Science of Science Research and Tools
Tutorial #02 of 12

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10a-noon, July 7, 2010

12 Tutorials in 12 Days at NIH—Overview

1st Week
1. Science of Science Research
2. **Information Visualization**
3. **CIShell Powered Tools: Network Workbench and Science of Science Tool**

2nd Week

4. **Temporal Analysis—Burst Detection**
5. **Geospatial Analysis and Mapping**
6. **Topical Analysis & Mapping**

3rd Week

7. **Tree Analysis and Visualization**
8. **Network Analysis**
9. **Large Network Analysis**

4th Week

10. **Using the Scholarly Database at IU**
11. **VIVO National Researcher Networking**
12. **Future Developments**

12 Tutorials in 12 Days at NIH—Overview

[#02] Information Visualization

- Introduction
- Designing Effective Visualizations
- Visualization Layers
- Visual Languages
- Promising Research Directions

Recommended Reading

- Information Visualization class at Indiana University, http://ella.slis.indiana.edu/~katy/S637-S10
- Edward R. Tufte (1990) Envisioning Information. Graphics Press.
- Edward R. Tufte (1992) The Visual Display of Quantitative Information. Graphics Press.
- Edward R. Tufte (1997) Visual Explanations: Images and Quantities, Evidence and Narrative. Graphics Press.
- Colin Ware (1999) Information Visualization: Perception for Design, Morgan Kaufmann Publishers.

[#02] Information Visualization

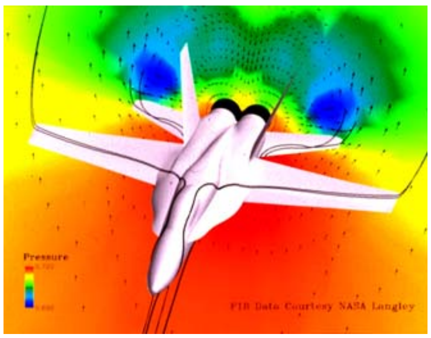
- **Introduction**
- **Designing Effective Visualizations**
- **Visualization Layers**
- **Visual Languages**
- **Promising Research Directions**

Information Visualization - Definition

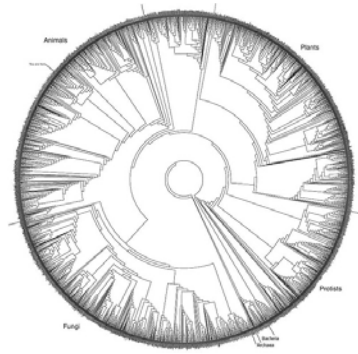
"Information Visualization is a process of transforming data and information that are not inherently spatial, into a visual form allowing the user to observe and understand the information."

(Source: Gershon and Eick, First Symposium on Information Visualization)

Scientific Visualization



Information Visualization



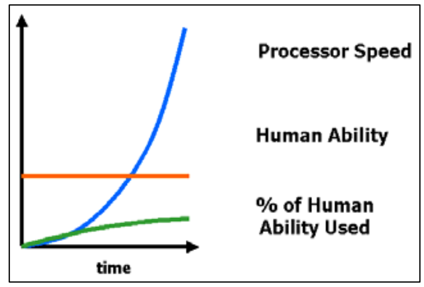
Information Visualization – Potential

- Rooted in geography, scientific visualization.
- Not even 20 years old.
- Growing fast.
- Interdisciplinary nature: computer graphics, electronic engineering, information systems, geography, information science, …

Well designed visualizations …

- Provide an ability to comprehend huge amounts of data.
- Reduce search time and reveal relations otherwise not being noticed (perception of emergent properties).
- Often reveal things not only about the data but how the data was collected - errors and artifacts jump out.
- Facilitate hypothesis formulation.
- Are effective sources of communication.

Information Visualization – Why Now?



- Information explosion.
- Work is becoming more 'knowledge-oriented'.

- Increasing computing power (doubles every 18 months - Moore's Law).
- Decreasing cost of storage.
- Fast graphics processors.
- Larger hard disk sizes -> more information available quickly.
- High resolution color monitors.
- Alternative user interfaces Idesk, CAVE (2 hands, audio, 3D).
- Connectivity between systems is expanding rapidly.

- Increasing visual intelligence.
- There is a bad mismatch between computer displays and the human perceptual system and between computer controls and human motor functions.

Information Visualization – Conferences and Journal

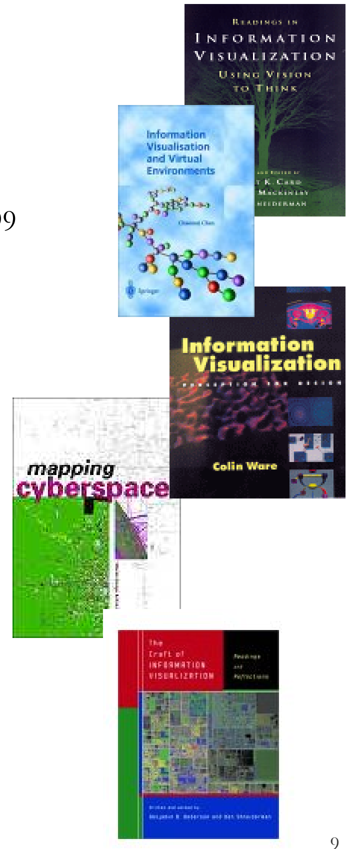
- IEEE Symposium on Information Visualization
- International Conference on Information Visualization
- Conference on Visual Data Exploration and Analysis
- SIGGRAPH

- Conference on Human Factors in Computing Systems
- International Conference on Human-Computer Interaction
- Intelligent User Interfaces
- Network Science Conference

- Publications of the ACM include IEEE symposium and conference on IV, SIGGRAPH, SIGIR, SIGCHI

- Information Visualization Journal, http://www.palgrave-journals.com/ivs

Information Visualization – Major Books



Readings in Information Visualization: Using Vision to Think
by Stuart K. Card, Jock D. MacKinlay, Ben Shneiderman, 1999
Information Visualization: Perception for Design
by Colin Ware, 1999
Information Visualisation and Virtual Environments
by Chaomei Chen, Nov 1999
Information Visualization
By Robert Spence, 2000, *http://www.booksites.net/spence*
http://www.ee.ic.ac.uk/research/information/www/Bobs.html
Mapping Cyberspace
by Martin Dodge and Rob Kitchin, 2000
http://www.mappingcyberspace.com/
The Craft of Information Visualization: Readings and Reflections
by Benjamin B. Bederson, Ben Shneiderman, 2003

More are listed on http://ella.slis.indiana.edu/~katy/S637-S09

Information Visualization – Recent Books

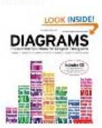
Beautiful Data: The Stories Behind Elegant Data S... by Toby Segaran (8) $40.09

Now You See It: Simple Visualization Techniques fo... by Stephen Few (14) $29.70

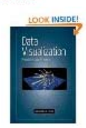
Beautiful Mapping: Leading Thinkers Demonstrate... by Turner Andrew $36.57

The Wall Street Journal Guide to Information Grap... by Dona M. Wong (13) $19.77

Data Flow 2: Visualizing Information in Graphic Design by R. Klanten (1) $49.14

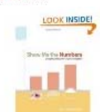


Diagrams: Innovative Solutions for Graphic Desi... by Jessica Glaser (1) $26.40



Data Visualization by Alexandru C. Telea (2) $55.20

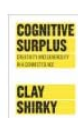
Bursts: The Hidden Pattern Behind Every... by Albert-Laszlo Barabasi (20) $17.79



Show Me the Numbers: Designing Tables and Graphs t... by Stephen Few (33) $29.70

Effective UI: The Art of Building Great User Exper... by EffectiveUI (12) $29.69

Visual Thinking: for Design (Morgan Kaufmann Series... by Colin Ware (3) $23.33



Cognitive Surplus: Creativity and Generosity in a... by Clay Shirky (9) $17.13

Information Dashboard Design: The Effective Visual... by Stephen Few (62) $23.09

Getting Started with Processing by Casey Reas (1) $13.59

Data Flow: Visualising Information in Graphic Design by R. Klanten (10) $49.14

[#02] Information Visualization

- Introduction
- Designing Effective Visualizations
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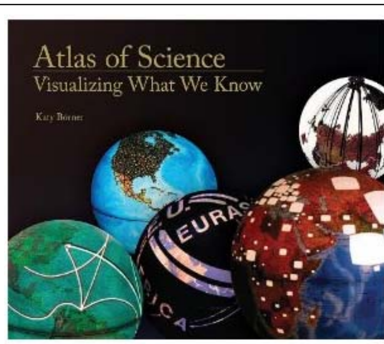
- Visual Languages
- Promising Research Directions

PRESENTING DATA AND INFORMATION:
A ONE-DAY COURSE TAUGHT BY EDWARD TUFTE

Everyone taking the course receives copies of all four books. The course is taught entirely by Edward Tufte.

"One visionary day....the insights of this class lead to new levels of understanding both for creators and viewers of visual displays." WIRED

"The Leonardo da Vinci of data." THE NEW YORK TIMES



Atlas of Science: Visualizing What We Know
[Hardcover]
Katy Börner (Author)

List Price: ~~$29.95~~
Price: **$19.77** & eligible for **FREE Super Saver Shipping** on orders over $25. Details
You Save: $10.18 (34%)
Pre-order Price Guarantee. Learn more.

This title has not yet been released.
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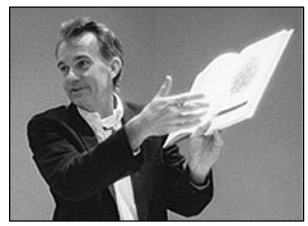
Designing Effective Visualizations

"The success of a visualization is based on deep knowledge and care about the substance, and the quality, relevance and integrity of the content." *(Tufte, 1983)*

Principle of Graphical Excellence

- Well-designed presentation of interesting data: substance, statistics, design.
- Complex ideas communicated with clarity, precision, and efficiency.
- Conveying the most knowledge in the shortest time with the least ink in the smallest space.
- It requires telling the truth about the data.
- It is nearly always multivariate.



(Tufte, 1983)

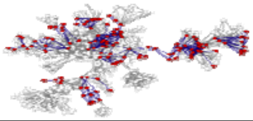
Five Principles in the Theory of Graphic Display

- Above all else show the data.
- Maximize the data-ink ratio, within reason.
- Erase non-data ink, within reason.
- Erase redundant data-ink.
- Revise and edit.

Visualizations should strive towards the following goals

- Focus on content of data not the visualization technique.
- Strive for integrity.
- Utilize classic designs and concepts proven by time.
- Comparative rather than descriptive visualizations.
- High resolution.

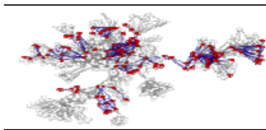
(Tufte, 1983)



Aesthetics

- Properly choose format and design
- Use words, numbers, drawings in close proximity
- Use lines of different weights as an attractive and compact way to display data.
- Reflect a balance, a proportion, a sense of relevant scale.
- Display an accessible complexity of detail.
- Let the graphics tell a story about the data.
- Avoid content-free decoration.
- Make use of symmetry to add beauty (although someone once said that "all true beauty requires some degree of asymmetry").
- Draw graphics an a professional manner, with the technical details of production done with care.

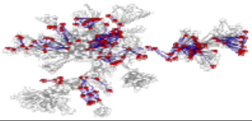
(Tufte, 1983)



Labeling

- Words spelled out.
- Words run left to right.
- Little messages explain data.
- Labels on the graphic; no legend needed.
- Graphic provokes curiosity.
- Blue contrasted with others.
- Clear, precise, modest type.
- Type is mixed case, with serifs

(Tufte, 1983)

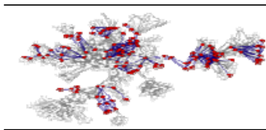


User Needs Driven Approach: General Tasks

Visualization can help to identify

- Trends in the data.
- Outliers.
- Jumps in the data (gaps).
- Maxima and minima like largest, smallest, most recent, oldest, etc.
- Boundaries (not the same as maxima or jumps).
- Clusters in the data.
- Structure in heterogeneous information.
- A particular item of interest within the context of an enormous amount of contextual data.

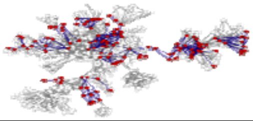
Each of these tasks requires a different visualization design!



Visual Encoding of Data (e.g., in a network)

- What data entities should be represented as nodes?
- What nodes are important?
- What relationships are important and should be represented as edges?
- What node/edge attributes are important and need to be encoded?
- What subset of nodes, edges, subgraphs need to be labeled and how?
- Are there aggregate attributes, e.g., clusters, that need to be communicated?
- Is there a temporal, geospatial, or semantic substrate that should augment the layout of nodes?
- Are there any existing metaphors that can guide the visual encoding of nodes, edges, and their attributes?

- How large is the network? What data can be omitted to provide users with a meaningful overview of the dataset?



Images and Words

- Words (mathematical symbols, natural language, music) are better for representing procedural information, logical conditions, abstract verbal concepts (freedom).
- Images (graphics, abstract & figurative imagery) are better for spatial structures, location, detail.
- Animation brings graphics closer to words in expressive capacity (causality, disassembly).

Images and words can be linked via

- Proximity
- Continuity/connectedness
- Common region
- Combinations thereof

Rules of thumb to integrate words and images:

- In written text - give text first then link to image.
- Highlight relevant part of info just before the start of relevant speech segment.
- Move viewpoint in visualization to draw attention to different features. Cinematography: Static scenes 'go dead' visually after a few glances.

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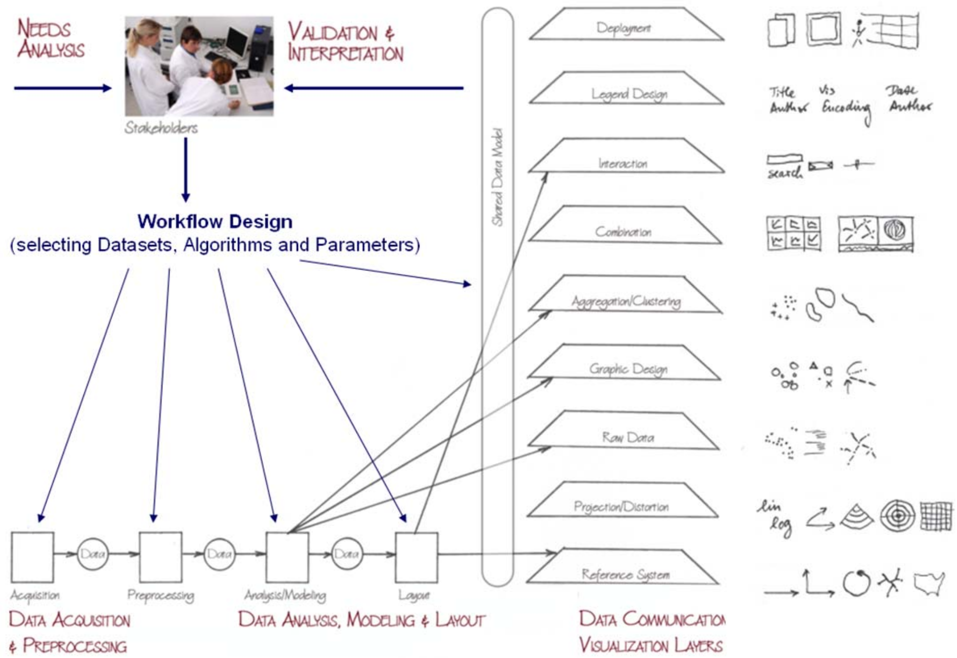
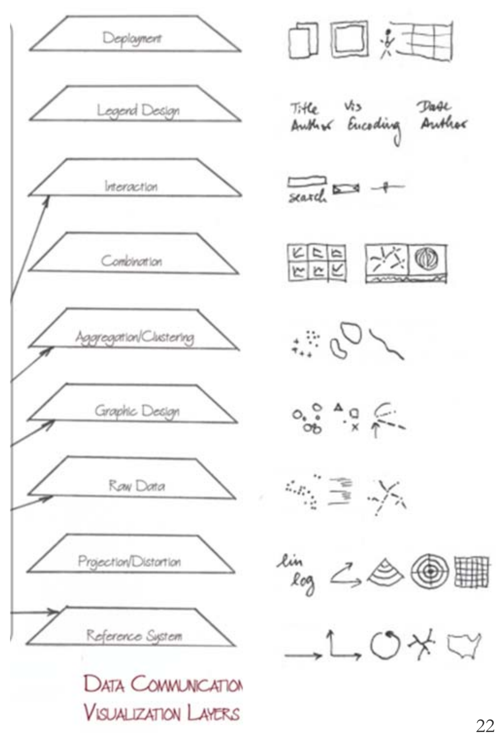
Needs-Driven Workflow Design using a modular data acquisition/analysis/modeling/visualization pipeline as well as modular visualization layers.



Börner, Katy (2010) *Atlas of Science*. MIT Press.

Needs-Driven Workflow Design using a modular data acquisition/analysis/modeling/visualization pipeline as well as modular visualization layers.

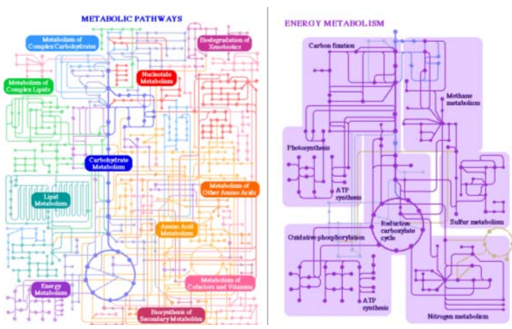
- **Deployment** of results is enabled through paper printouts, online animations, or interactive, three-dimensional, audiovisual environments.
- The **Legend Design** delivers guidance on the purpose, generation, and visual encoding of the data. Mapmakers should proudly sign their visualizations, adding credibility as well as contact information.
- In many cases, it is desirable to **Interact** with the data, that is, to zoom, pan, filter, search, and request details on demand. Selecting a data entity in one view might highlight this entity in other views.
- Sometimes it is beneficial to show multiple simultaneous views of the data, here referred to as **Combination**.
- Frequently, **Aggregation/Clustering** techniques are applied to identify data entities with common attribute values or dense connectivity patterns.
- **Graphic Design** refers to the visual encoding of data attributes using qualities such as size, color, and shape coding of nodes, linkages, or surface areas.
- Placing the **Raw Data** in a reference system reveals spatial patterns.
- **Projections/Distortions** of the reference system help emphasize certain areas or provide focus and context.
- **Reference Systems** organize the space.



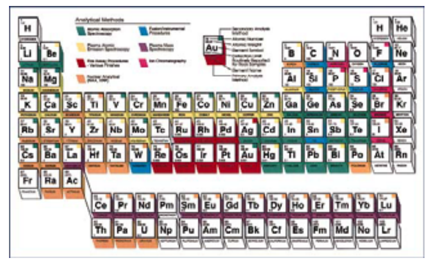
Reference System: organizing the display space.

Exercise

- Use known reference systems as much as possible.
- Provide overview map if space is large.
- Indicate user location and direction of view in map.
- Provide imagery of key landmarks and discrete but separately identifiable objects-there must be enough landmarks/objects that several are always visible at any instant.
- Strong visual cues indicating paths and regions help users understand structure of a space. Borders, boundaries and gridlines significantly improve navigation performance.



http://www.genome.ad.jp/kegg/pathway/map/map01100.html

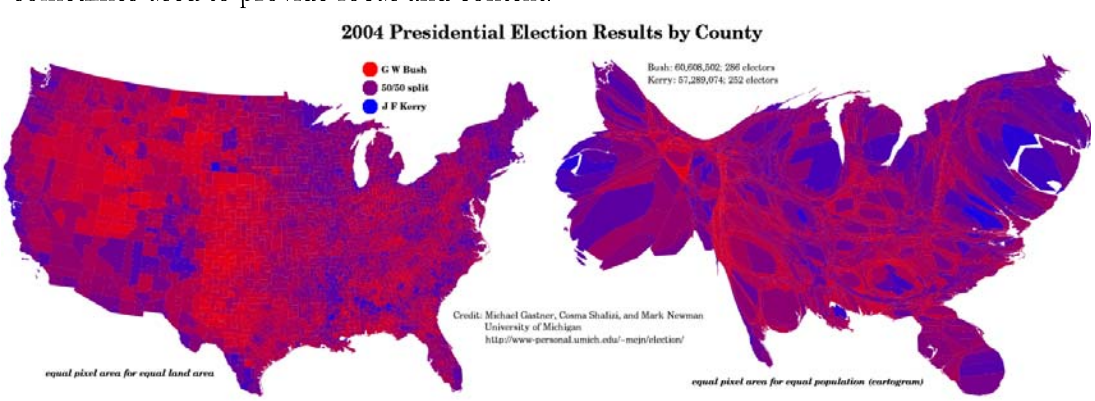


http://www.esemag.com/0300/elements.html

Projections/Distortions: Emphasize certain areas or provide focus and context.

Many (cartographic) **projections** exist. Projections are chosen such that distortions are minimized in accordance with map purpose.

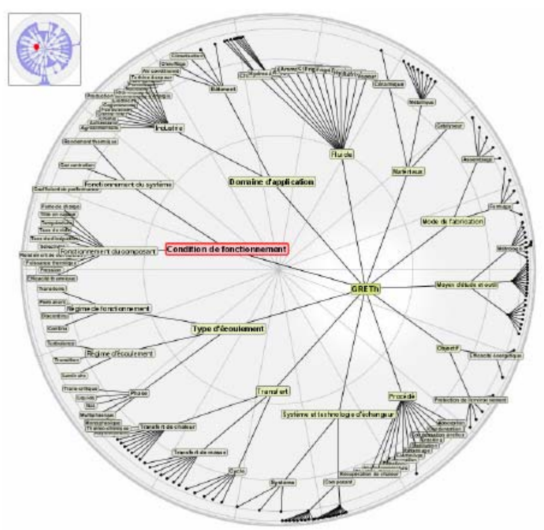
Distortion techniques such as equal-area cartograms (see below) are widely used for distorting the surface areas of countries according to given variables (for example, number of papers published). Given our familiarity with the world or U.S. map, these maps can be easily interpreted despite their distortion. Polar coordinates and hyperbolic spaces are sometimes used to provide focus and context.

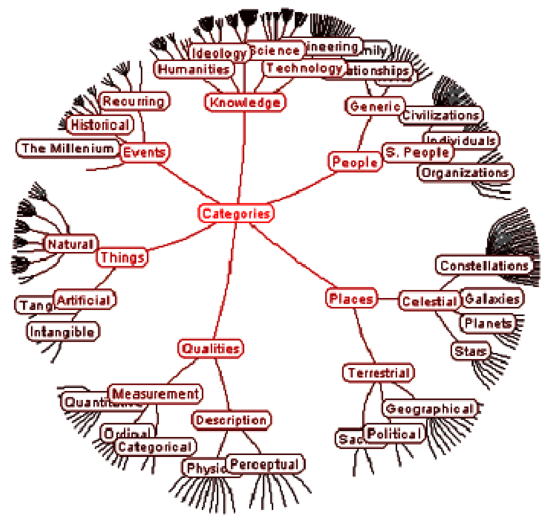


Gastner, Shalizi & Newman, 2004, http://www-personal.umich.edu/~mejn/election

Projections/Distortions: Emphasize certain areas or provide focus and context.

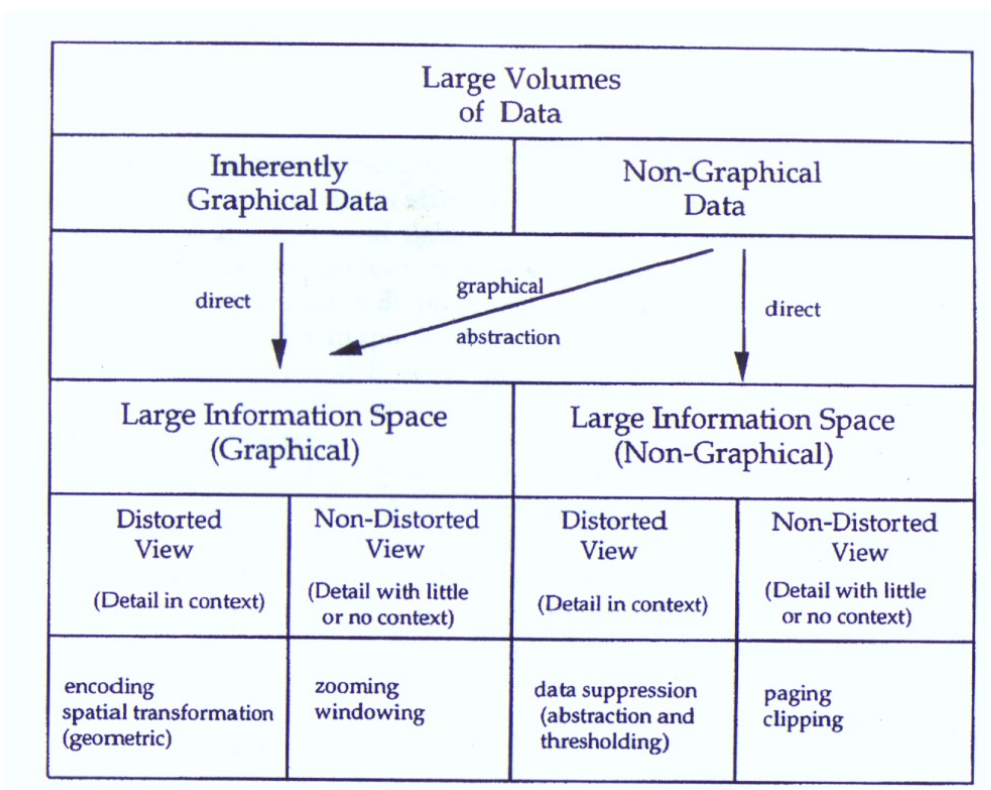
Polar coordinates (left) and hyperbolic spaces (right) are used to provide focus and context.



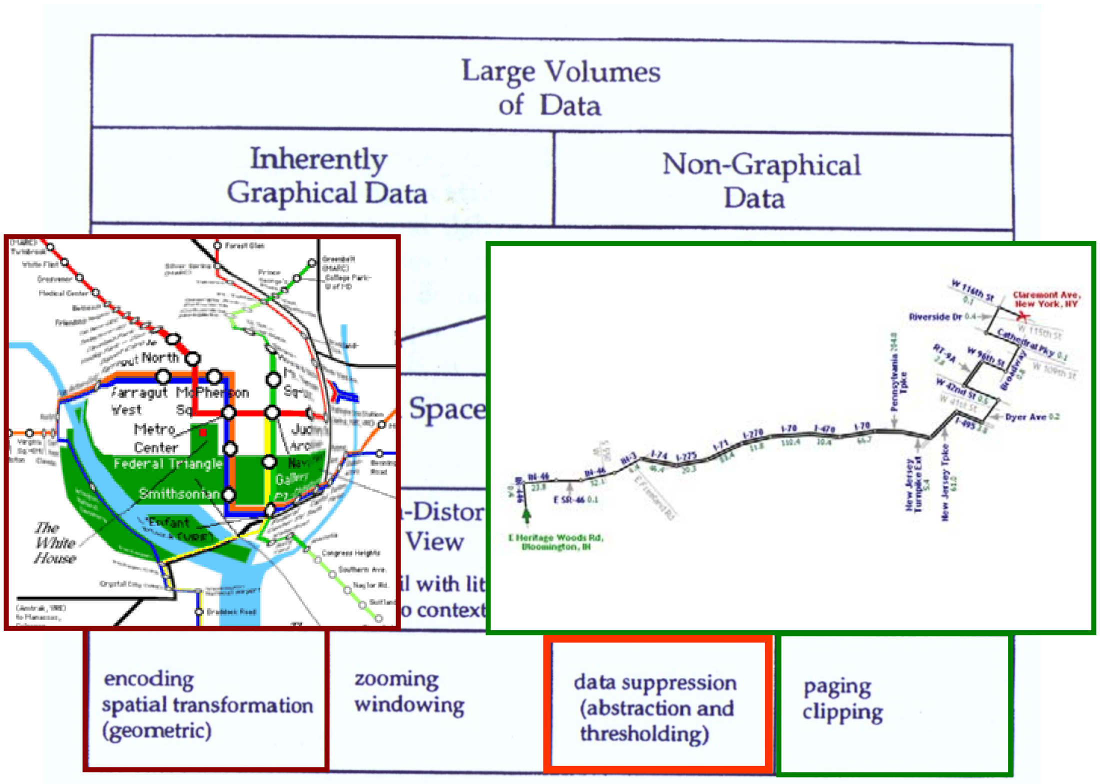


Visualisation of Ontology: a focus and context approach
Christophe Tricot and Christophe Roche

http://vw.indiana.edu/ivsi2004/jherr
Jeffrey Heer



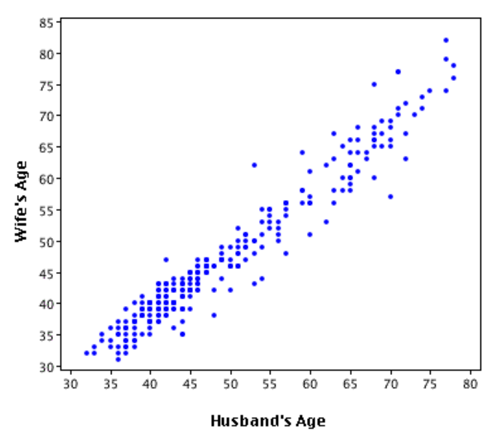
Leung, Y. K, Apperley, M. D., A Review and Taxonomy of Distortion-Oriented Presentation Techniques, ACM Transactions on Computer-Human Interaction, vol. 1 no 2, pp. 126160, 1994.

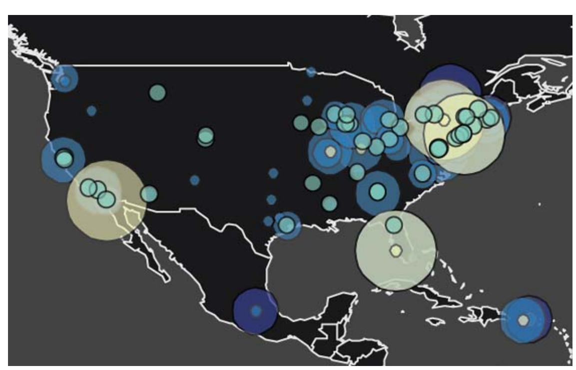


Leung, Y. K, Apperley, M. D., A Review and Taxonomy of Distortion-Oriented Presentation Techniques, ACM Transactions on Computer-Human Interaction, vol. 1 no 2, pp. 126160, 1994.

Raw Data: Reveal spatial patterns.

Density patterns and outliers may become visible, but data records having identical coordinates will appear as one data point.



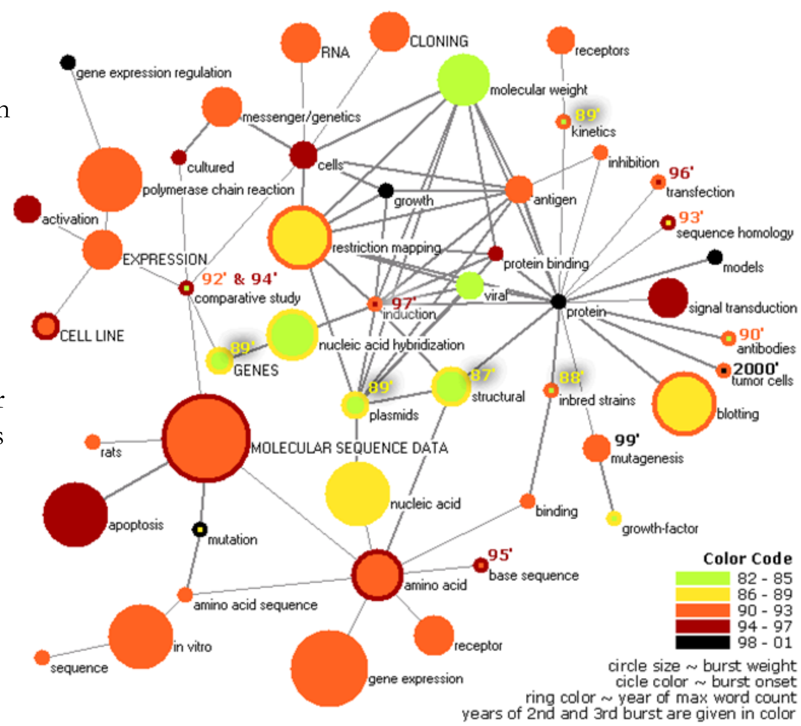


[*http://www.mzandee.net/~zandee/statistiek/stat-online*](http://www.mzandee.net/~zandee/statistiek/stat-online)

VIVO User Activity, see Tutorial 11

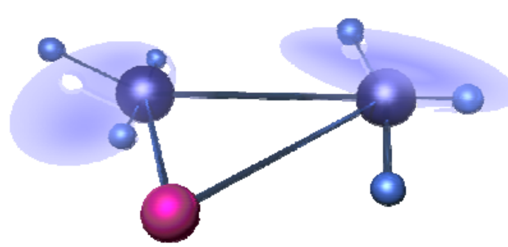
Graphic Design: Visually encoding data attributes using qualities such as size, color, and shape coding of nodes, linkages, or surface areas.

Most data records have multiple attributes, which can be represented by size-, color-, and shape-coding. Size-coding is made with the same coordinates; however, different attribute values make multiple records visible. Textual labels for major graphical elements help interpret a map. Landmarks ease navigation and exploration.



Aggregation/Clustering: Identify data entities with common attribute values or dense connectivity patterns.

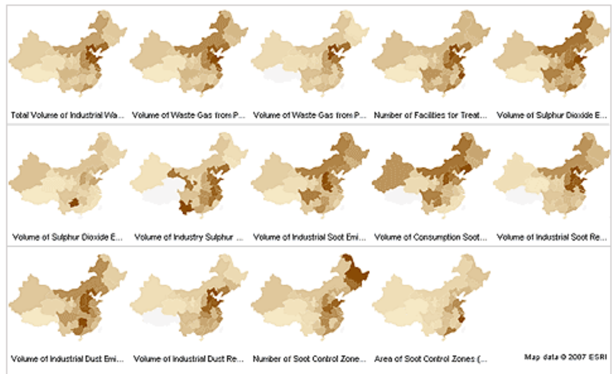
- High-density areas and limited screen/paper space often mandate the grouping of records into higher-level structures.
- For example, authors can be grouped by their geographic location or institution.
- Semantic spaces are often split into topic areas or network communities.
- Cluster boundaries can help to visually separate them.
- Network layouts often benefit from the identification of communities using betweenness centrality clustering, and the highlighting of backbone structures is calculated using pathfinder network scaling.



Combination: Show multiple simultaneous views of the data.

It is often beneficial to examine a data set from different perspectives—using **multiple, coupled windows**. For example, to look at the growth of a nation it might be beneficial to examine a geographic map of exported goods and a science map of federal funding with resulting patents.

Small multiples are graphical depictions of different attributes of a data set using the identical reference system—for example, a scatterplot. They can be examined within a user's eye span to support comparisons.



Small-multiples view: map of China showing several dimensions of air pollution.

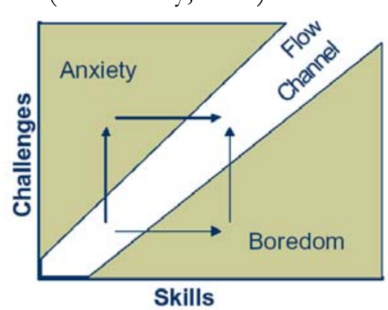
http://manyeyes.alphaworks.ibm.com/blog/2007/11

Interact: Zoom, pan, filter, search, request details on demand. Selecting a data entity in one view might highlight this entity in other views.

Often, data is too vast to be understood at once. Interaction via zooming and panning, exploration via brushing and linking, and access to details via search and selection are important. Ben Shneiderman's visual information seeking mantra—"Overview first, zoom and filter, then details-on-demand"—summarizes the major visual design guidelines.

Principles of interaction design

- Mapping between data and their visual representation should be fluid and dynamic. -> Principle of transparency - 'the tools itself disappear' (Rutkowsky, 1982).
- User obtains illusion of direct control.
- Provide visual feedback within 1/10 seconds (Shneiderman, 1987).
- Object constancy - use animation between displays instead of jumps.



ftp://ftp.cs.umd.edu/pub/hcil/Reports-Abstracts-Bibliography/2003-37html/2003-37.pdf

Legend Design: Communicate purpose, generation, and visual encoding of the data.

No visualization is complete without information on what data is shown and how it was processed, by whom, and when. As more advanced data preprocessing and analysis algorithms are developed, it becomes necessary to educate viewers on the effect of parameters and visualization layer instantiation decisions, which add credibility and support interpretation. Mapmakers should proudly sign their visualizations, adding credibility as well as contact information.

Each visualization should have a

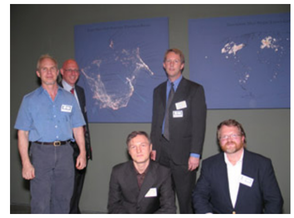
- Title
- Name of map maker
- Date of creation
- Explanation of all visual encodings, i.e., what do nodes, edges, colors, etc. represent?
- Information on dataset, dataset preparation, analysis.
- Short explanation of unique features and insights (if space permits).
- Web link(s) and/or reference(s) to additional information.

Deployment of results is enabled through paper printouts, online animations, or interactive, three-dimensional, audiovisual environments.

Static printouts
    High resolution of print
    No computer is in the way
Animations
    Show change over time
Interactive displays
    Zoom, pan, filter, details on demand
    Different simultaneous (coupled) views
Hands-on physical display
    Exploit spatial memory, touch sense
Hybrids
    Combine the best of different worlds –
    Illuminated Diagram

Illuminated Diagram Display

W. Bradford Paley, Kevin W. Boyack, Richard Kalvans, and Katy Börner (2007) Mapping, Illuminating, and Interacting with Science. SIGGRAPH 2007.



Large-scale, high resolution prints illuminated via projector or screen.

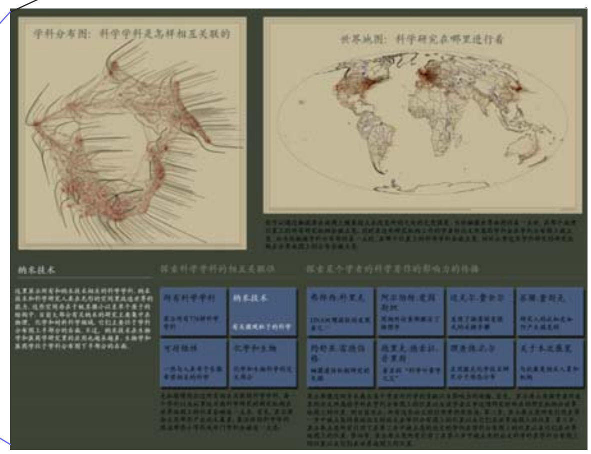
Interactive touch panel.

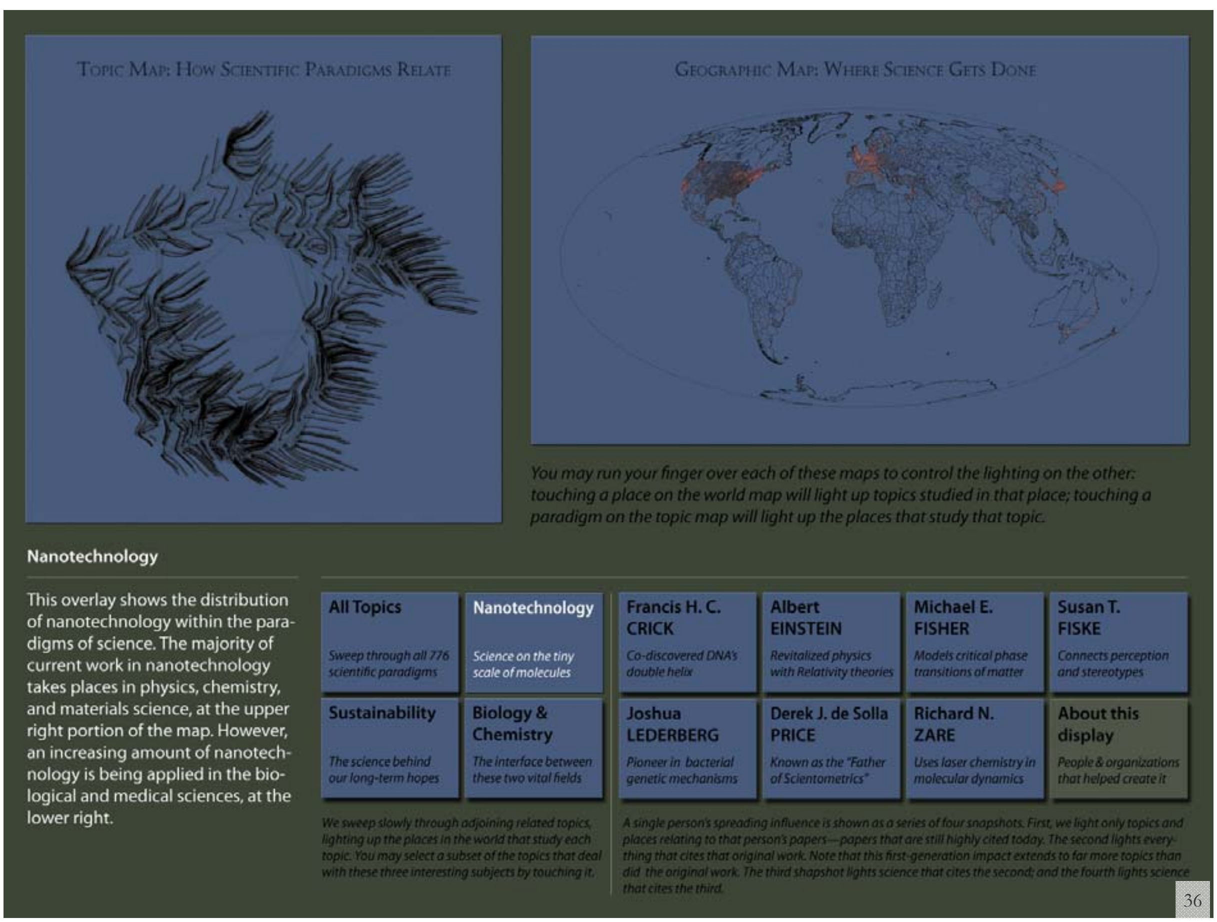
Questions:

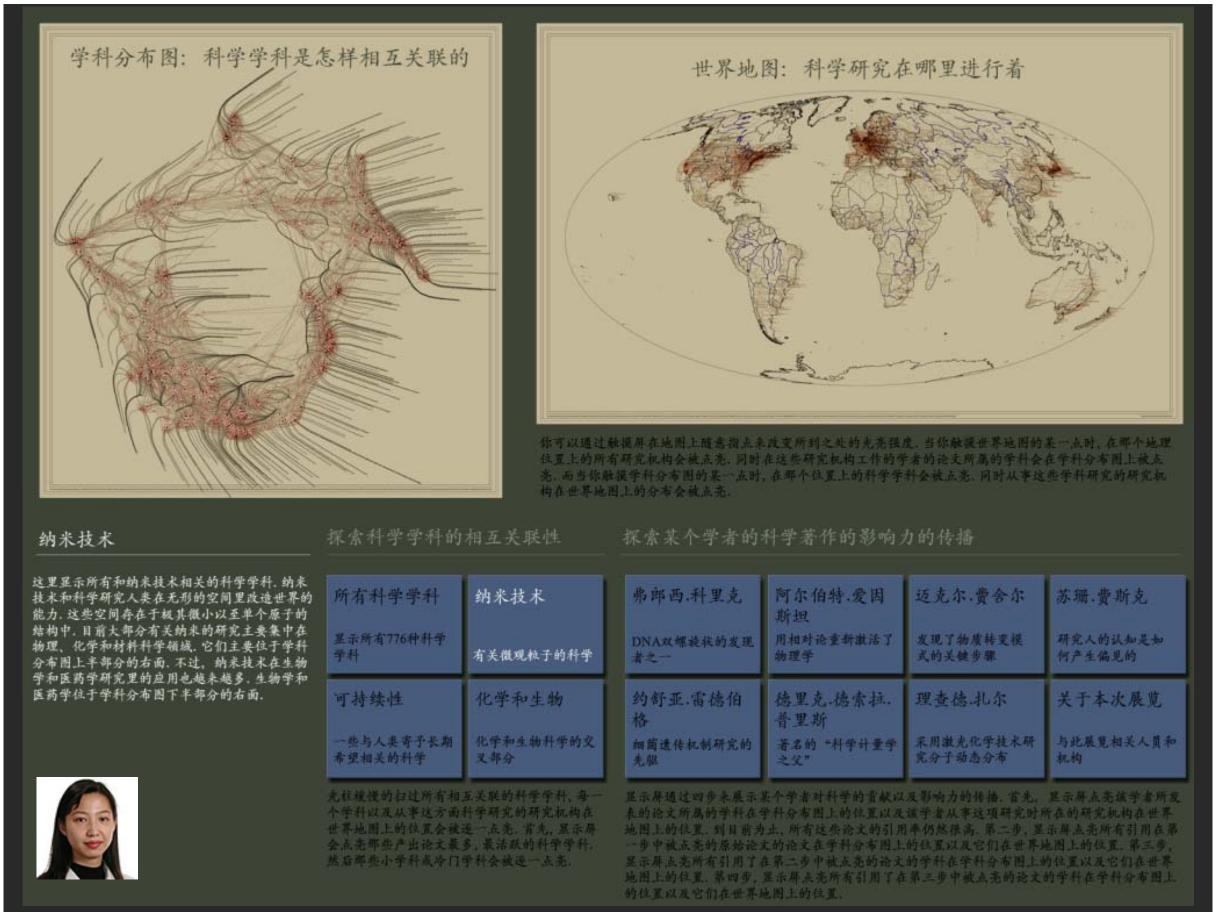
- Who is doing research on what topic and where?
- What is the 'footprint' of interdisciplinary research fields?
- What impact have scientists?

Contributions:

- Interactive, high resolution interface to access and make sense of data about scholarly activity.



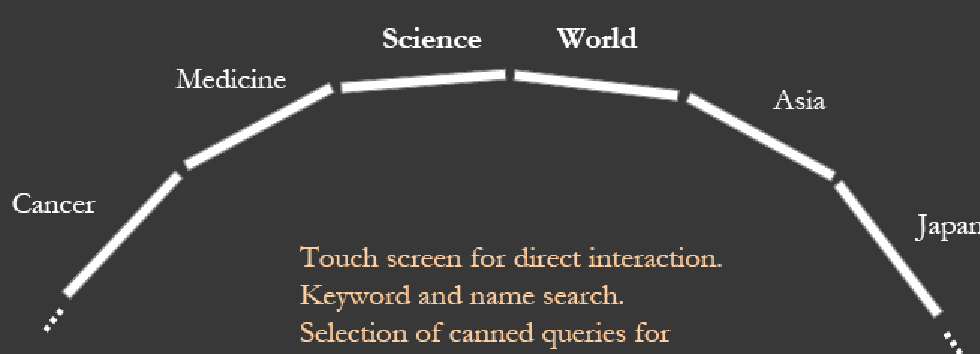




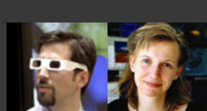
Re-implementation of Illuminated Diagram Software

by Advanced Visualization Lab, Indiana University

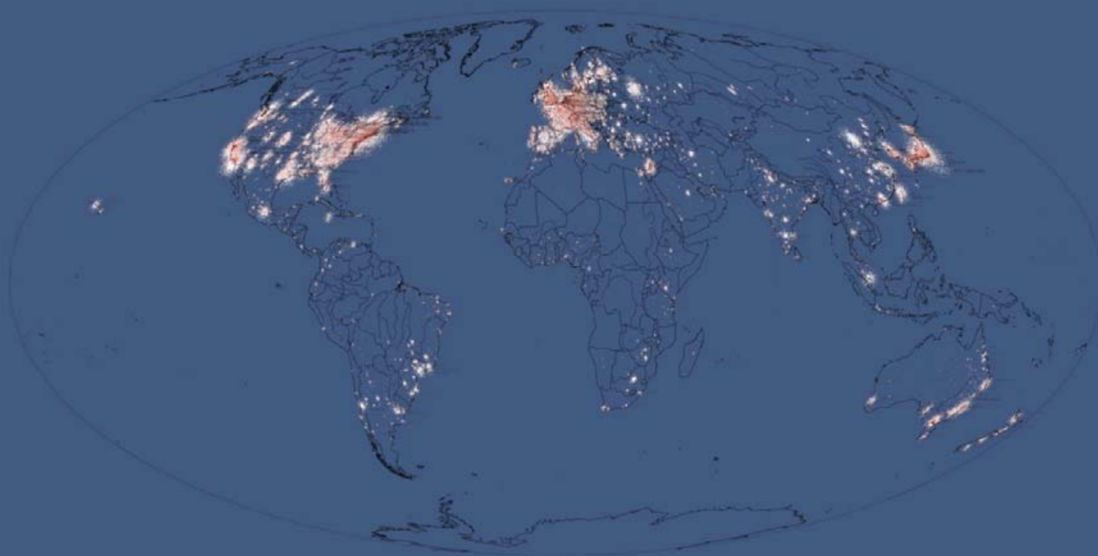
Drives unlimited number of ID screens.

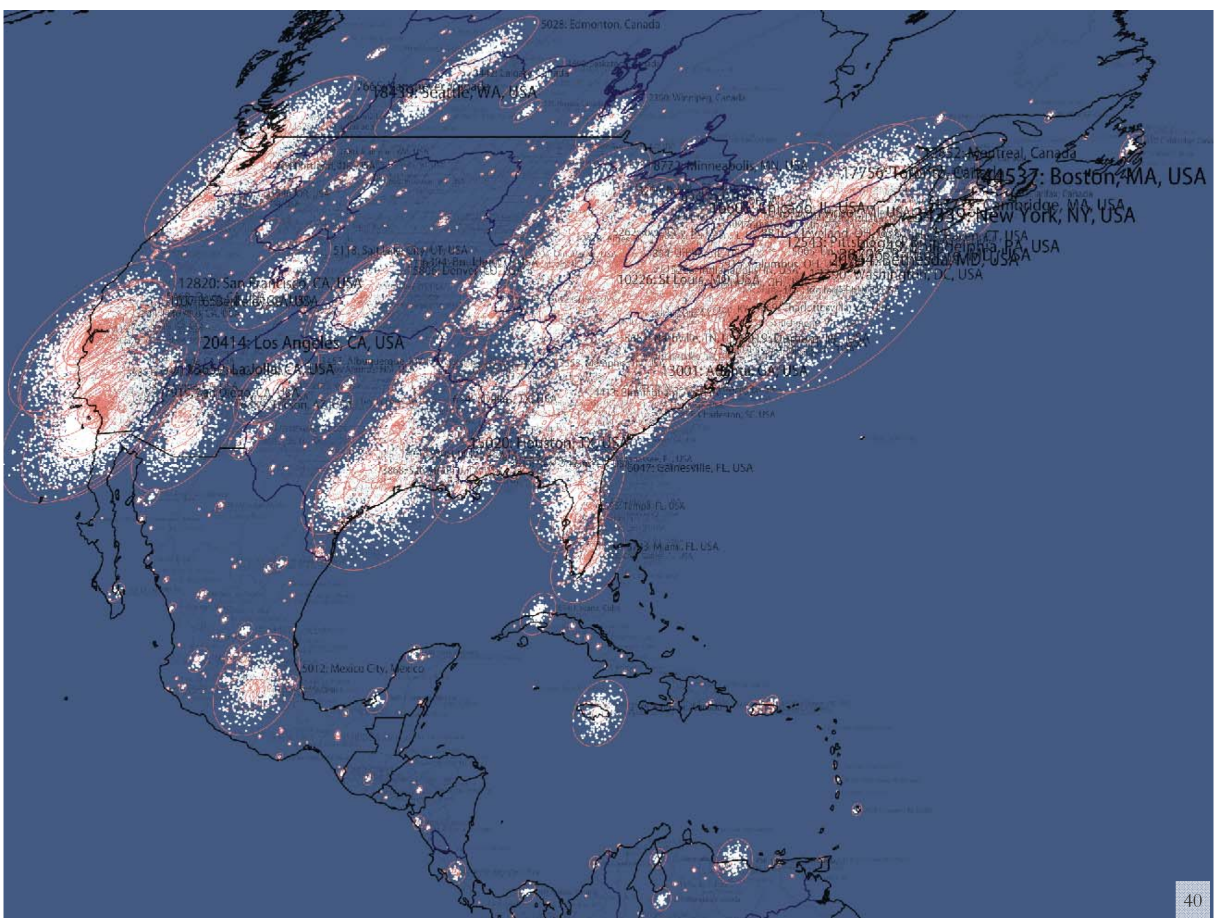


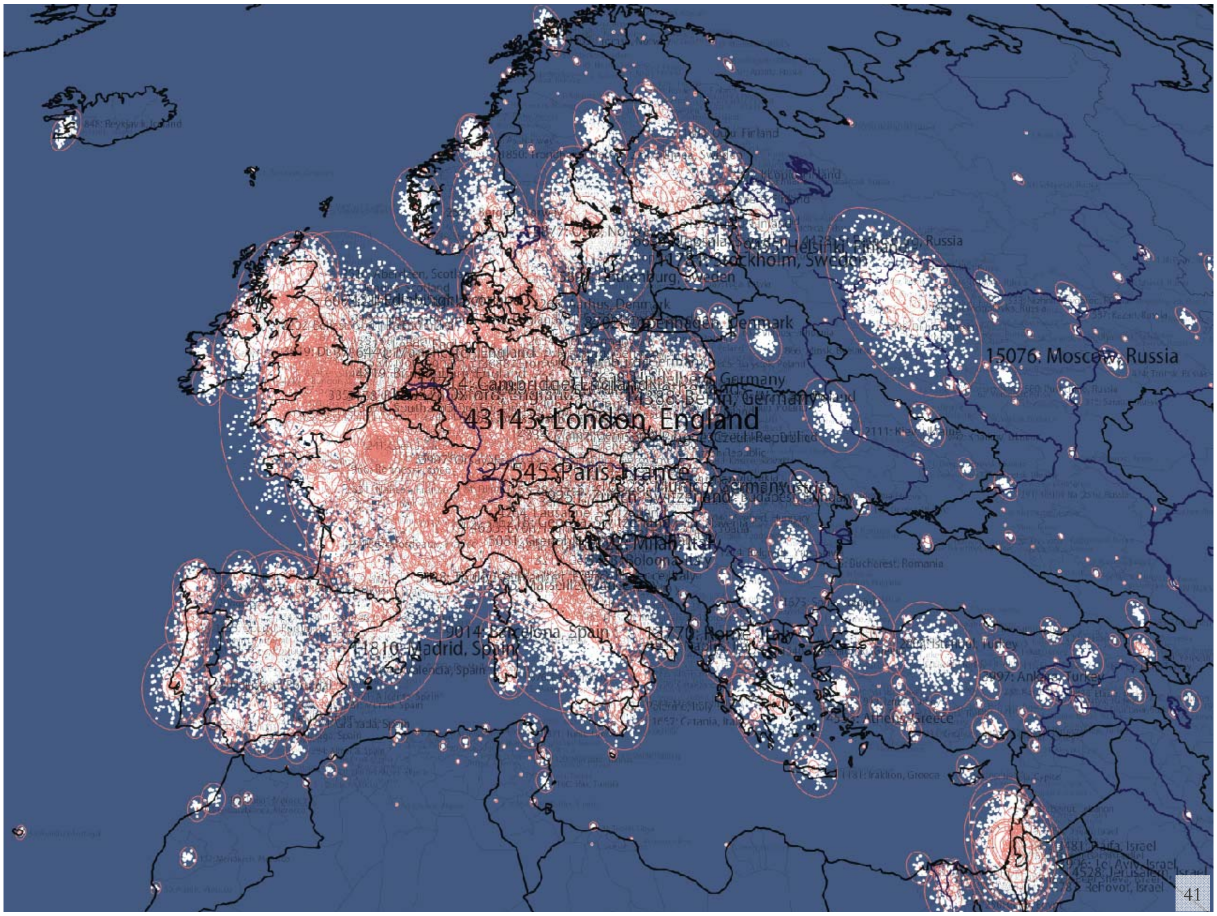
Touch screen for direct interaction.
Keyword and name search.
Selection of canned queries for
- interdisciplinary research areas
- famous people
- activity patterns, e.g., bursts, trends, etc.



Geographic Map: Where Science Gets Done

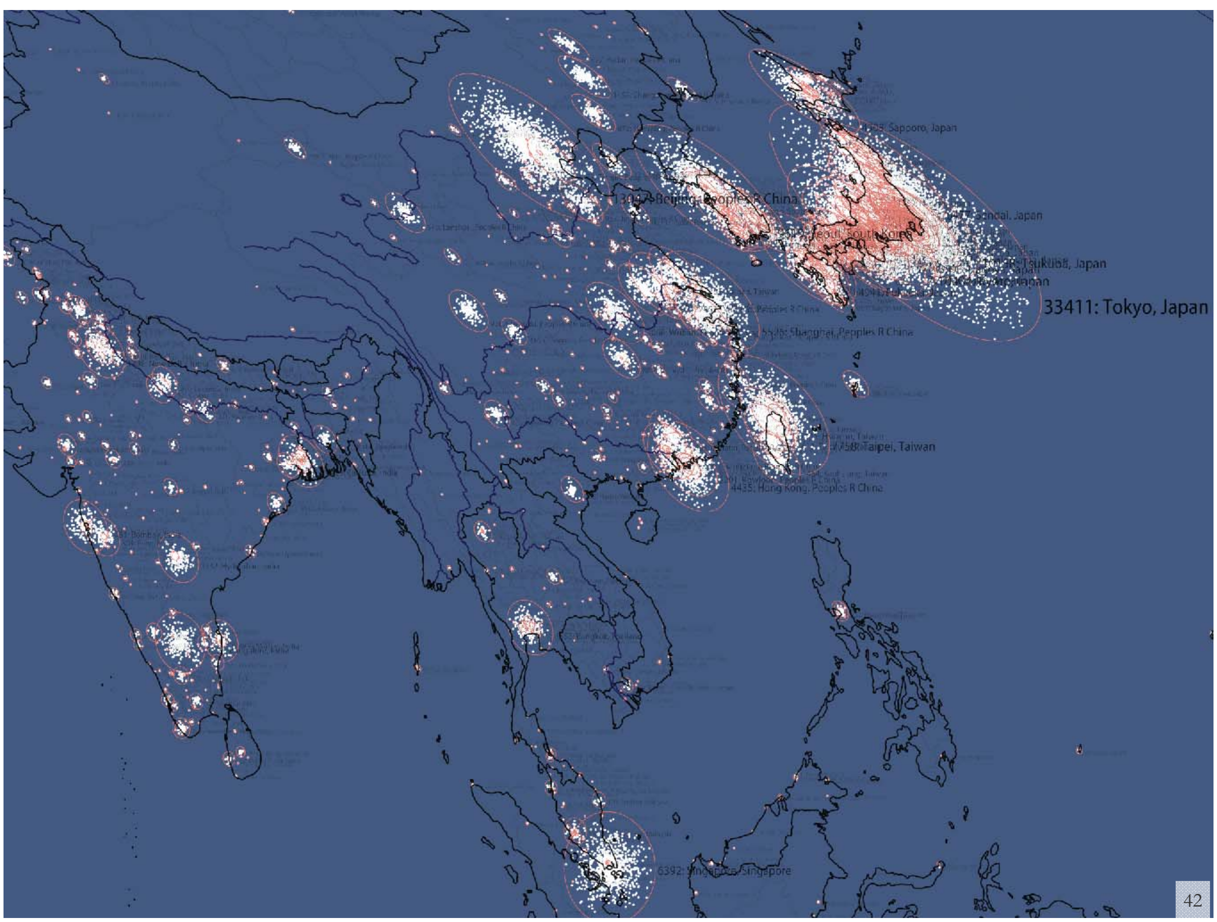






43143: London, England
15076: Moscow, Russia

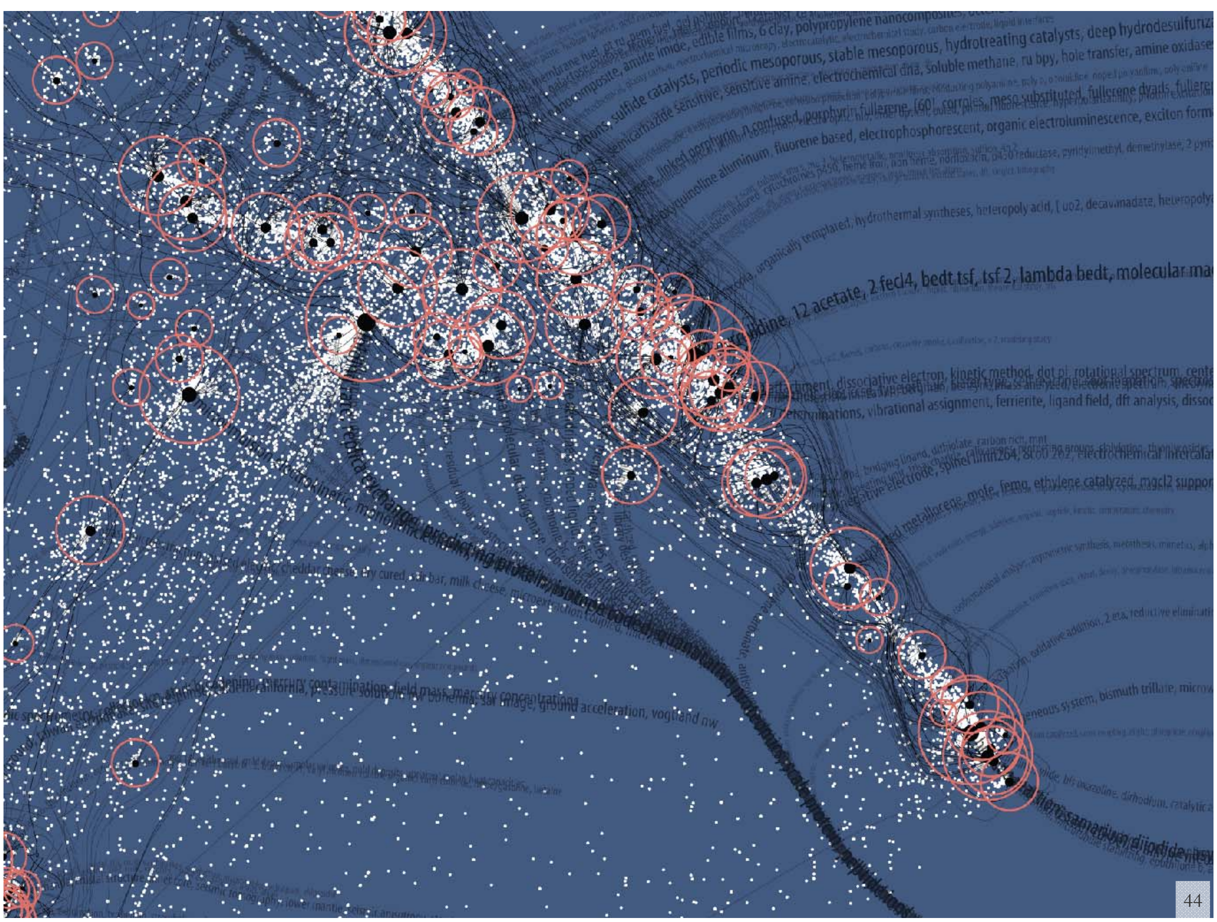
41



33411: Tokyo, Japan
7758: Taipei, Taiwan
4435: Hong Kong, Peoples R China

42


TOPIC MAP: HOW SCIENTIFIC PARADIGMS RELATE

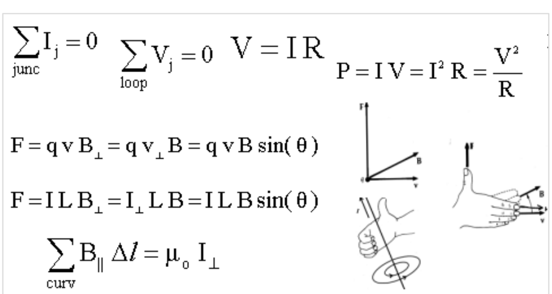

12 acetate, 2 fecl4, bedt tsf, tsf 2, lambda bedt, molecular
metallocene, mofe, femo, ethylene catalyzed, mgcl2
vibrational assignment, ferrierite, ligand field, dft analysis
dissociative electron, kinetic method, dot pi, rotational spectrum
hydrothermal syntheses, heteropoly acid
linked porphyrin, n confused, porphyrin fullerene
aluminum, fluorene based, electrophosphorescent, organic electroluminescence
sulfide catalysts, periodic mesoporous, stable mesoporous, hydrotreating catalysts
composite, amide imide, edible films, 6 clay, polypropylene nanocomposites
contamination, field mass, mass, concentrations
ground acceleration
bismuth triflate
samarium diiodide

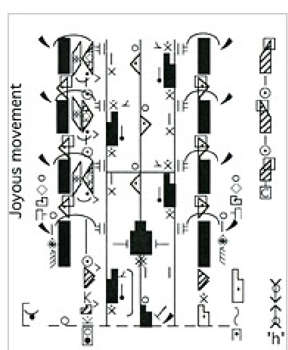
[#02] Information Visualization

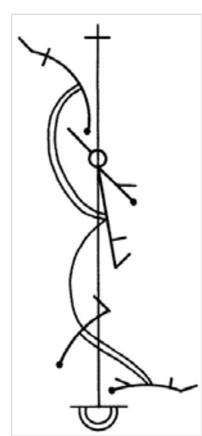
- Introduction
- Designing Effective Visualizations
- Visualization Layers
- Visual Languages
- Promising Research Directions

Visual Languages

Different sciences and arts use different visual encodings to communicate abstract data and concepts.







Exemplary Visual Encoding of Network Nodes and Edges

Social (People, Institutions)
Cognitive (Terms, Papers, Patents, Journals)
Regulations (Funding, Laws)

Three node symbols have same area size for same weight.

Undirected
Directed
Unweighted
Weighted

Combinations of weighted+directed+dotted are possible.

Direct link (citation) — Solid
Co-occurrence (co-author, co-word) — Dashed
Co-citation (author CC, paper CC) — Dotted

Exercise

Time, geo, topic are attributes.
Use node/edge **color** coding for qualitative variables, e.g., type, gender, and **area size** coding for quantitative values, e.g., counts.

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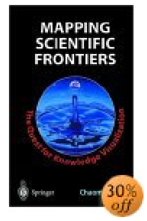
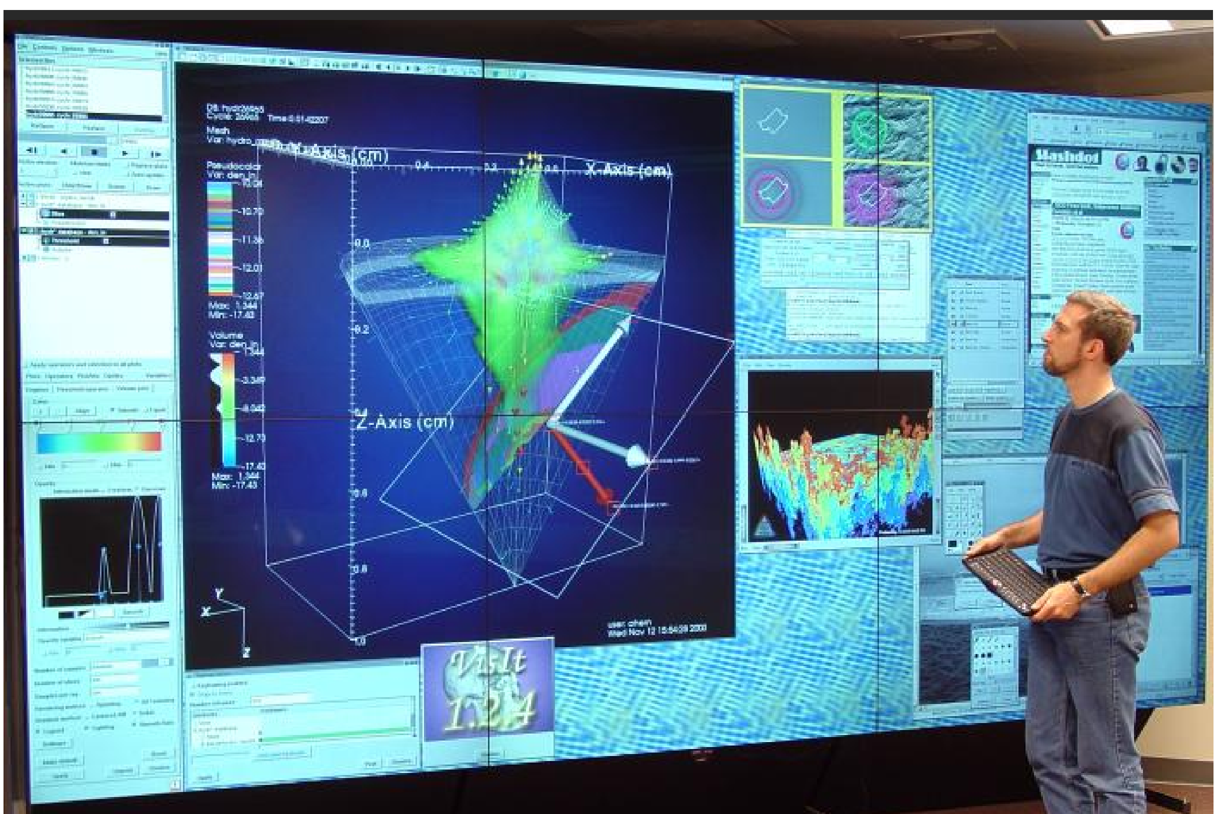
Top Ten List of Challenges

Adopted from Chen 2002

1. Domain Specific vs. Domain Independent
2. Quality vs. Timeliness
3. Interdisciplinary Nature
4. Validation
5. Design Metaphor
6. Coverage
7. Scale-up
8. Automatic Labeling
9. Individual Differences
10. Ethical Constraints





http://www.llnl.gov/icc/sdd/img/images/Cr_Tiled_Small.mpg

Science of Science Cyberinfrastructure

http://sci.slis.indiana.edu

Currently, diverse general tools (Excel, SPS, Pajek, etc.) and proprietary tools are used to study science and to gain science policy insight. The latter are patented, closed source, and rather expensive. Hence, most studies **cannot be replicated** due to price tags or legal issues.

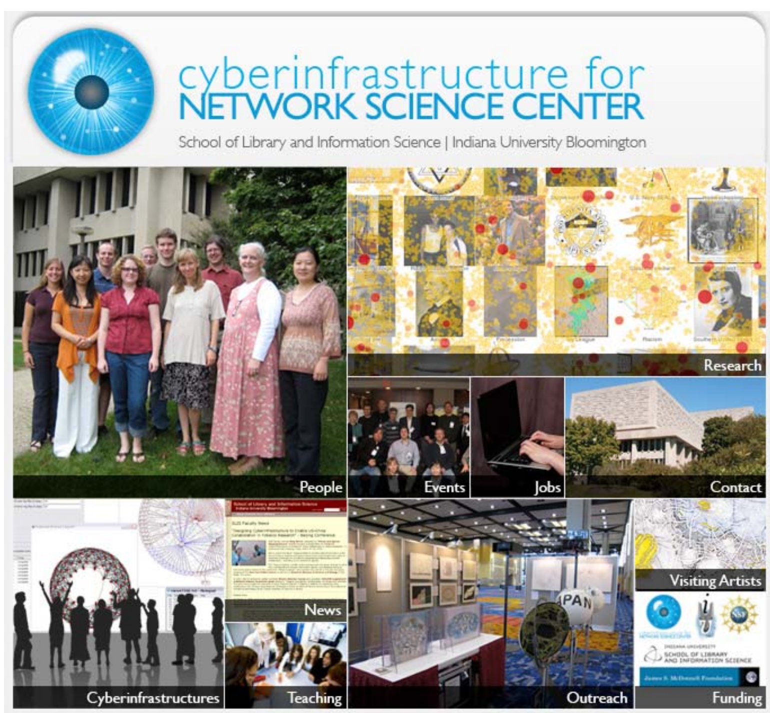
A true science of science will benefit from tools that are

- **Open source**—anybody can check and improve code.
- **Support many different data structures**—relevant static and steaming data comes in text or other format files, databases, RSS feeds.
- **Extensible**—new algorithms become available every day and it should be possible to integrate and use them.
- **Customizable**—different user groups have very different needs. It should be possible to quickly compile custom tools.
- **Scalable**—science is global and must be studied globally. Large scale datasets need to be processed using sufficient memory and processing power.
- **Workflow support**—different science studies require the application of many different algorithms and their parameter values in a specific sequence. It must be possible to log and share (ideally re-run) these workflows.

See Tutorial #3.

Please complete "Questionnaire #2" and "General Questionnaire."

Input



All papers, maps, cyberinfrastructures, talks, press are linked from http://cns.slis.indiana.edu