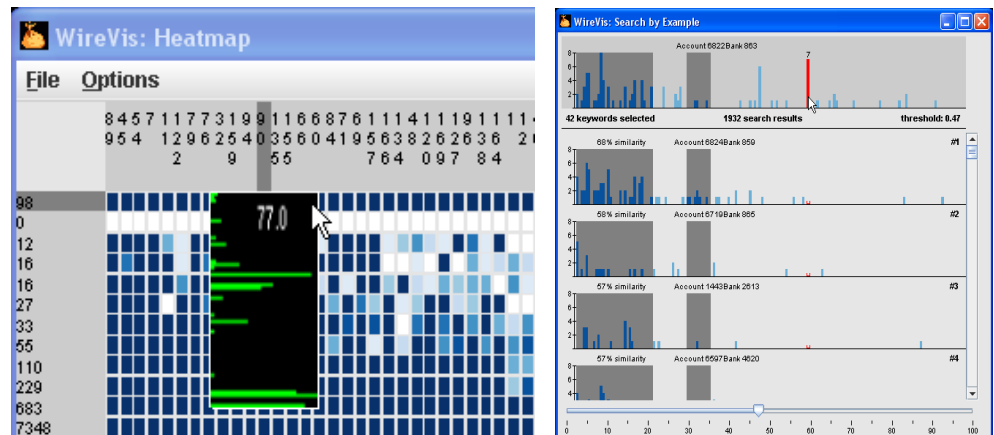
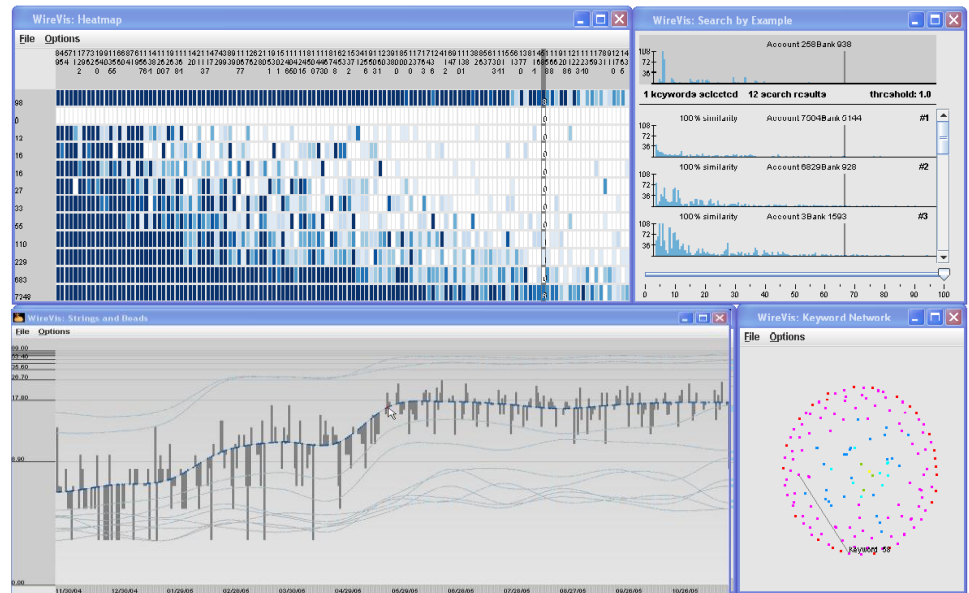


The visual analytics process



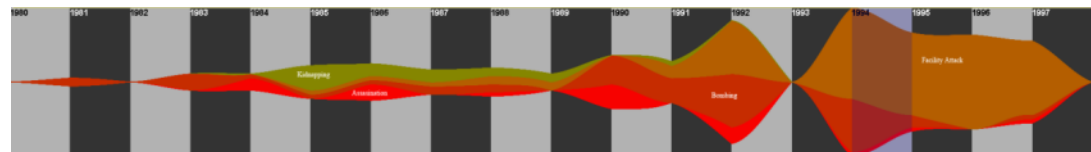
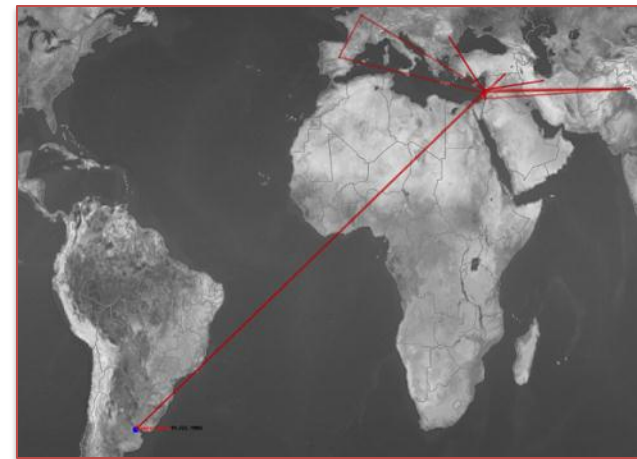
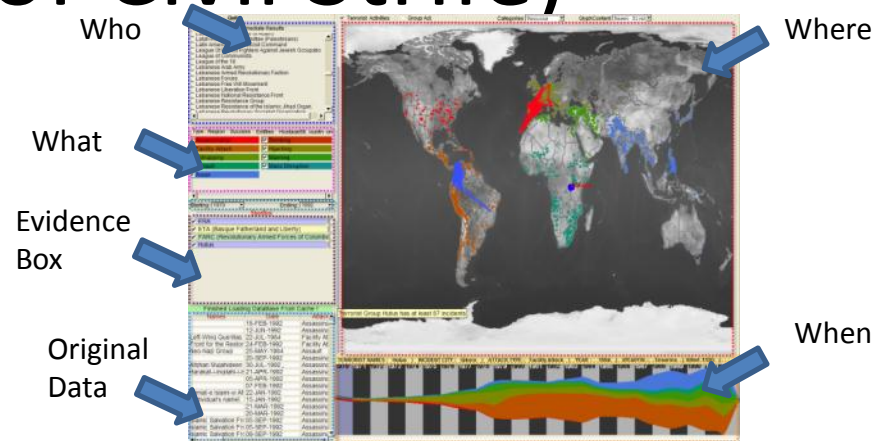
Examples of Visual Analytics Systems (Financial Fraud)

- Wire Fraud Detection
 - With Bank of America
 - Hundreds of thousands of transactions per day
- Global Terrorism
 - Application of the investigative 5 W's
- Bridge Maintenance
 - With US DOT
 - Exploring subjective inspection reports
- Biomechanical Motion
 - Interactive motion comparison methods



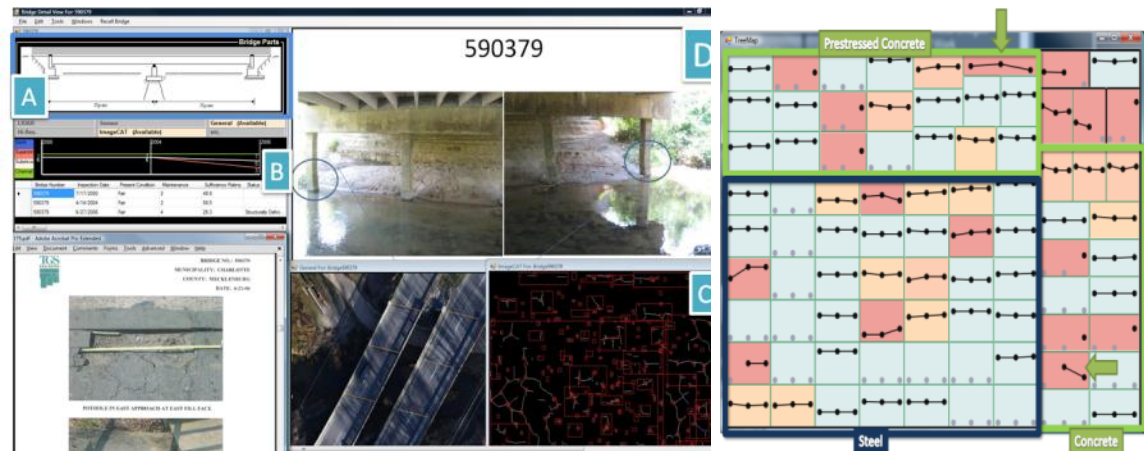
Examples of Visual Analytics Systems (Analysis of Civil Strife)

- Wire Fraud Detection
 - With Bank of America
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- Global Terrorism
 - Application of the investigative 5 W's
- Bridge Maintenance
 - With US DOT
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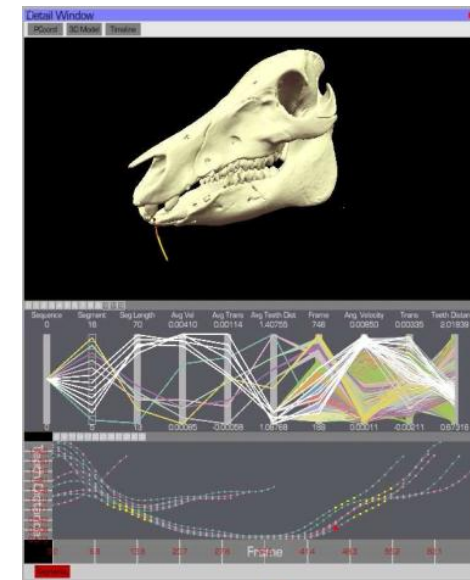
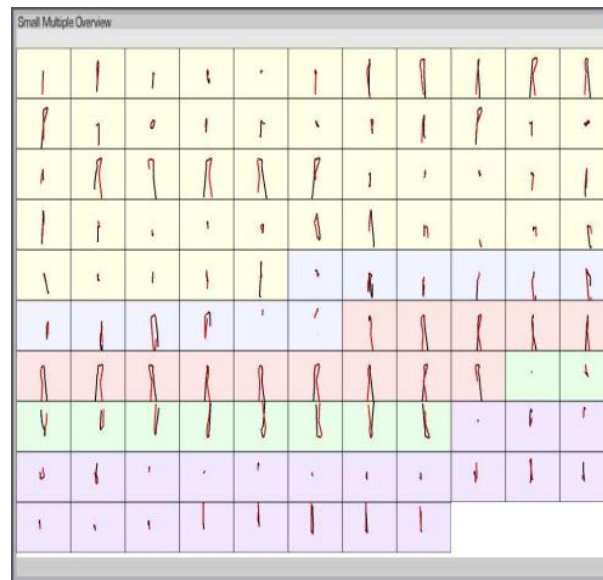
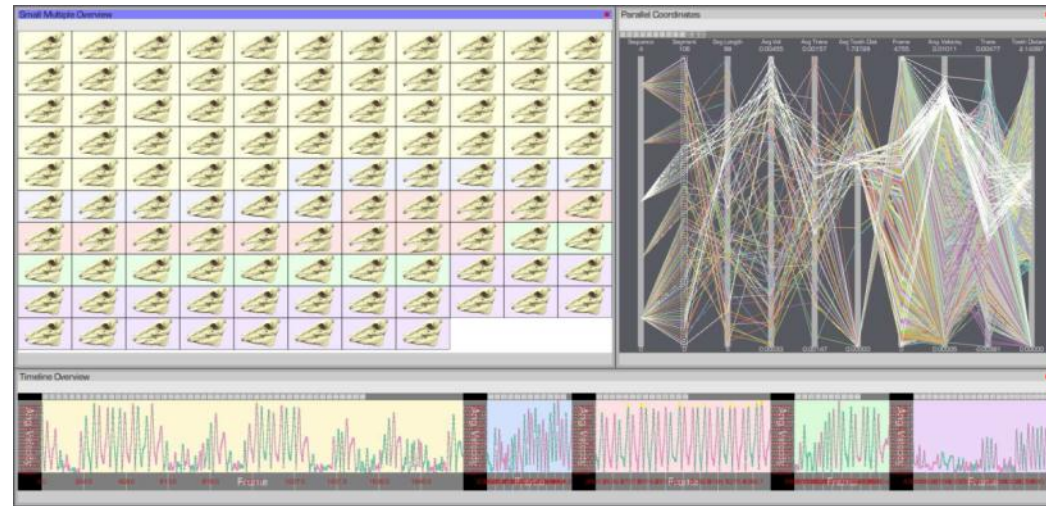
Examples of Visual Analytics Systems (Transportation Analysis)

- Wire Fraud Detection
 - With Bank of America
 - Hundreds of thousands of transactions per day
- Global Terrorism
 - Application of the investigative 5 W's
- Bridge Maintenance
 - With US DOT
 - Exploring subjective inspection reports
- Biomechanical Motion
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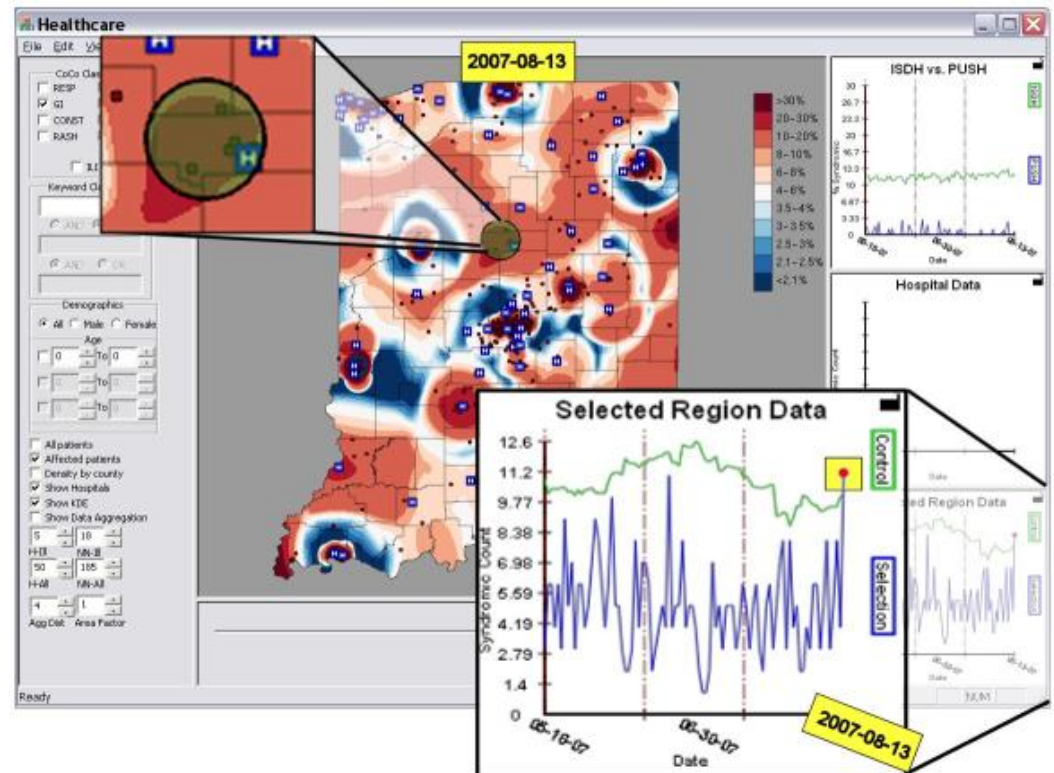
Examples of Visual Analytics Systems (Biomechanical Motion)

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Other Examples of Visual Analytics Systems (Pandemic / Healthcare)

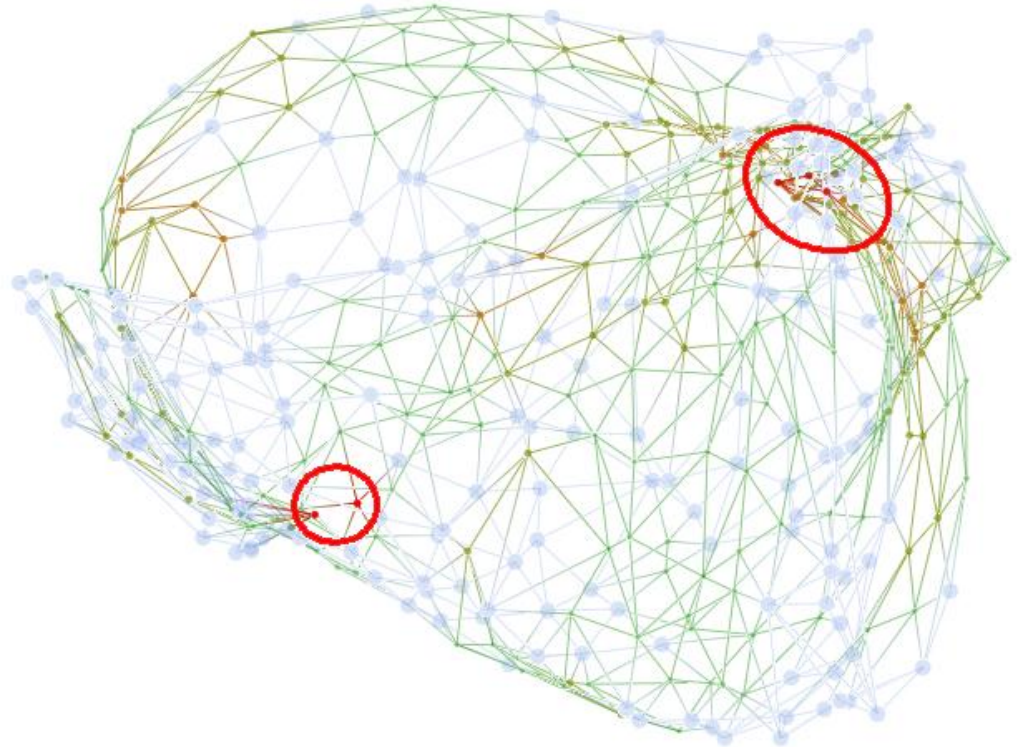
- Healthcare
 - Unreliable data sources
 - Spatiotemporal analysis
- Network Security
 - Large amounts of transactional data
- Energy / Power Grid
 - Graph-based visualization
 - Identifies failure points in the system
- Multimedia Analysis
 - Text analysis
 - Image and video analysis



Courtesy of R. Maciejewski, Purdue University

Other Examples of Visual Analytics Systems (Network Security)

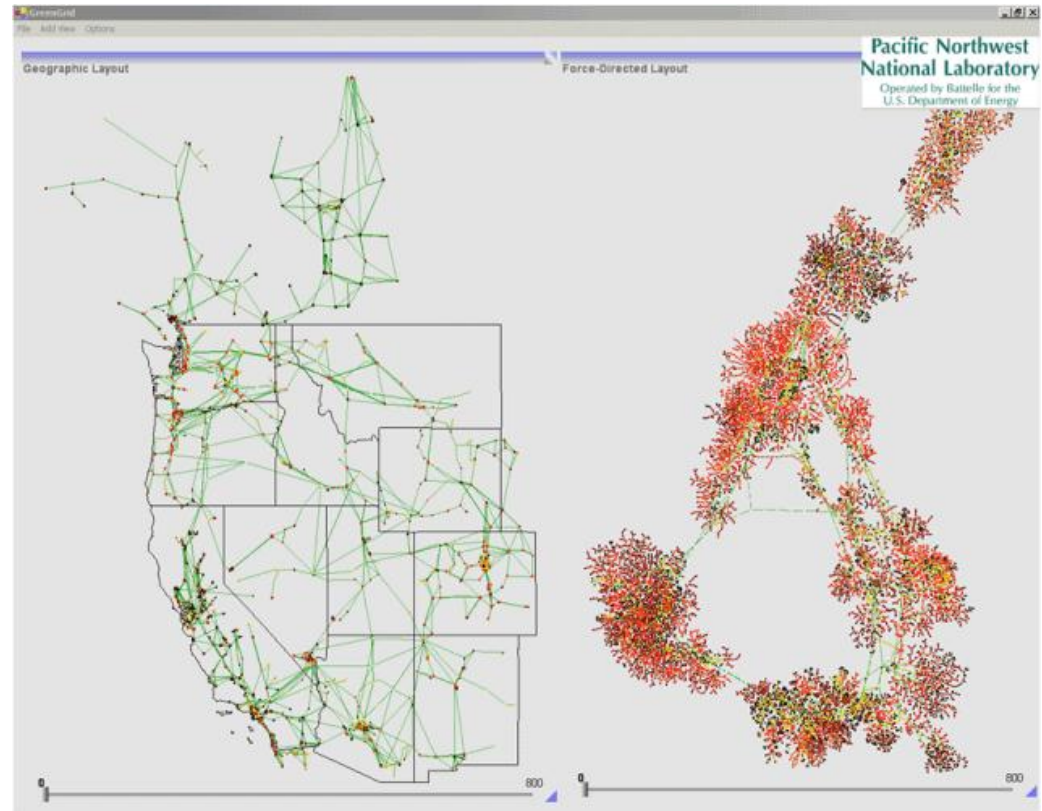
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 - Text analysis
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Courtesy of A. Lu, UNC Charlotte

Other Examples of Visual Analytics Systems (Energy / Power Grid)

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 - Graph-based visualization
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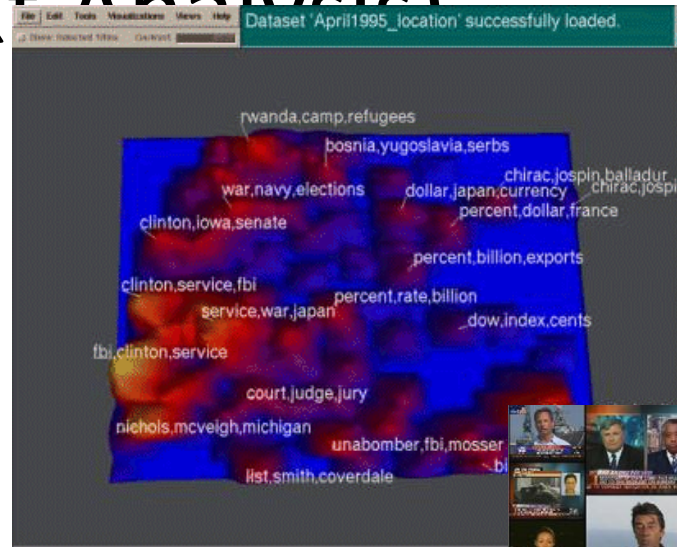


Courtesy of Pacific Northwest National Lab

Other Examples of Visual Analytics Systems

(Text Analysis)

- Healthcare
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Courtesy of Pacific Northwest National Lab

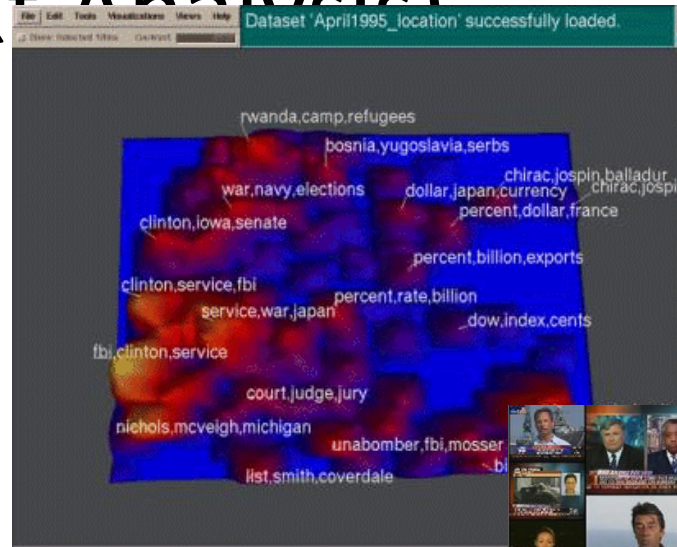


Courtesy of J. Fan, UNC Charlotte

Other Examples of Visual Analytics Systems

(Text Analysis)

- Healthcare
 - Unreliable data sources
 - Spatiotemporal analysis
- Network Security
 - Large amounts of transactional data
- Energy / Power Grid
 - Graph-based visualization
 - Identifies failure points in the system
- Multimedia Analysis
 - Text analysis
 - Image and video analysis
- And Many Others!



Courtesy of Pacific Northwest National Lab



Courtesy of J. Fan, UNC Charlotte

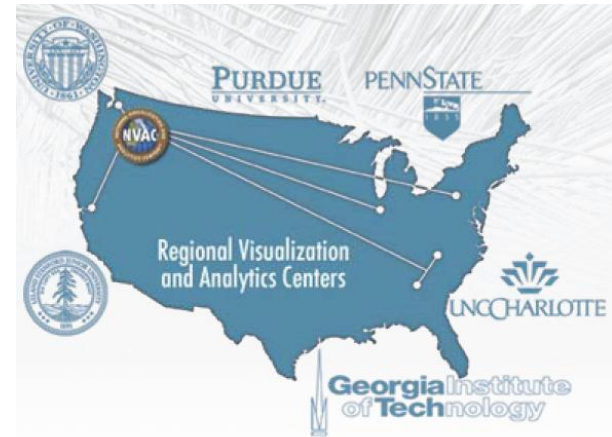
Research Challenges

- Scale
 - Scale of data
 - Scale of visualization
 - Scale of analysis
- Incorporating automated computing
 - Dimension reduction
 - Identifying trends, patterns, and outliers
 - Integration with human analysis
- Understanding human cognition
 - In different situations
 - In overcoming biases
 - In relating to personalities
- Analytical provenance
 - Report generation
 - Validation and verification of results
- Many others...



Visual Analytics Research in the US

- Five regional centers
 - Stanford University
 - University of Washington
 - Purdue University
 - Pennsylvania State University
 - University of North Carolina at Charlotte



National Visualization and Analytics Center™

Some useful websites

- Visual complexity

<http://www.visualcomplexity.com/vc/>

- Information Aesthetics

<http://infosthetics.com/>

- IBM many eyes

<http://manyeyes.alphaworks.ibm.com/manyeyes/>

- Swiver <http://www.swivel.com/>