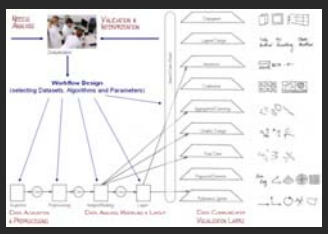
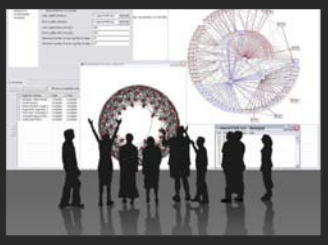
Envisioning Biomedical Science

Dr. Katy Börner
Cyberinfrastructure for Network Science Center, Director
Information Visualization Laboratory, Director
School of Library and Information Science
Indiana University, Bloomington, IN
katy@indiana.edu



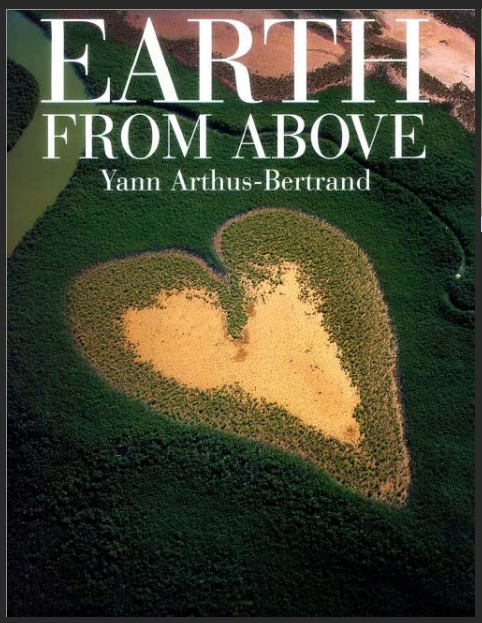
With special thanks to Kevin W. Boyack, Micah Linnemeier, Russell J. Duhon, Patrick Phillips, Joseph Biberstine, Chintan Tank Nianli Ma, Angela M. Zoss, Hanning Guo, Mark A. Price, Scott Weingart

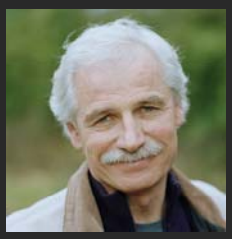


Seminar, The Beckman Institute for Advanced Science and Technology
University of Illinois, IL

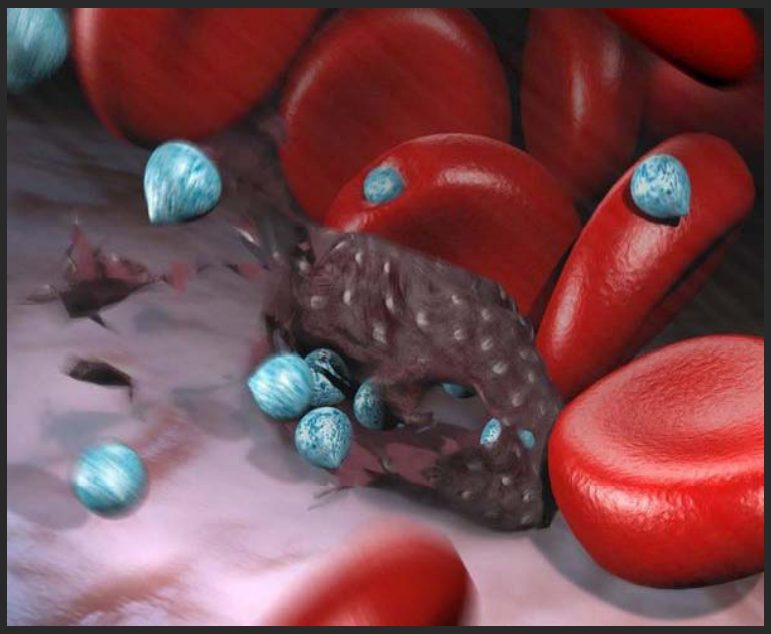
December 3rd, 2009

Biomedical Science from Above



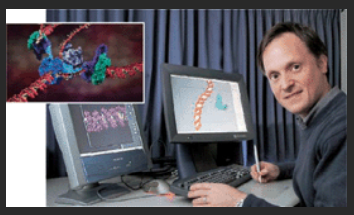


http://www.home-2009.com

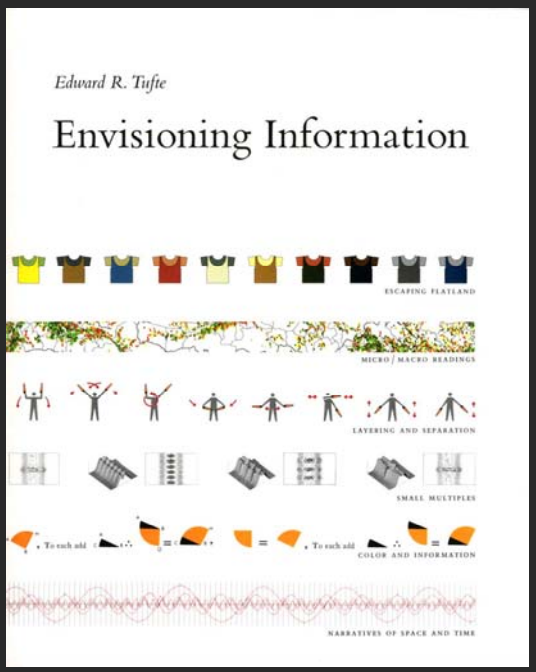


http://www.malarialifecycle.com

The Whole Brain Catalog:
http://wholebraincatalog.org



Drew Berry

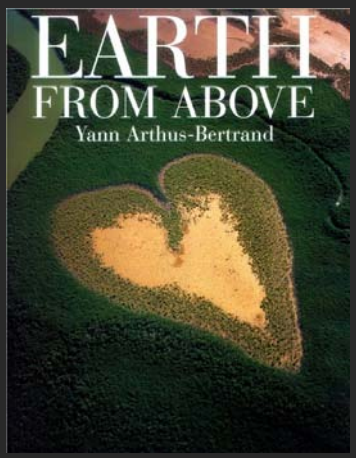


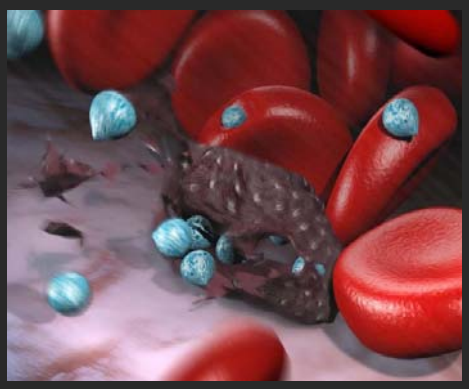
All three care deeply about

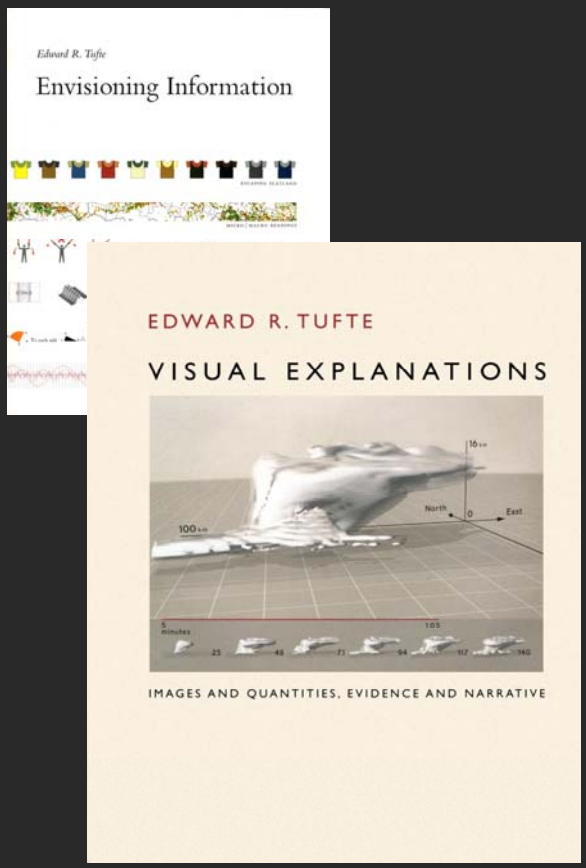
1. Data,
2. Existing expertise and insight needs, and
3. Are able to acquire the resources it takes to

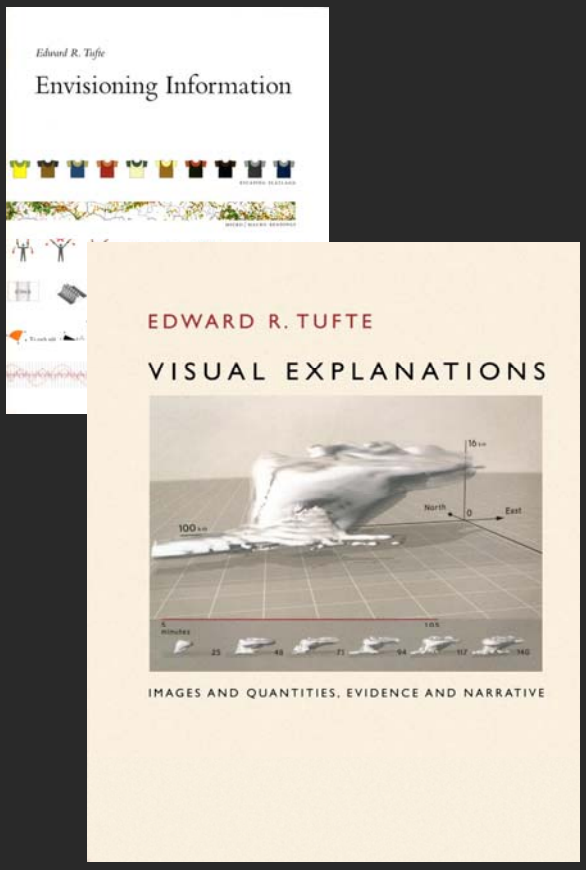
- Spent months/years to deeply understand the problem/possible solutions.
- Render data optimally for the human perceptual-cognitive system – given our current understanding of human perception/cognition and technology.

The result are insightful yet perceptually stunning, intellectually stimulating, and emotion provoking imagery.









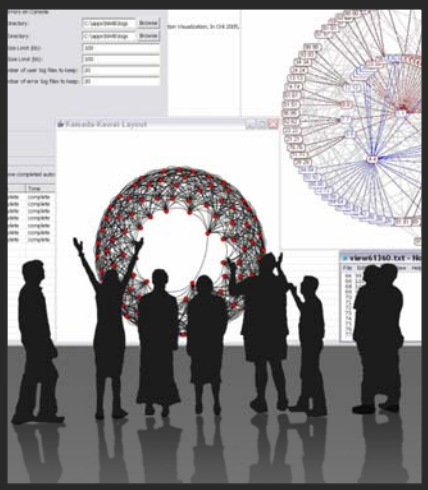
Today's massive amounts of streaming data cannot be rendered by hand.

How to use computers to envision biomedial science ?

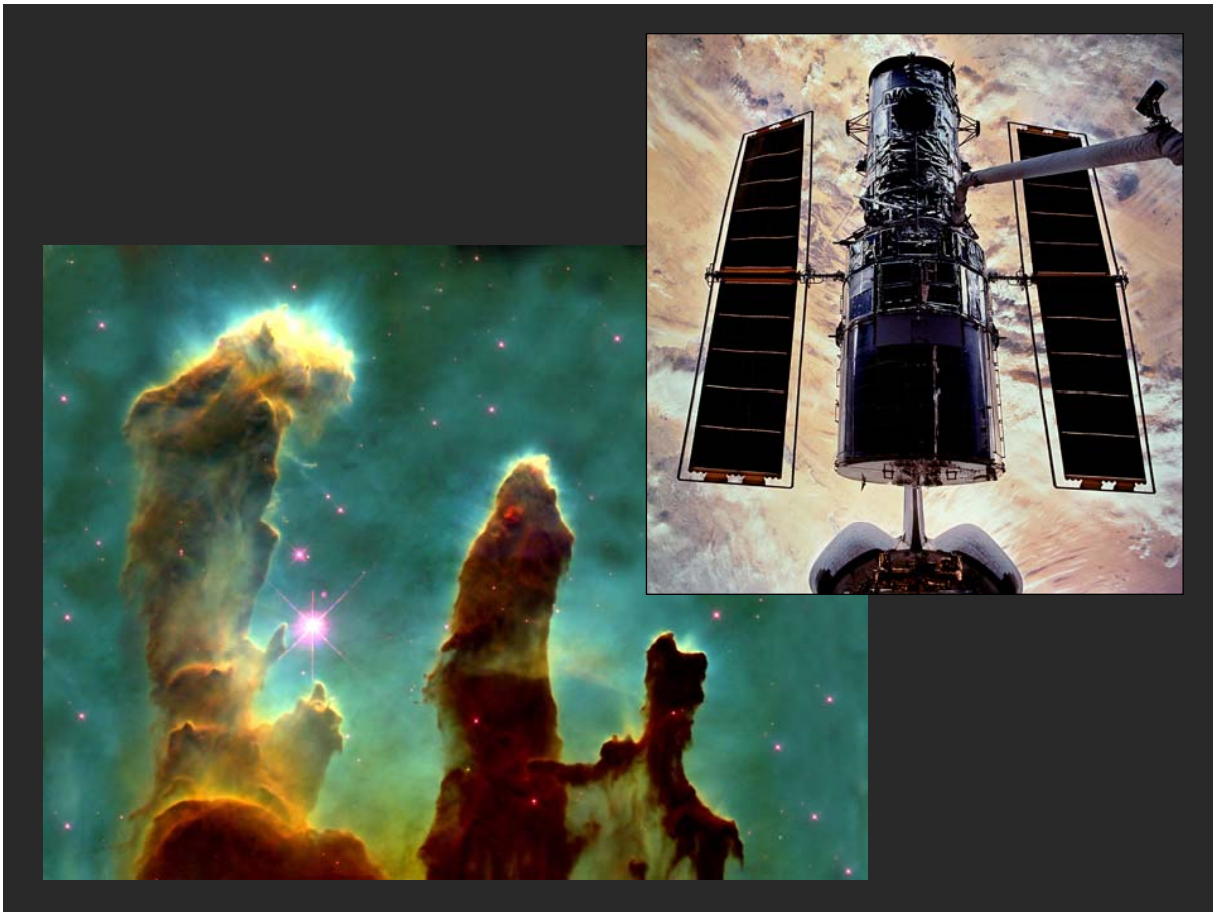
How to combine data mining and visualization algorithms to explore and communicate biomedial science?

Microscopes

Telescopes



Macroscopes



Structure of the Remaining Talk

1.) Type of Analysis vs. Level of Analysis

Exemplified in Biomedicine

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

Implementation in different plug-and-play tools/CIs

1.) Type of Analysis vs. Level of Analysis

	Micro/Individual (1-100 records)	***Meso/Local (101–10,000 records)***	***Macro/Global (10,000 < records)***
Statistical Analysis/Profiling	Individual person and their expertise profiles	Larger labs, centers, universities, research domains, or states	All of NSF, all of USA, all of science.
Temporal Analysis (When)	Funding portfolio of one individual	Mapping topic bursts in 20-years of PNAS	113 Years of Physics Research
Geospatial Analysis (Where)	Career trajectory of one individual	Mapping a states intellectual landscape	PNAS Publications
Topical Analysis (What)	Base knowledge from which one grant draws.	Knowledge flows in Chemistry research	VxOrd/Topic maps of NIH funding
Network Analysis (With Whom?)	NSF Co-PI network of one individual	Co-author network	NSF's core competency

Type of Analysis vs. Level of Analysis

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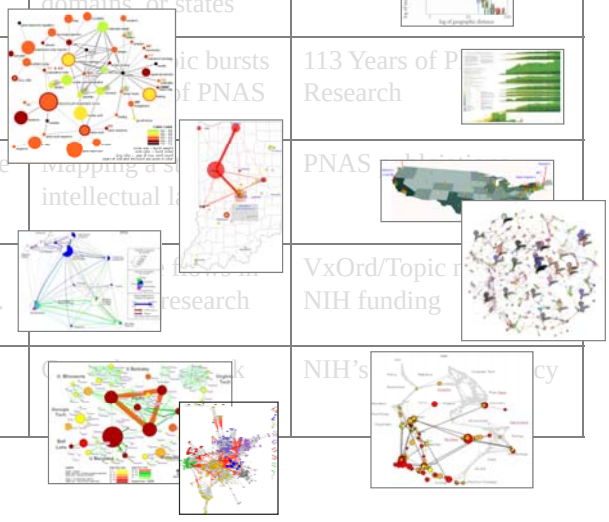
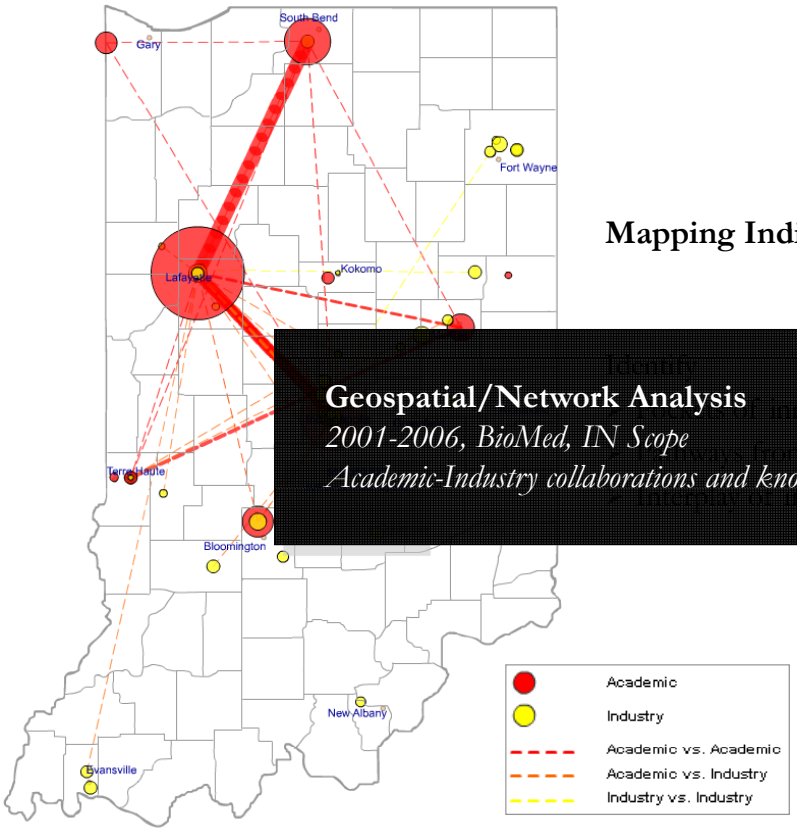




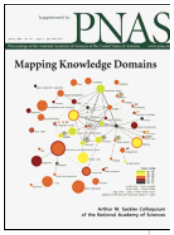
Mapping Indiana's Intellectual Space

Geospatial/Network Analysis
2001-2006, BioMed, IN Scope
Academic-Industry collaborations and knowledge diffusion

Mapping Topic Bursts

Co-word space of the top 50 highly frequent and bursty words used in the top 10% most highly cited PNAS publications in 1982-2001.

Mane & Börner. (2004) PNAS, 101(Suppl. 1): 5287-5290.



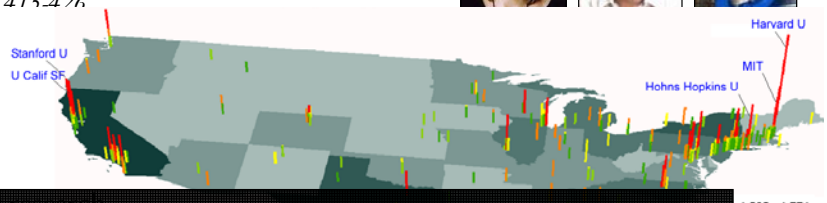
Temporal/Topical Analysis
1982-2001, US, PNAS (BioMed) Scope
Topic evolution and bursts

Spatio-Temporal Information Production and Consumption of Major U.S. Research Institutions

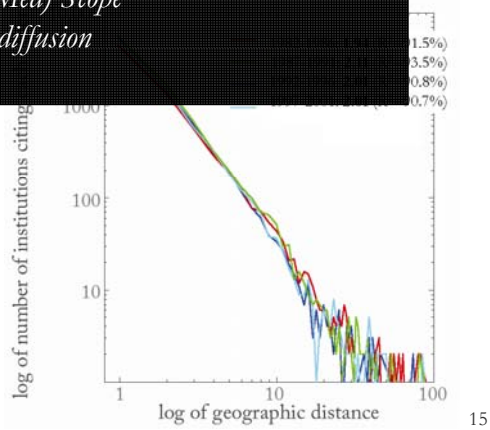
Börner, Katy, Penumarthy, Shashikant, Meiss, Mark and Ke, Weimao. (2006) Mapping the Diffusion of Scholarly Knowledge Among Major U.S. Research Institutions. Scientometrics. 68(3), pp. 415-426.

Research questions:

1. Does space still matter in the Internet age?
2. Does one still have to study and work at major research institutions in order to produce high quality data and high quality research?
3. Does the Internet change publication patterns, i.e., more co-author links between papers produced at geographically distant research instructions?



Temporal/Geospatial Analysis
1982-2001, US, PNAS (BioMed) Scope
Citation impact and knowledge diffusion



Contributions:

- Answer to Qs 1 + 2 is YES.
- Answer to Qs 3 is NO.
- Novel approach to analyzing the dual role of institutions as information producers and consumers and to study and visualize the diffusion of information among them.

Research Collaborations by the Chinese Academy of Sciences

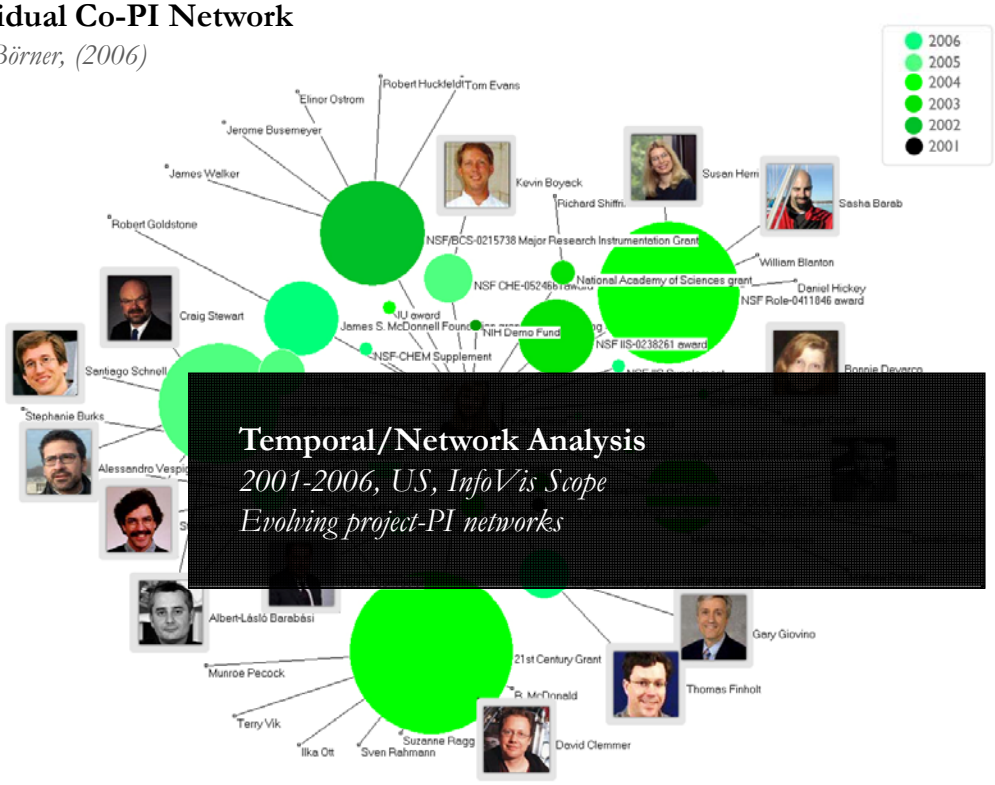
By Weixia (Bonnie) Huang, Russell J. Duhon, Elisha F. Hardy, Katy Börner, Indiana University, USA

Geospatial Analysis
World, Chinese Academy of Science
Collaboration and knowledge diffusion via co-author networks

This map highlights the research co-authorship collaborations of the Chinese Academy of Sciences with locations in China and countries around the world. The large geographic map shows the research collaborations of all CAS institutes. Each smaller geographic map shows the research collaborations by the CAS researchers in one province-level administrative division. Collaborations between CAS researchers are not included in the data. On each map, locations are colored on a logarithmic scale by the number of collaborations from red to yellow. The darkest red is 3,395 collaborations by all of CAS with researchers in Beijing. Also, flow lines are drawn from the location of focus to all locations collaborated with. The width of the flow line is linearly proportional to the number of collaborations with the locations it goes to, with the smallest flow lines representing one collaboration and the largest representing differing amounts on each geographic map.

Individual Co-PI Network

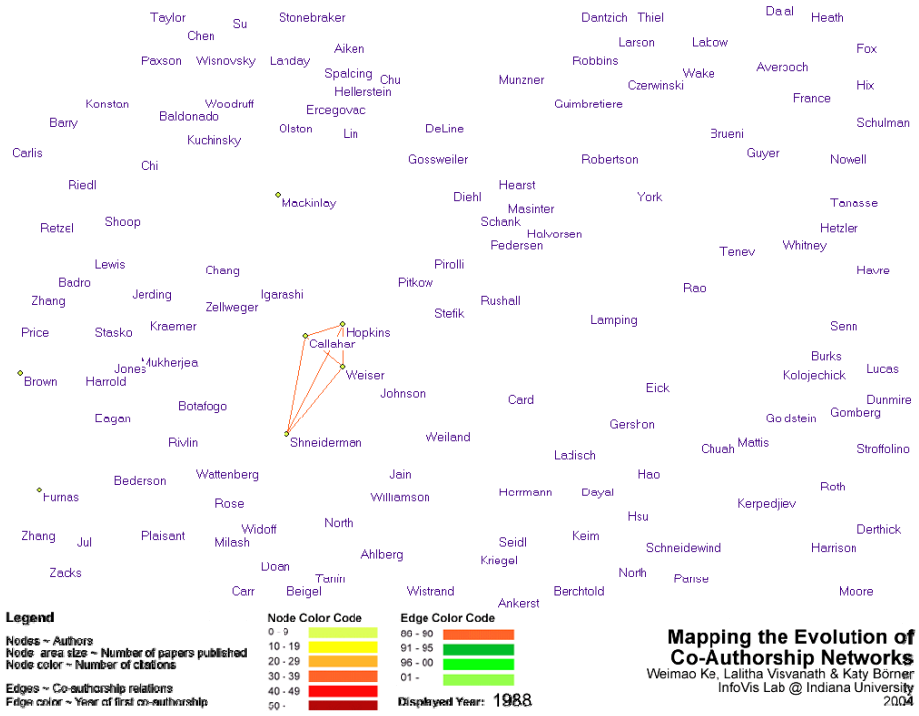
Ke & Börner, (2006)



Temporal/Network Analysis
2001-2006, US, InfoVis Scope
Evolving project-PI networks

Mapping the Evolution of Co-Authorship Networks

Ke, Visvanath & Börner, (2004) Won 1st price at the IEEE InfoVis Contest.



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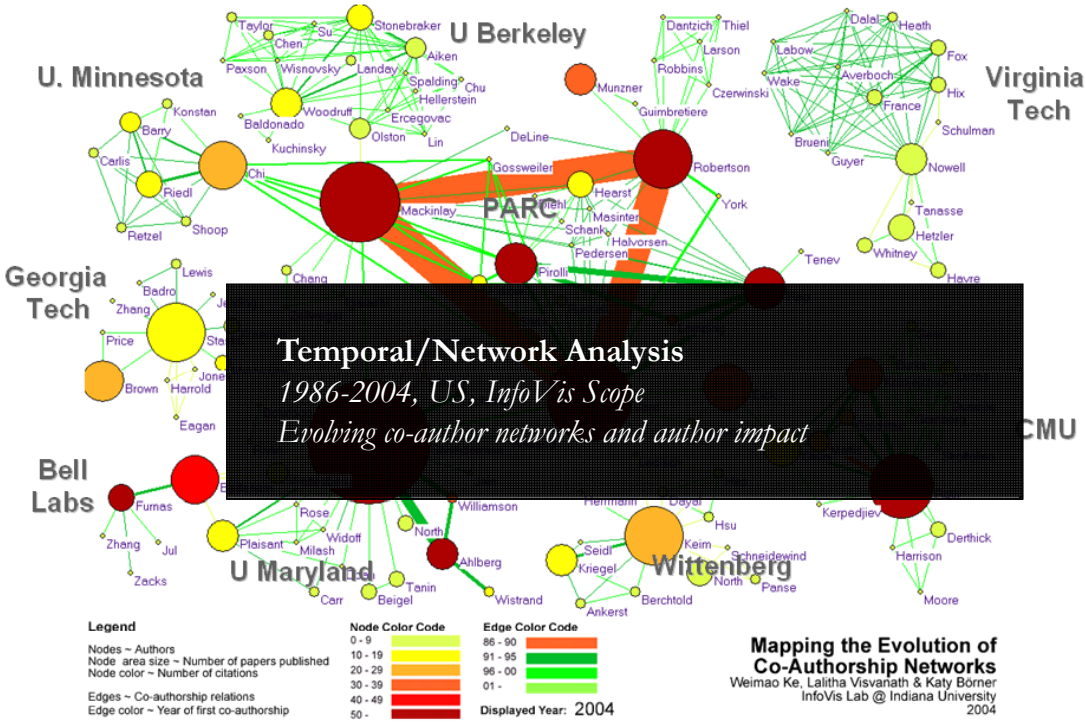


Studying the Emerging Global Brain: Analyzing and Visualizing the Impact of Co-Authorship Teams

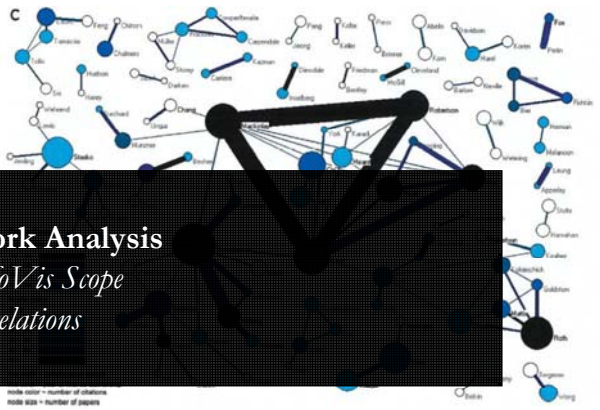
Börner, Dall'Asta, Ke & Vespignani (2005) Complexity, 10(4):58-67.

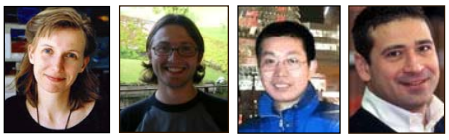
Research question:

- Is science driven by prolific single experts or by high-impact co-authorship teams?

Contributions:

- New approach to allocate citational credit.
- Novel weighted gra
- Visualization of th
co-author network
- Centrality measure
impact.
- Global statistical analysis of paper production and citations in correlation with co-authorship team size over time.
- Local, author-centered entropy measure.

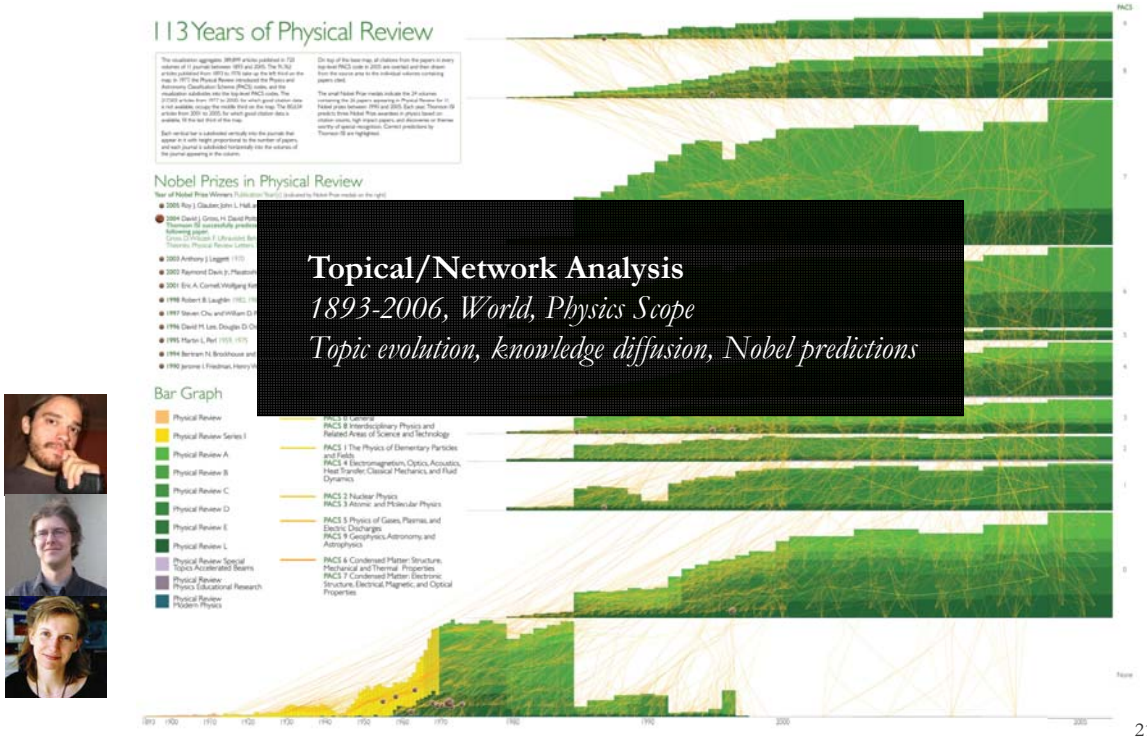




113 Years of Physical Review

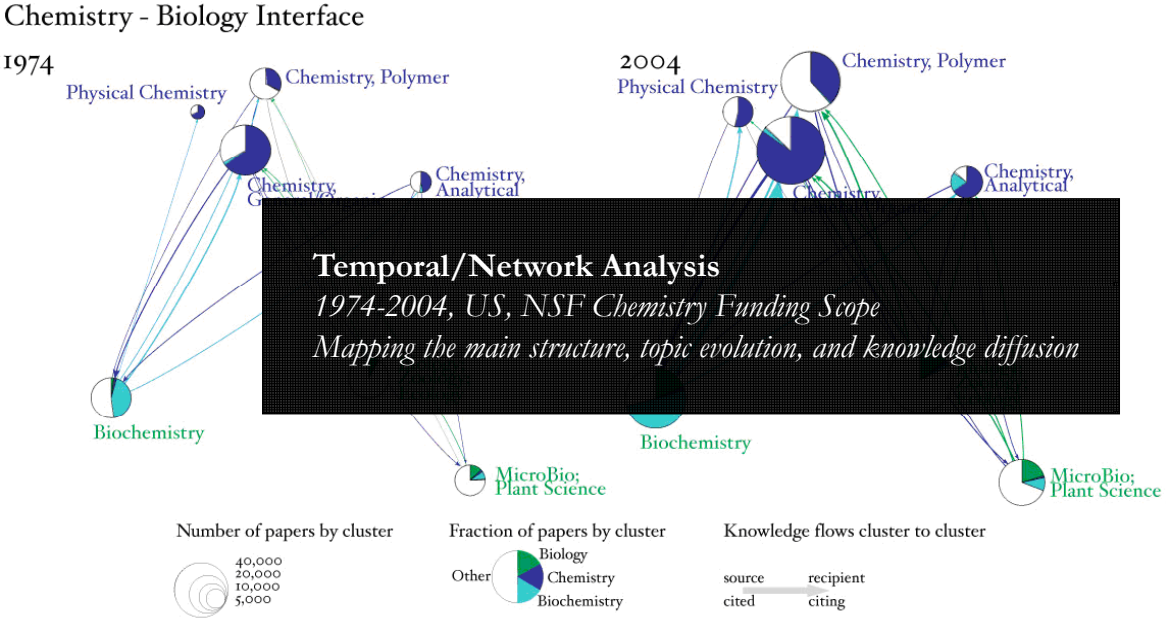
http://scimaps.org/dev/map_detail.php?map_id=171

Bruce W. Herr II and Russell Duhon (Data Mining & Visualization), Elisha F. Hardy (Graphic Design), Shashikant Penumarthy (Data Preparation) and Katy Börner (Concept)



Topical Composition and Knowledge Flow Patterns in Chemistry Research for 1974 and 2004

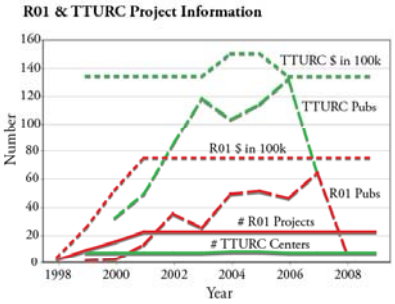
Kevin W. Boyack, Katy Börner, & Richard Klavans (2007)

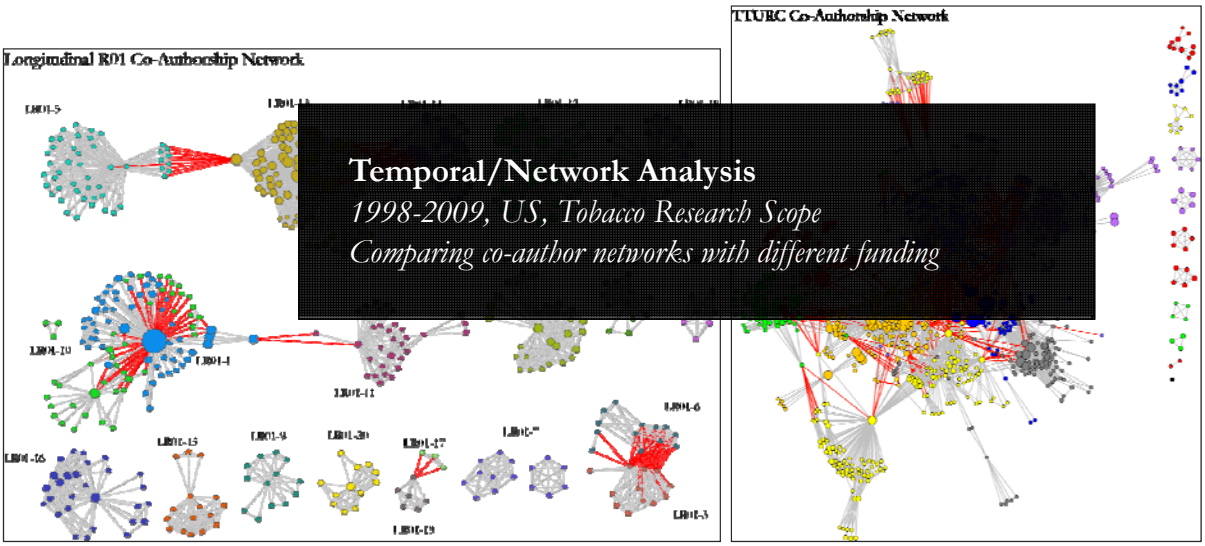


Mapping Transdisciplinary Tobacco Use Research Centers Publications

Compare R01 investigator based funding with TTURC Center awards in terms of number of publications and evolving co-author networks.

Zoss & Börner, forthcoming.

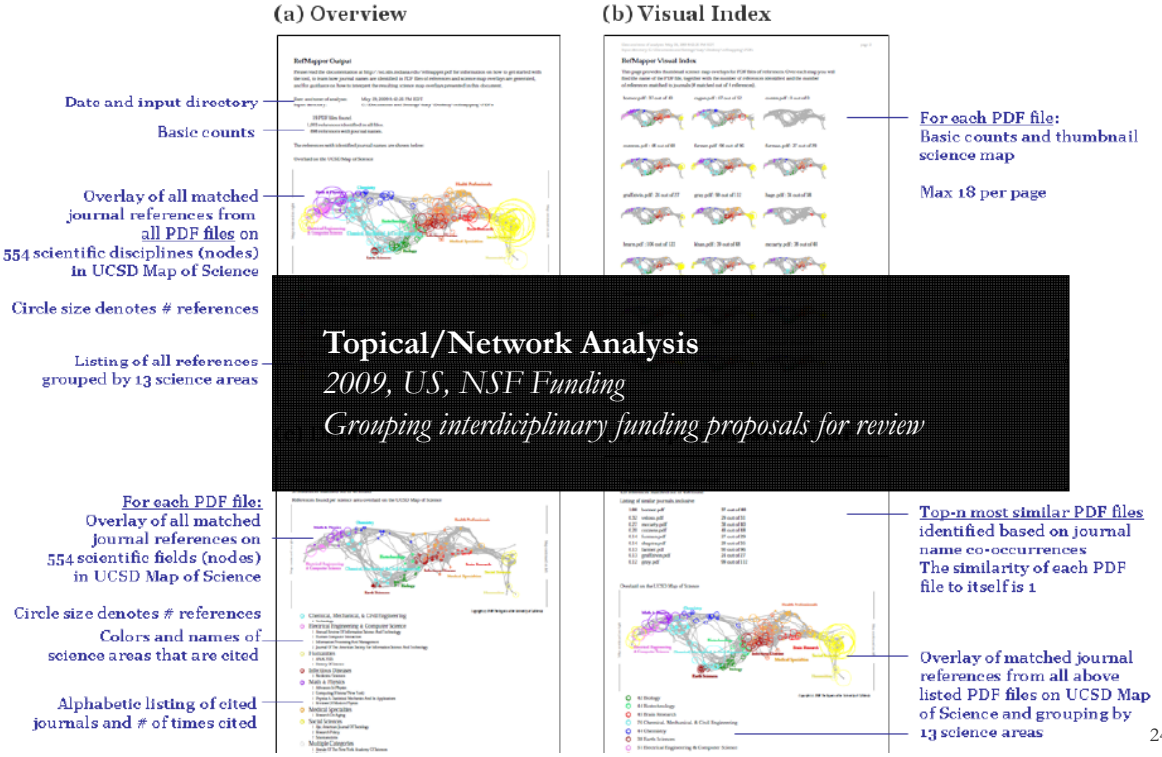




Temporal/Network Analysis
1998-2009, US, Tobacco Research Scope
Comparing co-author networks with different funding

Reference Mapper

Duhon & Börner, forthcoming.

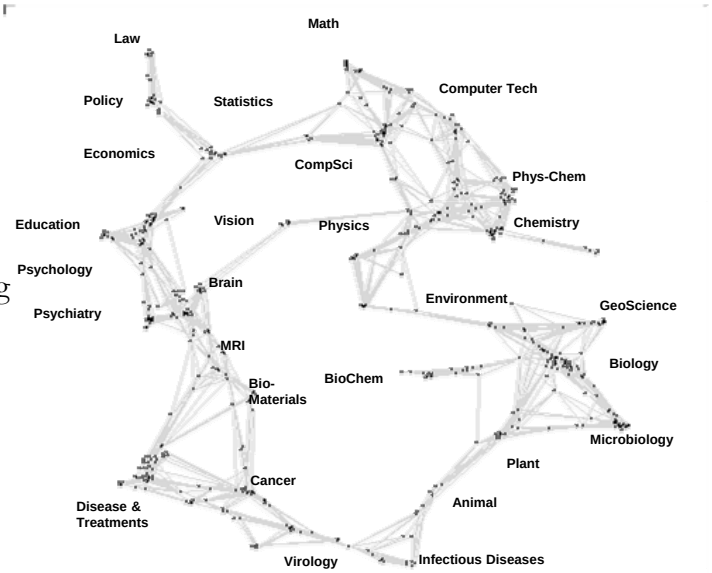


Topical/Network Analysis
2009, US, NSF Funding
Grouping interdiciplinary funding proposals for review

Latest 'Base Map' of Science

Kevin W. Boyack, Katy Börner, & Richard Klavans (2007). Mapping the Structure and Evolution of Chemistry Research. 11th International Conference on Scientometrics and Informetrics. pp. 112-123.

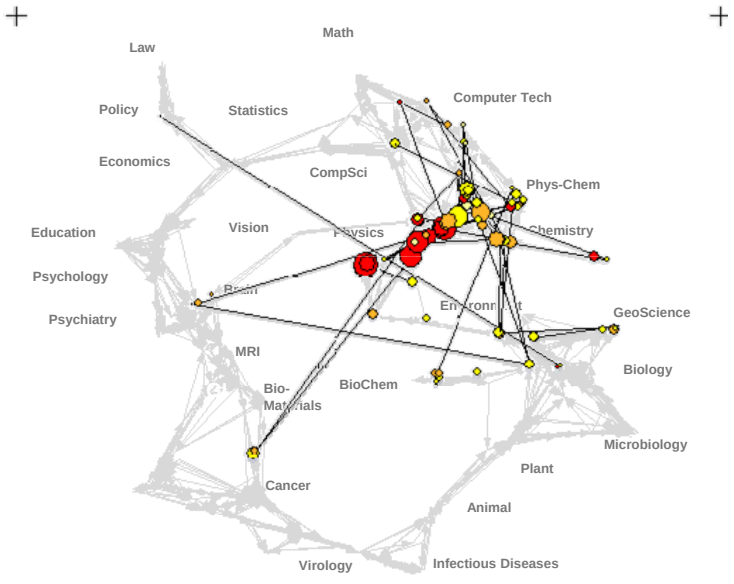
- Uses combined SCI/SSCI from 2002
  - 1.07M papers, 24.5M references, 7,300 journals
  - Bibliographic coupling of papers, aggregated to journals
- Initial ordination and clustering of journals gave 671 clusters
- Coupling counts were reaggregated at the journal cluster level to calculate the
  - (x,y) positions for each journal cluster
  - by association, (x,y) positions for each journal



Science map applications: Identifying core competency

Kevin W. Boyack, Katy Börner, & Richard Klavans (2007).

Funding patterns of the US Department of Energy (DOE)



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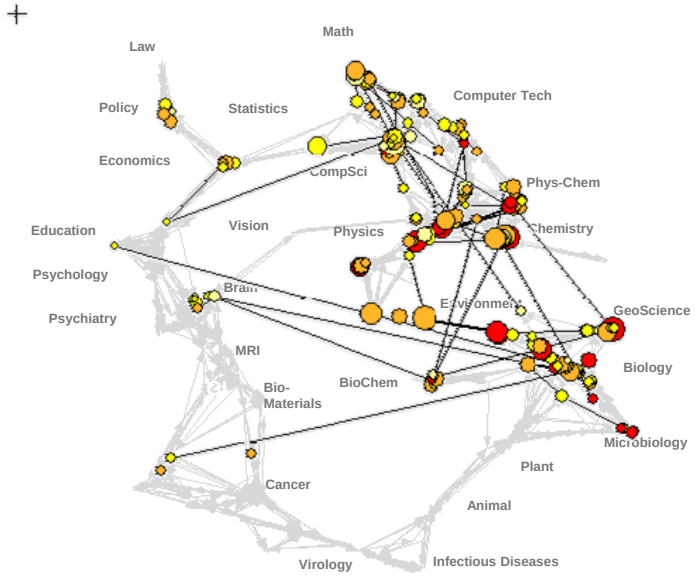
Funding Patterns of the National Science Foundation (NSF)



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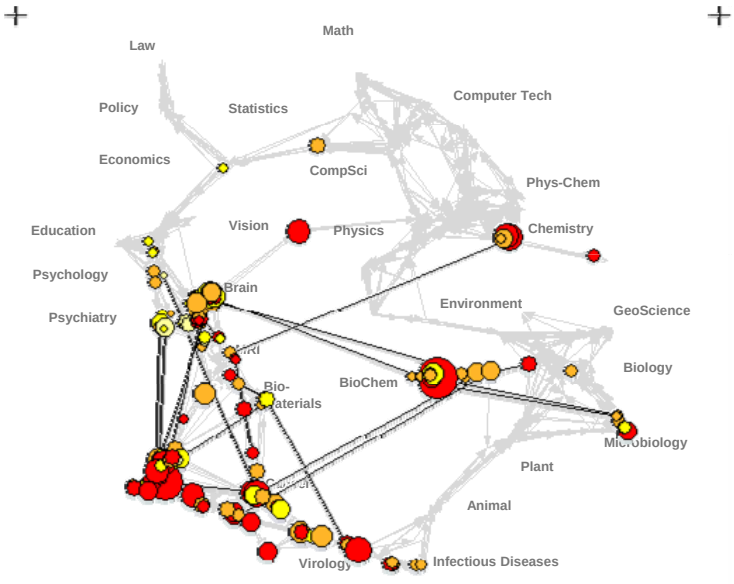

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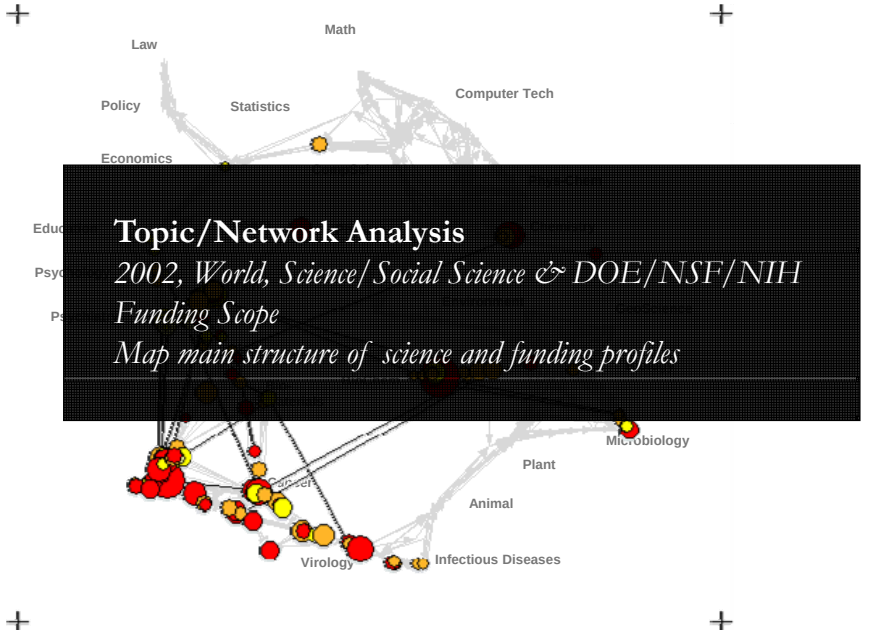
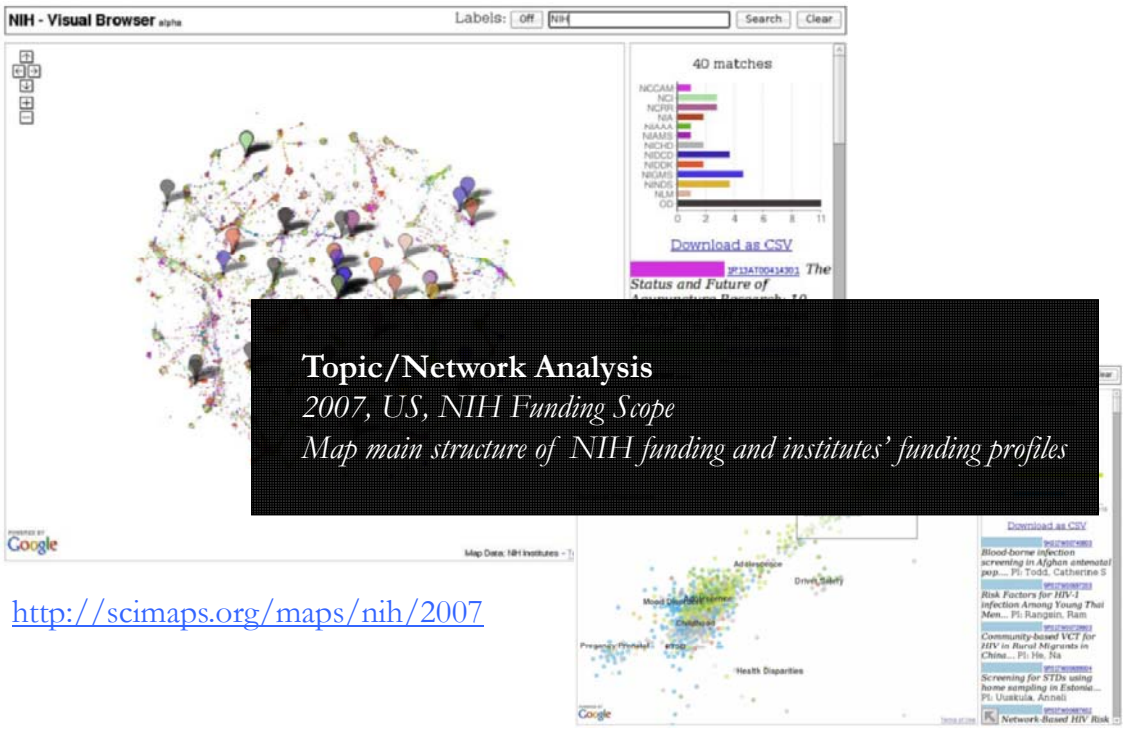


Interactive Science Map of NIH Funding

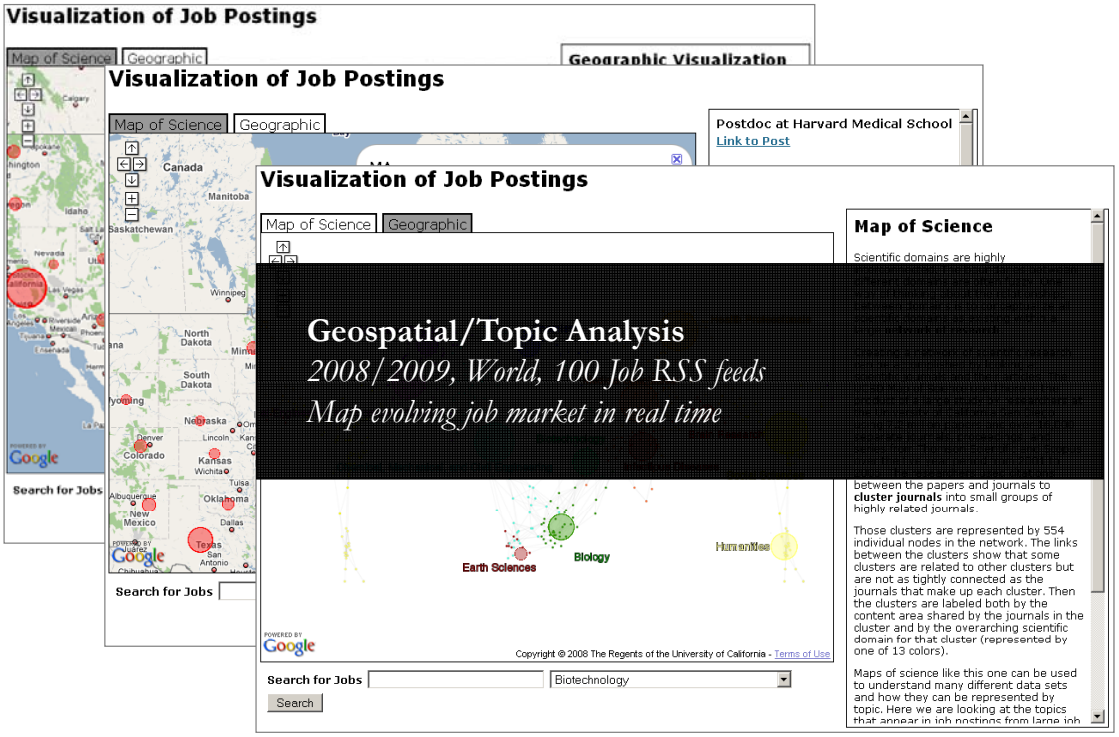
Herr II, Bruce W., Talley, Edmund M, Burns, Gully APC, Newman, David & La Rowe, Gavin. (2009).



http://scimaps.org/maps/nih/2007

Interactive World and Science Map of S&T Jobs

Angela Zoss, Michael Connover, Katy Börner (in preparation).



Structure of the Remaining Talk

1.) Type of Analysis vs. Level of Analysis

Exemplified in Biomedicine

2.) Needs-Driven Workflow Design

using a modular data acquisition/analysis/modeling/ visualization pipeline as well as modular visualization layers.

Implementation in different plug-and-play tools/CIs

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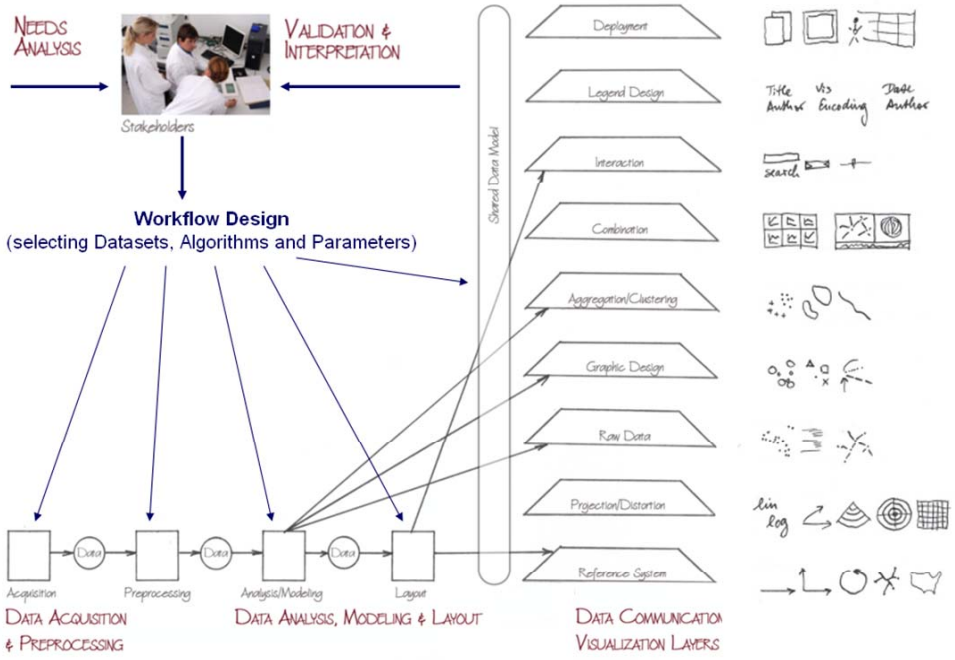


Börner, Katy (2010) Atlas of Science. MIT Press. 33

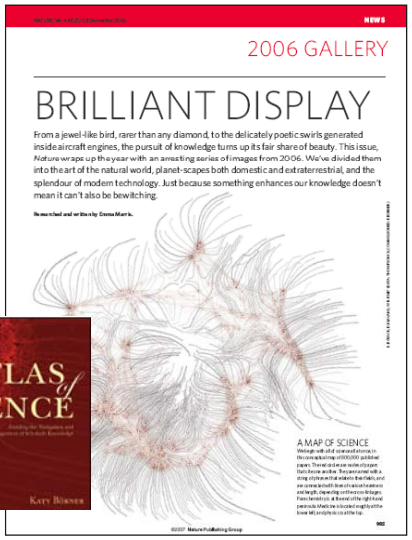
Computational Scientometrics: Studying Science by Scientific Means

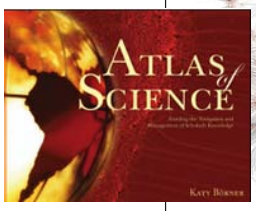
Börner, Katy, Chen, Chaomei, and Boyack, Kevin. (2003). **Visualizing Knowledge Domains.** In Blaise Cronin (Ed.), *ARIST*, Medford, NJ: Information Today, Inc./American Society for Information Science and Technology, Volume 37, Chapter 5, pp. 179-255. http://ivl.slis.indiana.edu/km/pub/2003-borner-arist.pdf

Shiffrin, Richard M. and Börner, Katy (Eds.) (2004). **Mapping Knowledge Domains**. *Proceedings of the National Academy of Sciences of the United States of America*, 101(Suppl_1). http://www.pnas.org/content/vol101/suppl_1/

Börner, Katy, Sanyal, Soma and Vespignani, Alessandro (2007). **Network Science.** In Blaise Cronin (Ed.), *ARIST*, Information Today, Inc./American Society for Information Science and Technology, Medford, NJ, Volume 41, Chapter 12, pp. 537-607. http://ivl.slis.indiana.edu/km/pub/2007-borner-arist.pdf

Börner, Katy (2010) Atlas of Science. MIT Press. http://scimaps.org/atlas





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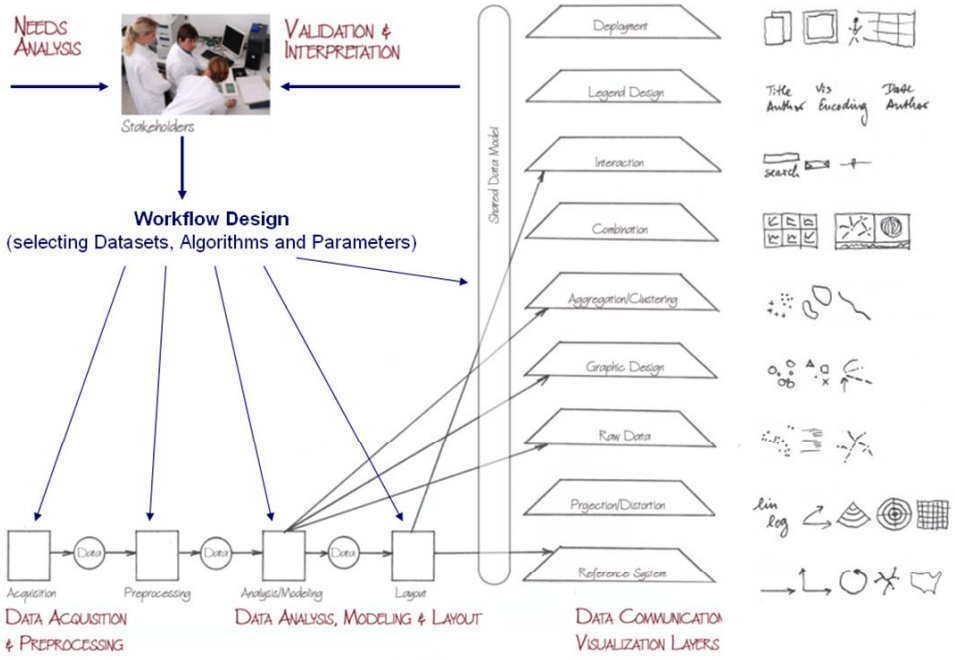
2.) Needs-Driven Workflow Design

using a modular data acquisition/analysis/modeling/ visualization pipeline as well as modular visualization layers.



Börner, Katy (2010) Atlas of Science. MIT Press. 35

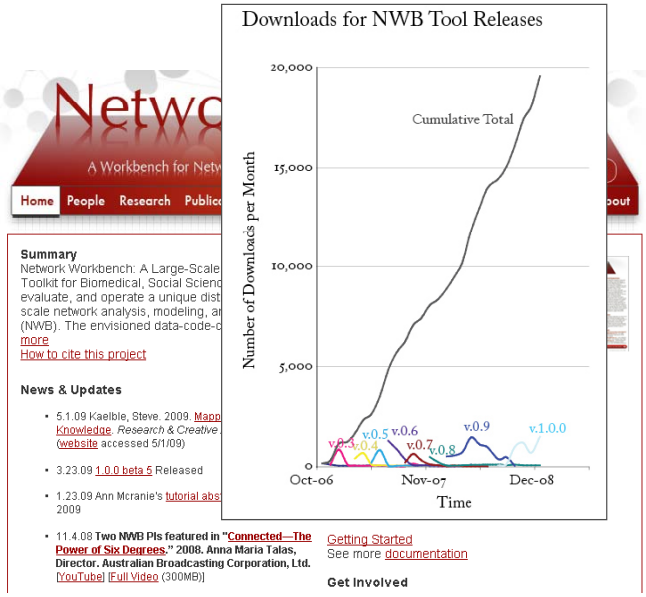
Network Workbench Tool

http://nwb.slis.indiana.edu

The Network Workbench (NWB) tool supports researchers, educators, and practitioners interested in the study of biomedical, social and behavioral science, physics, and other networks.

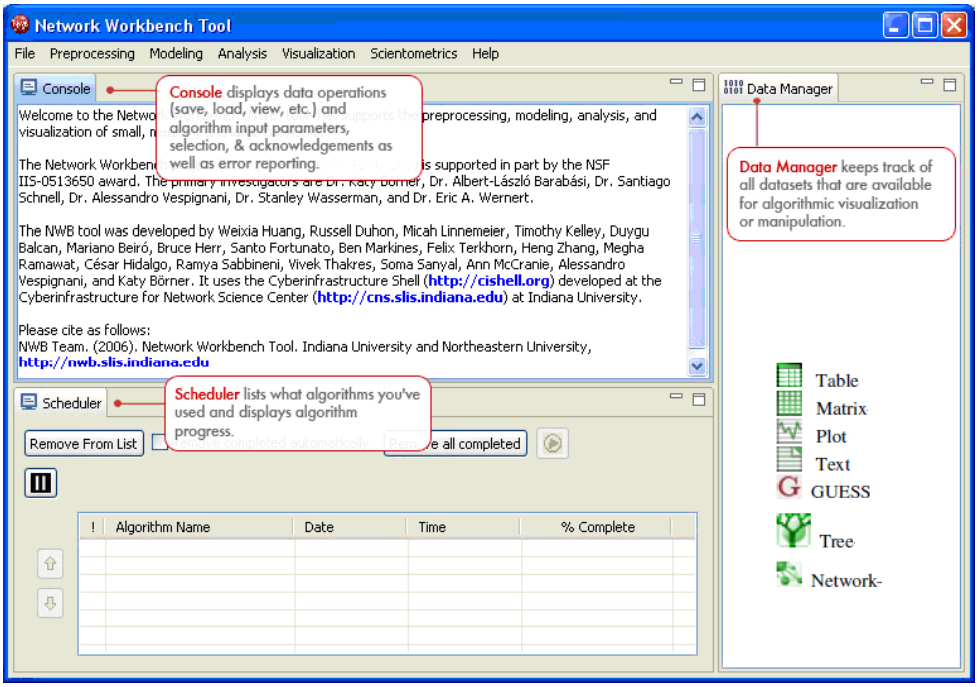
In Aug. 2009, the tool provides more 160 plugins that support the preprocessing, analysis, modeling, and visualization of networks.

It has been downloaded more than 35,000 times since December 2006.

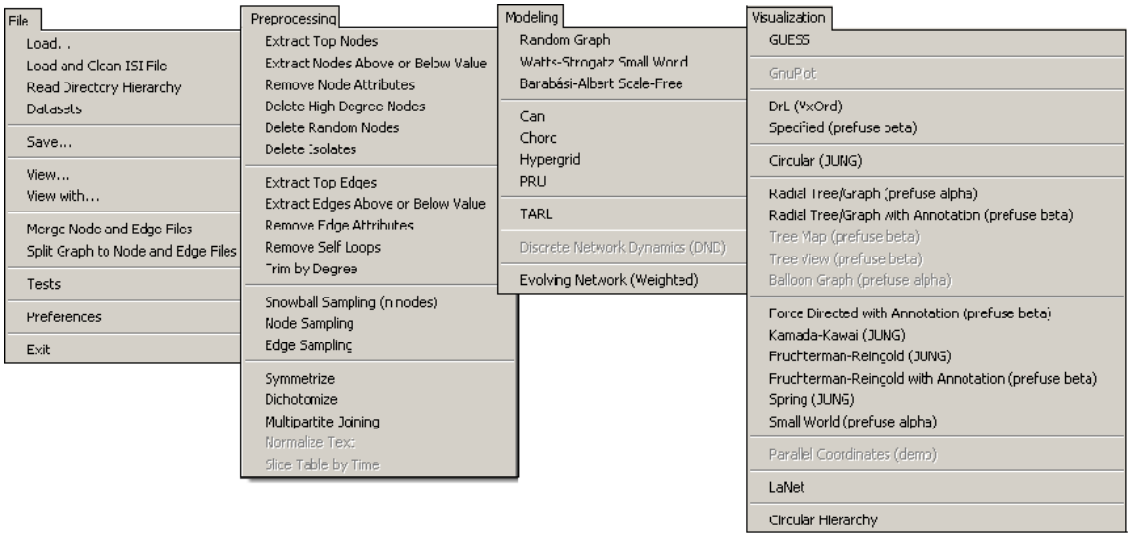


Herr II, Bruce W., Huang, Weixia (Bonnie), Penumarthy, Shashikant & Börner, Katy. (2007). Designing Highly Flexible and Usable Cyberinfrastructures for Convergence. In Bainbridge, William S. & Roco, Mihail C. (Eds.), Progress in Convergence - Technologies for Human Wellbeing (Vol. 1093, pp. 161-179), Annals of the New York Academy of Sciences, Boston, MA.

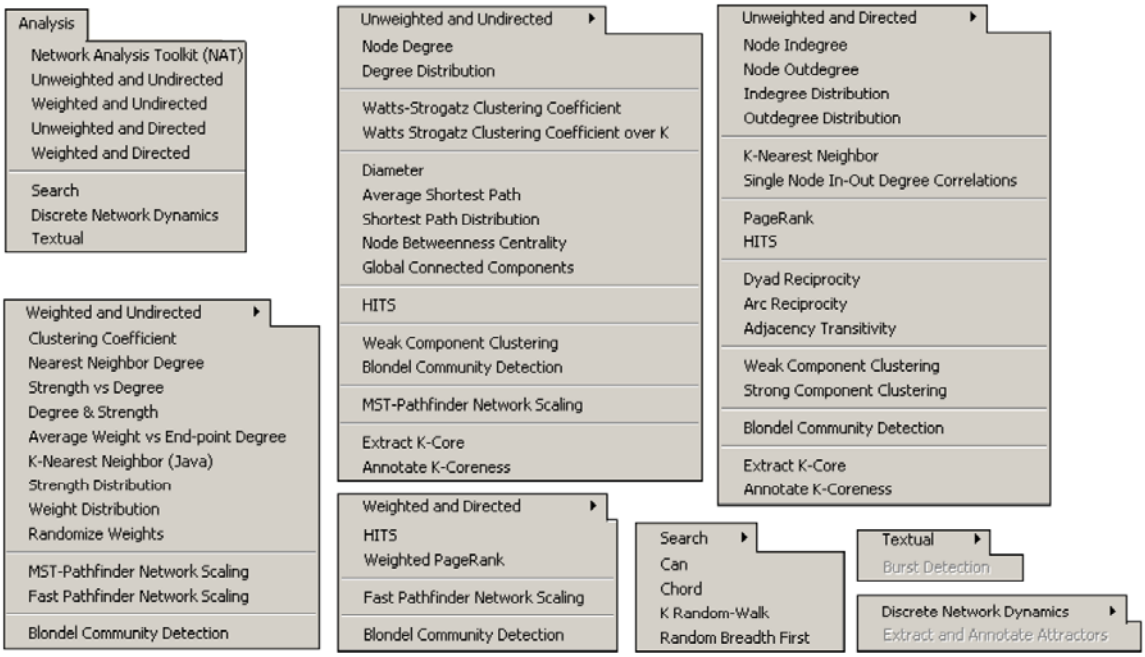
NWB Tool Interface Components



File, Preprocessing, Modeling, and Visualization Menus



Analysis Menu and Submenus



Project Details

Investigators: Katy Börner, Albert-Laszlo Barabasi, Santiago Schnell, Alessandro Vespignani & Stanley Wasserman, Eric Wernert

Software Team: Lead: Micah Linnemeier

Members: Patrick Phillips, Russell Duhon, Tim Kelley & Ann McCranie

Previous Developers: Weixia (Bonnie) Huang, Bruce Herr, Heng Zhang, Duygu Balcan, Bryan Hook, Ben Markines, Santo Fortunato, Felix Terkhorn, Ramya Sabbineni, Vivek S. Thakre & Cesar Hidalgo

Goal: Develop a large-scale network analysis, modeling and visualization toolkit for physics, biomedical, and social science research.

Amount: $1,120,926, NSF IIS-0513650 award

Duration: Sept. 2005 - Aug. 2009

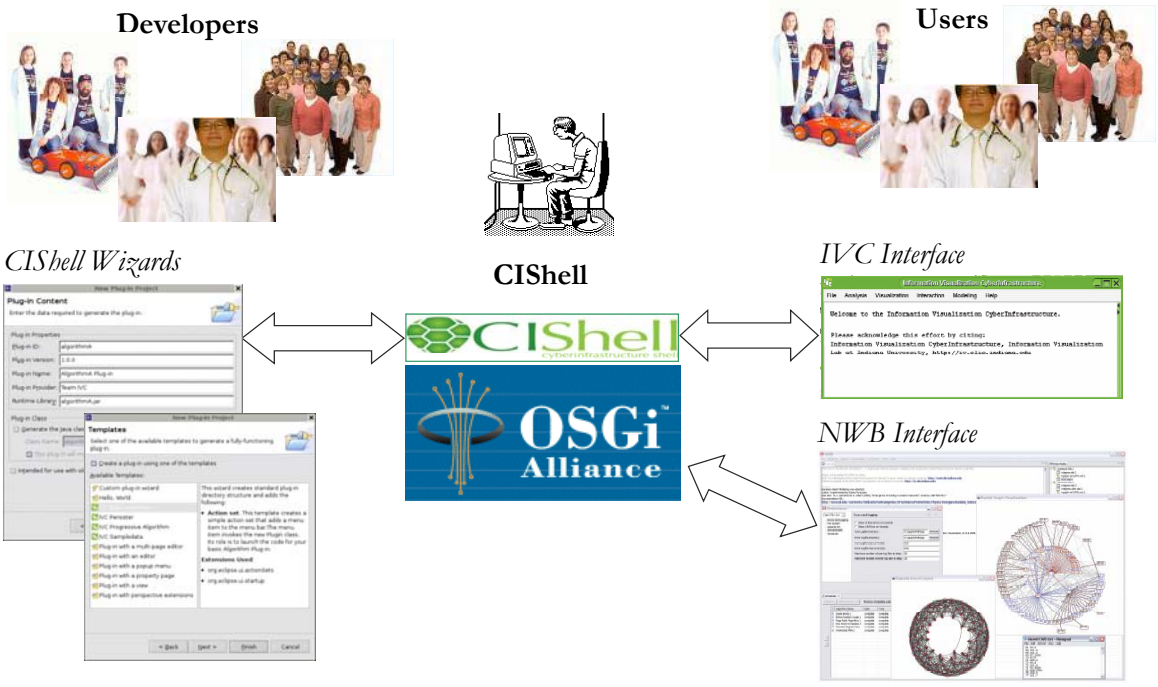
Website: http://nwb.slis.indiana.edu

Project Details (cont.)

NWB Advisory Board:

James Hendler (Semantic Web) http://www.cs.umd.edu/~hendler/
Jason Leigh (CI) http://www.evl.uic.edu/spiff/
Neo Martinez (Biology) http://online.sfsu.edu/~webhead/
Michael Macy, Cornell University (Sociology) http://www.soc.cornell.edu/faculty/macy.shtml
Ulrik Brandes (Graph Theory) http://www.inf.uni-konstanz.de/~brandes/
Mark Gerstein, Yale University (Bioinformatics) http://bioinfo.mbb.yale.edu/
Stephen North (AT&T) http://public.research.att.com/viewPage.cfm?PageID=81
Tom Snijders, University of Groningen http://stat.gamma.rug.nl/snijders/
Noshir Contractor, Northwestern University http://www.spcomm.uiuc.edu/nosh/

CIShell – Serving Non-CS Algorithm Developers & Users



CIShell – Builds on OSGi Industry Standard

CIShell is built upon the Open Services Gateway Initiative (OSGi) Framework.

OSGi (http://www.osgi.org) is

- A standardized, component oriented, computing environment for networked services.
- Successfully used in the industry from high-end servers to embedded mobile devices since 8 years.
- Alliance members include IBM (Eclipse), Sun, Intel, Oracle, Motorola, NEC and many others.
- Widely adopted in open source realm, especially since Eclipse 3.0 that uses OSGi R4 for its plugin model.

Advantages of Using OSGi

- Any CIShell algorithm is a service that can be used in any OSGi-framework based system.
- Using OSGi, running CIShells/tools can connected via RPC/RMI supporting peer-to-peer sharing of data, algorithms, and computing power.

Ideally, CIShell becomes a standard for creating OSGi Services for algorithms.

NWB Tool: Supported Data Formats

Personal Bibliographies

- Bibtex (.bib)
- Endnote Export Format (.enw)

Data Providers

- Web of Science by Thomson Scientific/Reuters (.isi)
- Scopus by Elsevier (.scopus)
- Google Scholar (access via *Publish or Perish* save as CSV, Bibtex, EndNote)
- Awards Search by National Science Foundation (.nsf)

Scholarly Database (all text files are saved as .csv)

- Medline publications by National Library of Medicine
- NIH funding awards by the National Institutes of Health (NIH)
- NSF funding awards by the National Science Foundation (NSF)
- U.S. patents by the United States Patent and Trademark Office (USPTO)
- Medline papers – NIH Funding

Network Formats

- NWB (.nwb)
- Pajek (.net)
- GraphML (.xml or .graphml)
- XGMML (.xml)

Burst Analysis Format

- Burst (.burst)

Other Formats

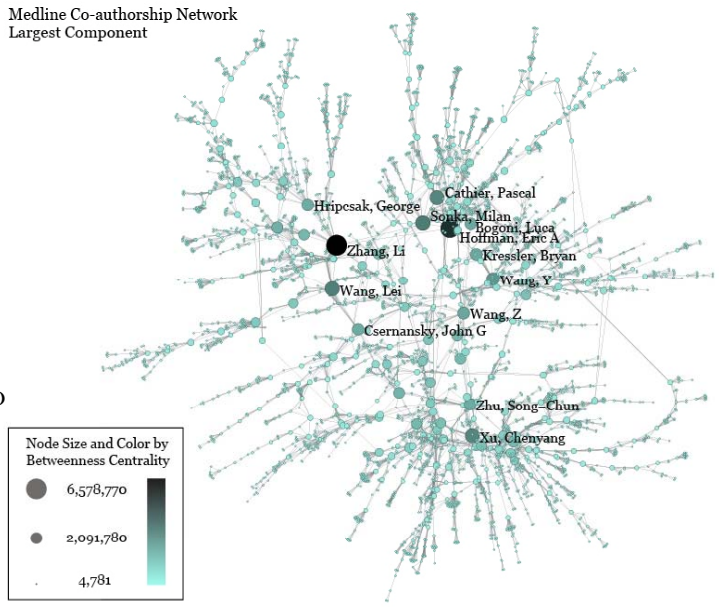
- CSV (.csv)
- Edgelist (.edge)
- Pajek (.mat)
- TreeML (.xml)

NWB Tool: Output Formats

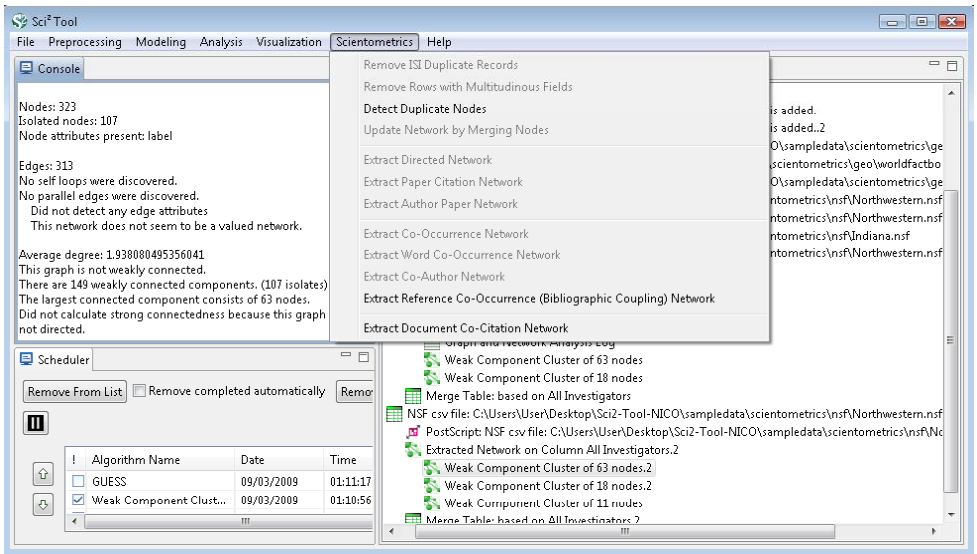
- NWB tool can be used for data conversion. Supported output formats comprise:
- CSV (.csv)
- NWB (.nwb)
- Pajek (.net)
- Pajek (.mat)
- GraphML (.xml or .graphml)
- XGMML (.xml)

- GUESS
  Supports export of images into common image file formats.

- Horizontal Bar Graphs
- saves out raster and ps files.



Sci² Tool for Science of Science Research and Practice



Acknowledgments
This work is supported in part by the Cyberinfrastructure for Network Science center and the School of Library and Information Science at Indiana University, the National Science Foundation under Grant No. SBE-0738111 and IIS-0513650, and the James S. McDonnell Foundation.

INDIANA UNIVERSITY SCHOOL OF LIBRARY AND INFORMATION SCIENCE

James S. McDonnell Foundation

Sci² Tool: Algorithms

See https://nwb.slis.indiana.edu/community

Preprocessing
Extract Top N% Records
Extract Top N Records
Normalize Text
Slice Table by Line

Extract Top Nodes
Extract Nodes Above or Below Value
Delete Isolates

Extract top Edges
Extract Edges Above or Below Value
Remove Self Loops
Trim by Degree
MST-Pathfinder Network Scaling
Fast Pathfinder Network Scaling

Snowball Sampling (in nodes)
Node Sampling
Edge Sampling

Symmetrize
Dichotomize
Multipartite Joining

Geocoder

Extract ZIP Code

Modeling
Random Graph
Watts-Strogatz
Small World
Barabási-Albert Scale-Free
TARL

Analysis
Network Analysis Toolkit (NAT)
Unweighted & Undirected
- Node Degree
- Degree Distribution
- ---
- K-Nearest Neighbor (Java)
- Watts-Strogatz Clustering Coefficient
- Watts Strogatz Clustering Coefficient over K
- ---
- Diameter
- Average Shortest Path
- Shortest Path Distribution
- Node Betweenness Centrality
- ---
- Weak Component Clustering
- Global Connected Components
- ---
- Extract K-Core
- Annotate K-Coreness
- ---
- HITS

Weighted & Undirected
- Clustering Coefficient
- Nearest Neighbor Degree
- Strength vs Degree
- Degree & Strength
- Average Weight vs End-point Degree
- Strength Distribution
- Weight Distribution
- Randomize Weights
- ---
- Blondel Community Detection
- ---
- HITS

Unweighted & Directed
- Node Indegree
- Node Outdegree
- Indegree Distribution
- Outdegree Distribution
- ---
- K-Nearest Neighbor
- Single Node in-Out Degree Correlations
- ---
- Dyad Reciprocity
- Arc Reciprocity
- Adjacency Transitivity
- ---
- Weak Component Clustering
- Strong Component Clustering
- ---

Sci² Tool: Algorithms cont.

See https://nwb.slis.indiana.edu/community

- ---
- Extract K-Core
- Annotate K-Coreness
- ---
- HITS
- PageRank

Weighted & Directed
- HITS
- Weighted PageRank

Textual
Burst Detection

Visualization
GnuPlot
GUESS
Image Viewer

Radial Tree/Graph (prefuse alpha)
Radial Tree/Graph with Annotation (prefuse beta)
Tree View (prefuse beta)
Tree Map (prefuse beta)
Force Directed with Annotation (prefuse beta)
Fruchterman-Reingold with Annotation (prefuse beta)

DrL (VxOrd)
Specified (prefuse beta)

Horizontal Line Graph
Circular Hierarchy
Geo Map (Circle Annotation Style)
Geo Map (Colored-Region Annotation Style)
***Science Map (Circle Annotation)**

Scientometrics
Remove ISI Duplicate Records
Remove Rows with Multitudinous Fields
Detect Duplicate Nodes
Update Network by Merging Nodes

Extract Directed Network
Extract Paper Citation Network
Extract Author Paper Network

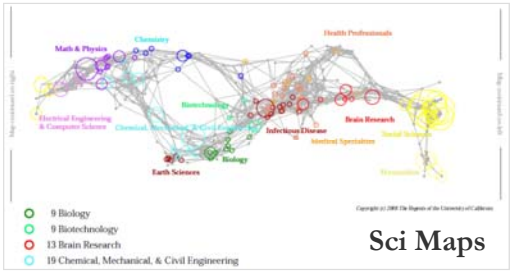
Extract Co-Occurrence Network
Extract Word Co-Occurrence Network
Extract Co-Author Network
Extract Reference Co-Occurrence (Bibliographic Coupling) Network
---
Extract Document Co-Citation Network

* Requires permission from UCSD
All four+ save into Postscript files.

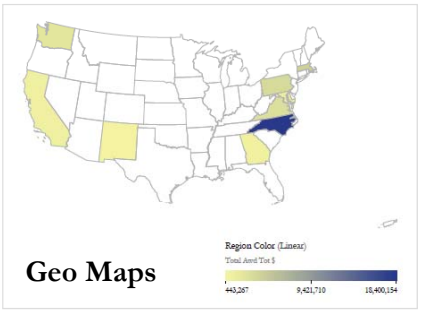
General Network extraction

Sci² Tool

Plugins that render into Postscript files:



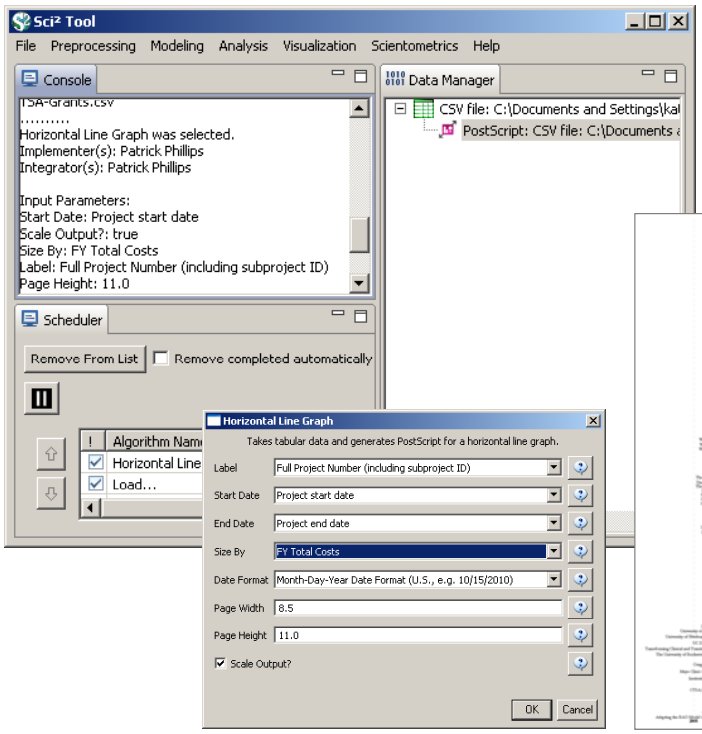
Sci Maps

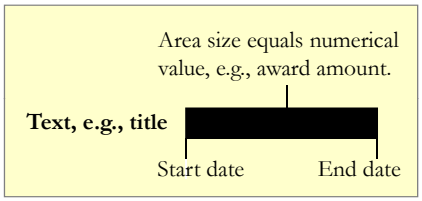


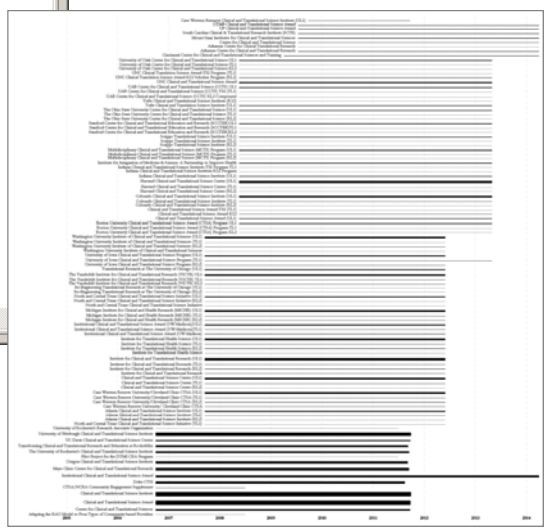
Geo Maps

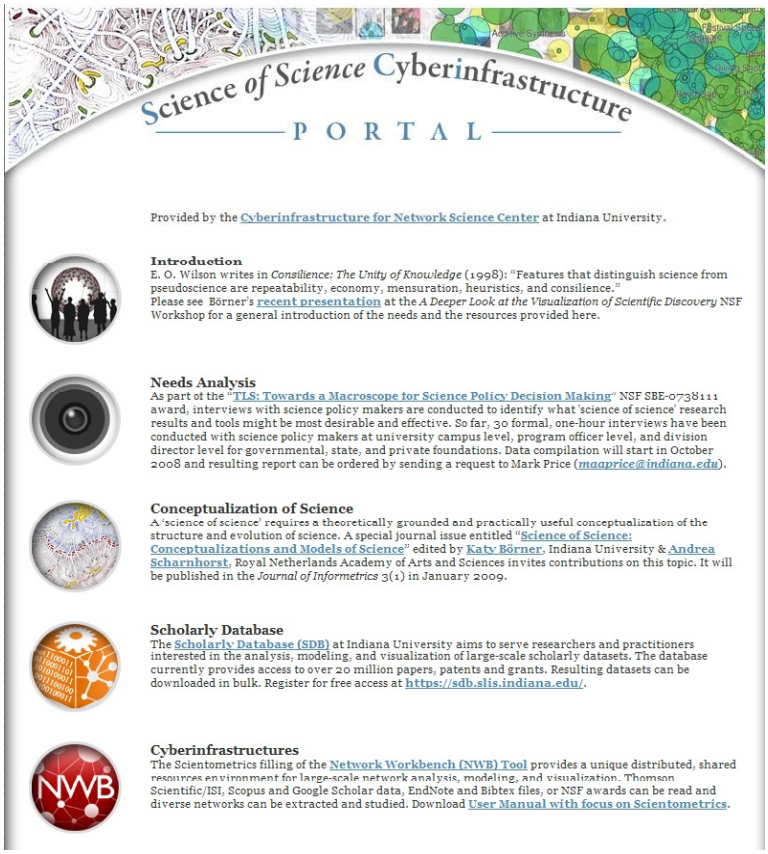
Börner, Katy, Huang, Weixia (Bonnie), Linnemeier, Micah, Duhon, Russell Jackson, Phillips, Patrick, Ma, Nianli, Zoss, Angela, Guo, Hanning & Price, Mark. (2009). Rete-Netzwerk-Red: Analyzing and Visualizing Scholarly Networks Using the Scholarly Database and the Network Workbench Tool. Proceedings of ISSI 2009: 12th International Conference on Scientometrics and Informetrics, Rio de Janeiro, Brazil, July 14-17 . Vol. 2, pp. 619-630.

Temporal: Horizontal Bargraphs









http://sci.slis.indiana.edu

OSGi/CIShell Adoption

CIShell/OSGi is at the core of different CIs and a total of 169 unique plugins are used in the
- ***Information Visualization*** (http://iv.slis.indiana.edu),
- ***Network Science (NWB Tool)*** (http://nwb.slis.indiana.edu),
- ***Scientometrics and Science Policy (Sci^2 Tool)*** (http://sci.slis.indiana.edu), and
- ***Epidemics*** (http://epic.slis.indiana.edu) research communities.

Most interestingly, a number of other projects recently adopted OSGi and one adopted CIShell:

Cytoscape (http://www.cytoscape.org) lead by Trey Ideker, UCSD is an open source bioinformatics software platform for visualizing molecular interaction networks and integrating these interactions with gene expression profiles and other state data (Shannon et al., 2002).

Taverna Workbench (http://taverna.sourceforge.net) lead by Carol Goble, University of Manchester, UK is a free software tool for designing and executing workflows (Hull et al., 2006). Taverna allows users to integrate many different software tools, including over 30,000 web services.

MAEviz (https://wiki.ncsa.uiuc.edu/display/MAE/Home) managed by Shawn Hampton, NCSA is an open-source, extensible software platform which supports seismic risk assessment based on the Mid-America Earthquake (MAE) Center research.

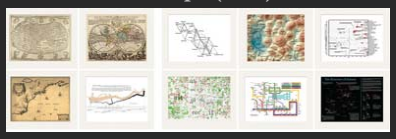
TEXTrend (http://www.textrend.org) lead by George Kampis, Eötvös University, Hungary develops a framework for the easy and flexible integration, configuration, and extension of plugin-based components in support of natural language processing (NLP), classification/mining, and graph algorithms for the analysis of business and governmental text corpuses with an inherently temporal component.

As the functionality of OSGi-based software frameworks improves and the number and diversity of dataset and algorithm plugins increases, the capabilities of custom tools will expand.

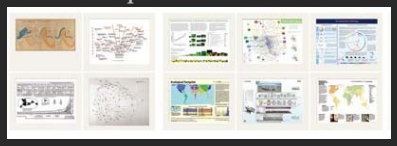
Mapping Science Exhibit – 10 Iterations in 10 years

http://scimaps.org

The Power of Maps (2005)



Science Maps for Economic Decision Makers (2008)



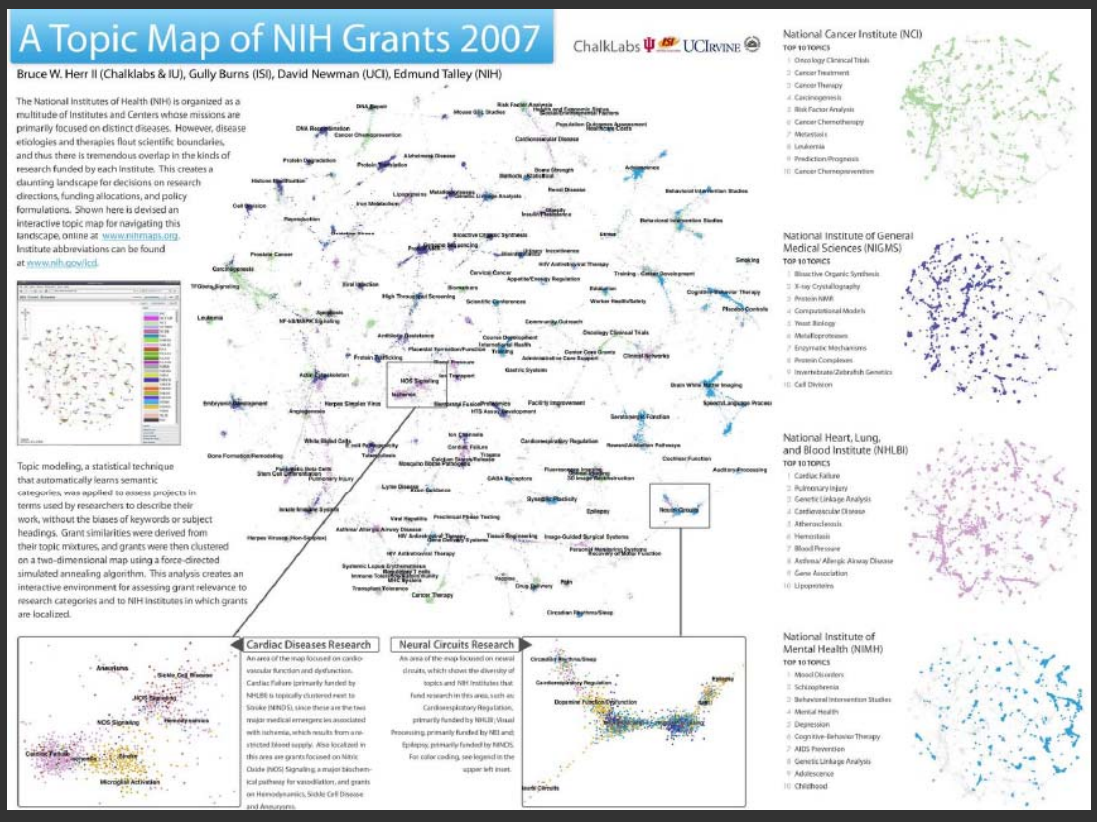
The Power of Reference Systems (2006)

Science Maps for Science Policy Makers (2009)
Science Maps for Scholars (2010)
Science Maps as Visual Interfaces to Digital Libraries (2011)
Science Maps for Kids (2012)
Science Forecasts (2013)

The Power of Forecasts (2007)

How to Lie with Science Maps (2014)

Exhibit has been shown in 72 venues on four continents. Currently at
- NSF, 10th Floor, 4201 Wilson Boulevard, Arlington, VA
- Wallenberg Hall, Stanford University, CA
- Center of Advanced European Studies and Research, Bonn, Germany
- Science Train, Germany.



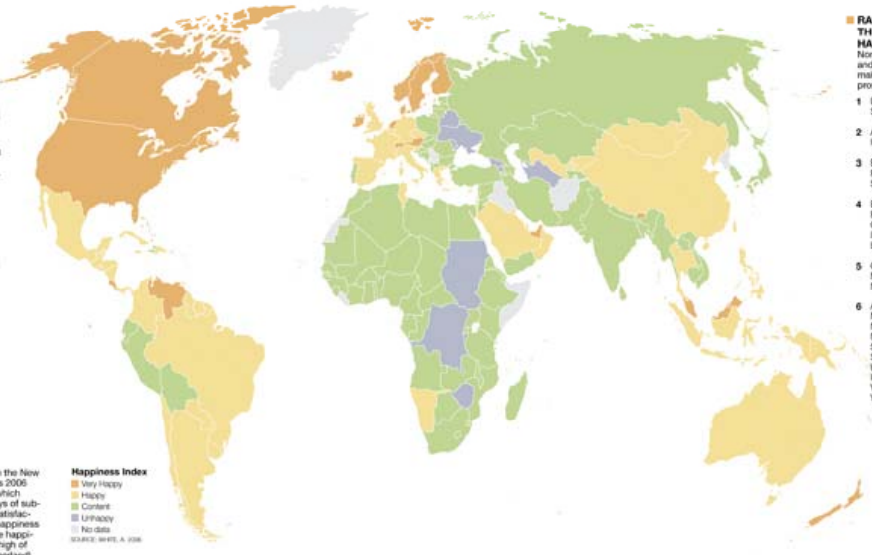
Herr II, Bruce W., Gully Burns, David Newman, Edmund Talley. 2007. A Topic Map of NIH Grants 2007. Bloomington, IN.

Happiness Depends on Various Factors

"It's time we admitted there's more to life than money."
- David Cameron, U.K. leader of the opposition, 2006

Social scientists are starting to include relative happiness with hard data on economic status, health, and other factors as they assess quality of life. They rely on surveys of "subjective well-being"—how good people feel about their lives. A world map of one "happiness index" shows many, but not all, wealthy northern countries faring well. Residents of sub-Saharan Africa and the former Soviet Union, meanwhile, report particularly low levels of contentment.

Any attempt to measure happiness will fall short—each life is a series of joys, struggles, and sorrows, and satisfaction can depend as much on outlook as on circumstances. Averages obscure the happy moments in struggling nations, as well as people who suffer from poor health, poverty, or discrimination in countries that rank high. Still, happiness indices can help researchers move beyond simple economics as they track progress—or backsliding—over time.



RANKING THE WORLD'S HAPPIEST PLACES
Northern Europe, North America, and several wealthy countries make the list, but so do many less prosperous island nations.

1 DENMARK
SWITZERLAND

2 AUSTRIA
ICELAND

3 BAHAMAS
FINLAND
SWEDEN

4 BHUTAN
BRUNEI
CANADA
IRELAND
LUXEMBOURG

5 COSTA RICA
MALTA
NETHERLANDS

6 ANTIGUA AND BARBUDA
MALAYSIA
NEW ZEALAND
NORWAY
SEYCHELLES
ST. KITTS AND NEVIS
UNITED ARAB EMIRATES
UNITED STATES
VANUATU
VENEZUELA

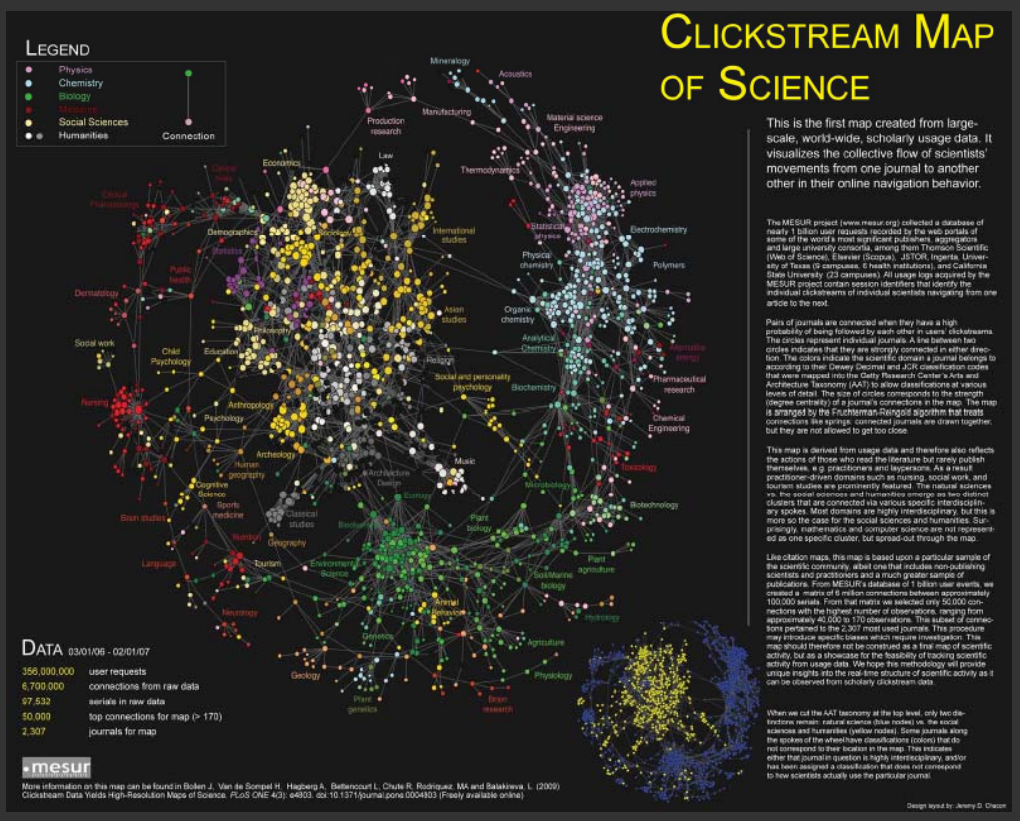
MEASURING THE INTANGIBLE
The map is derived from the New Economics Foundation's 2006 "Happy Planet Index," which drew on over 100 surveys of subjective well-being. Its "satisfaction with life scale"—a happiness index—ranks the relative happiness of nations, from a high of 273 (Denmark and Switzerland) to a low of 100 (Burundi).

DEFINING WELL-BEING
By comparing the happiness index to data from the UN, the CIA, and other sources, a U.K. psychologist determined that good health and health care, enough money for fundamental needs, and access to basic education are the most important factors for subjective well-being. European countries top all three measures.

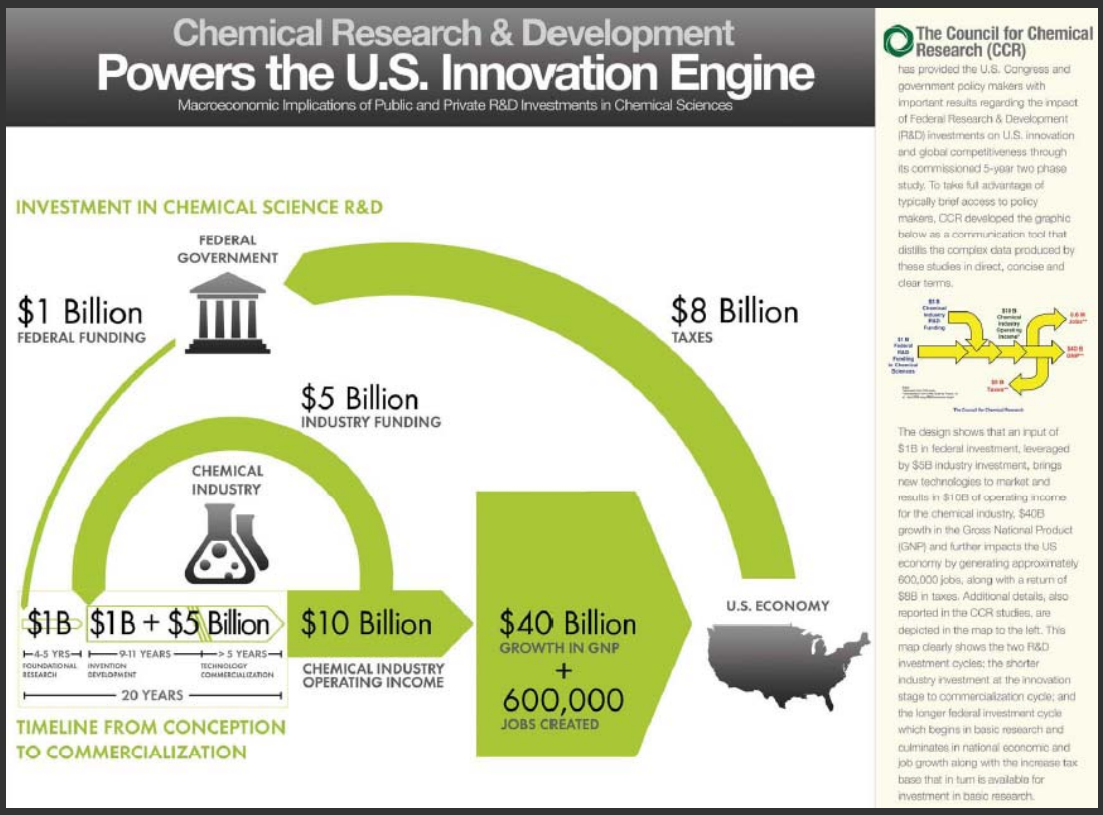
HEALTH
Japan boasts the world's longest life expectancy—one measure of overall health. Swaziland, at the other end of the scale, is plagued by poverty, disease, and violence. Disparities in access to health care divide many countries into haves and have-nots.

WEALTH
Money still can't buy love, or happiness, and wealthy people aren't always more content. Still, tiny Luxembourg, which takes top rank in per capita Gross Domestic Product (GDP), also rates a 253 on the happiness index. Real poverty means real misery, a fate shared by billions.

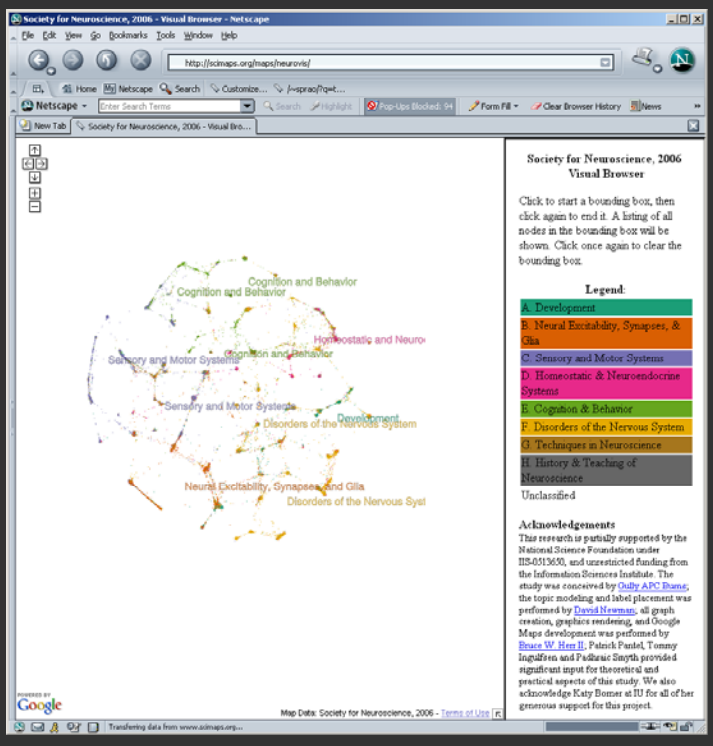
EDUCATION
Residents of Australia can expect to spend more time in school—an average of almost 21 years—than citizens of any other country. But only a basic education is needed to see a significant jump in overall happiness. Around the world, hundreds of millions lack even that.



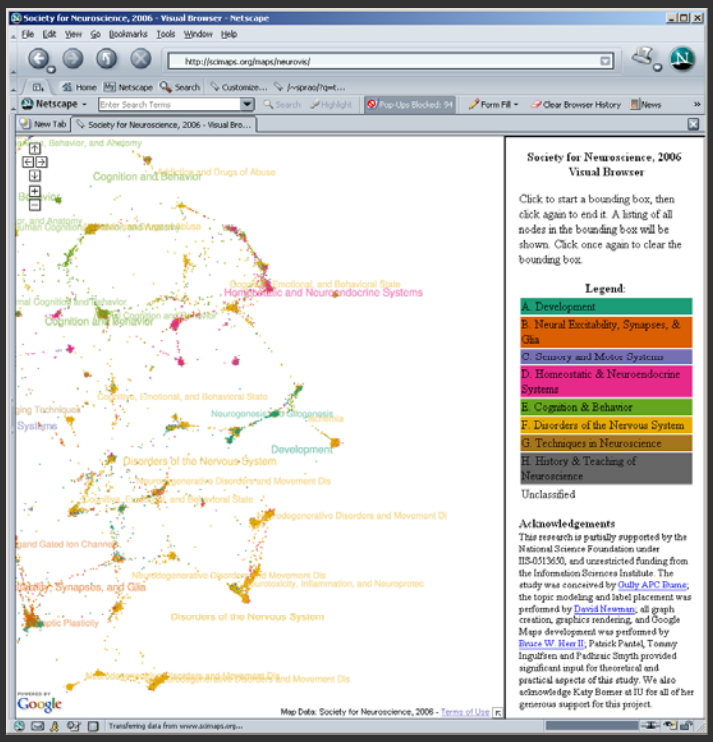
Bollen, Johan, Herbert Van de Sompel, Aric Hagberg, Luis M.A. Bettencourt, Ryan Chute, Marko A. Rodriquez, Lyudmila Balakireva. 2008. A Clickstream Map of Science.



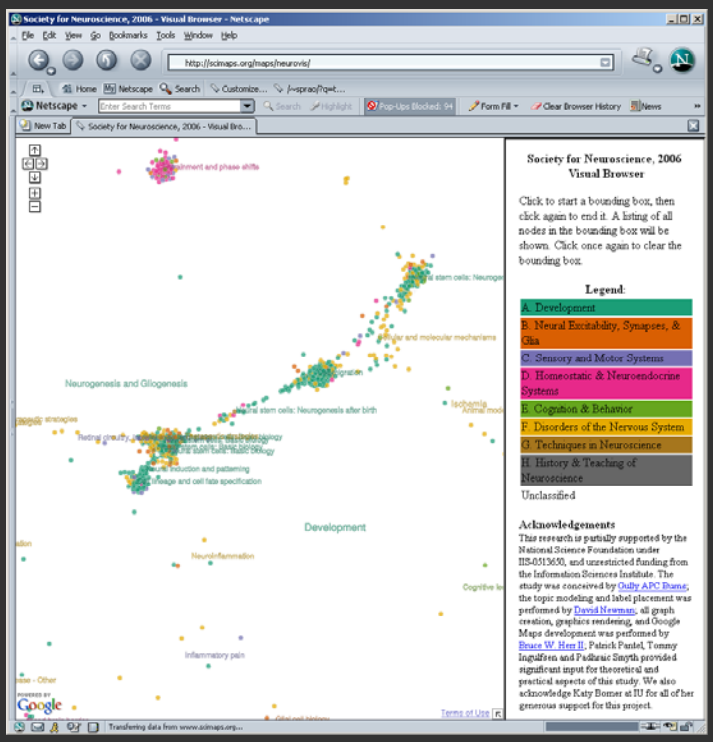
Council for Chemical Research. 2009. Chemical R&D Powers the U.S. Innovation Engine. Washington, DC. Courtesy of the Council for Chemical Research.



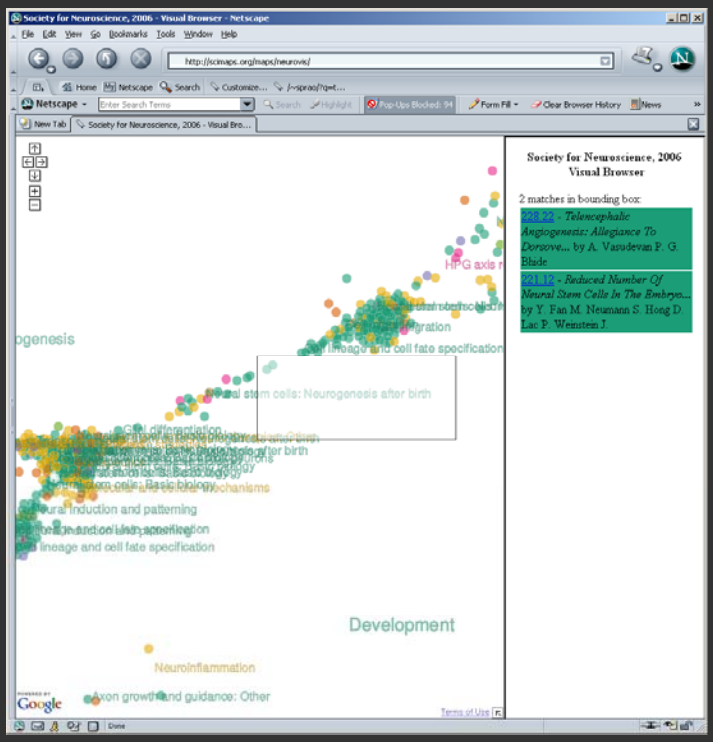
Bruce W. Herr II, Gully Burns (USC), David Newman (UCI), Society for Neuroscience, 2006 Visual Browser, 2007, http://scimaps.org/maps/neurovis/



Bruce W. Herr II, Gully Burns (USC), David Newman (UCI), Society for Neuroscience, 2006 Visual Browser, 2007, http://scimaps.org/maps/neurovis/

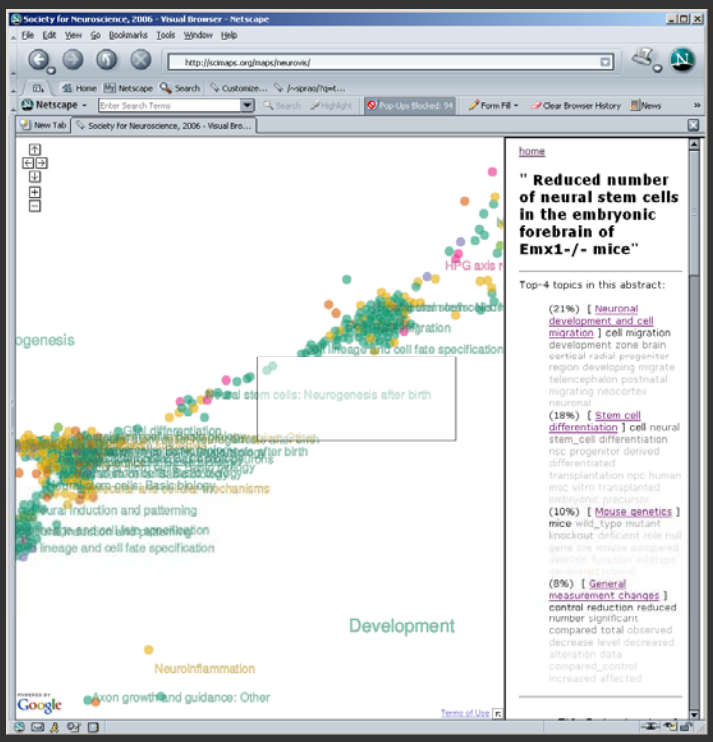


Bruce W. Herr II, Gully Burns (USC), David Newman (UCI), Society for Neuroscience, 2006 Visual Browser, 2007, http://scimaps.org/maps/neurovis/



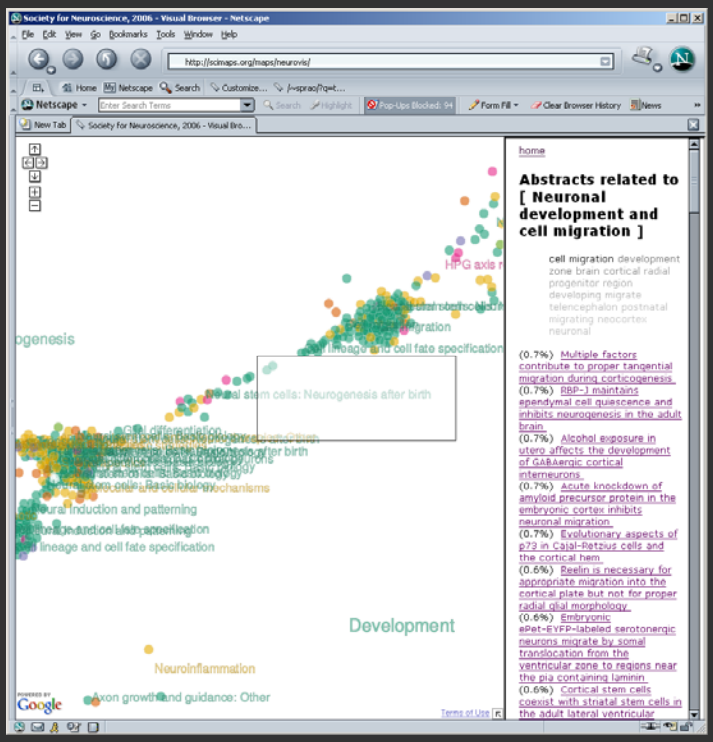
Bruce W. Herr II, Gully Burns (USC), David Newman (UCI), Society for Neuroscience, 2006 Visual Browser, 2007, http://scimaps.org/maps/neurovis/

61



Bruce W. Herr II, Gully Burns (USC), David Newman (UCI), Society for Neuroscience, 2006 Visual Browser, 2007, http://scimaps.org/maps/neurovis/

62



Bruce W. Herr II, Gully Burns (USC), David Newman (UCI), Society for Neuroscience, 2006 Visual Browser, 2007, http://scimaps.org/maps/neurovis/

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.

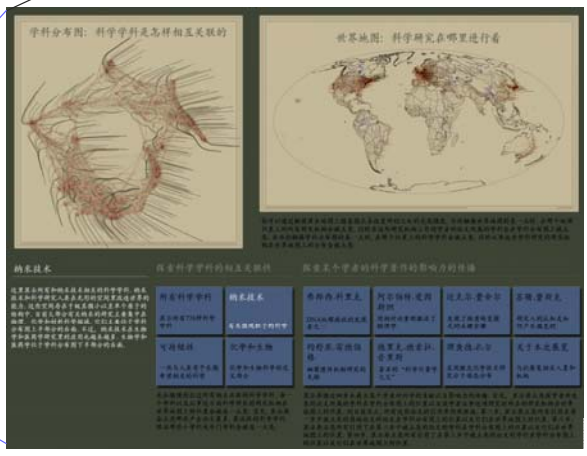
Questions:

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

Interactive touch panel.

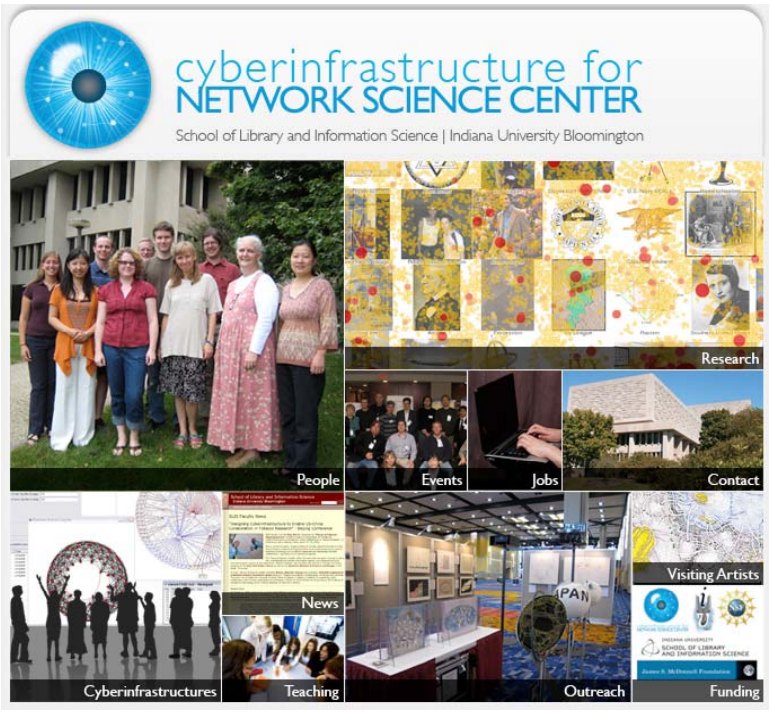
Contributions:

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



Debut of 5th Iteration of Mapping Science Exhibit at MEDIA X was on May 18, 2009 at Wallenberg Hall, Stanford University, *http://mediax.stanford.edu*, *http://scaleindependentthought.typepad.com/photos/scimaps*

Science Maps in "Expedition Zukunft" science train visiting 62 cities in 7 months
12 coaches, 300 m long
Opening was on April 23rd, 2009 by German Chancellor Merkel
http://www.expedition-zukunft.de



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