Towards Plug-and-Play Macroscopes for Science Policy Decision Making

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 the members at the Cyberinfrastructure for Network Science Center and the Mapping Science exhibit map makers and advisory board members.

JST-CRDS Workshop
Evidence-based Policy Making for Science, Technology and Innovation Policy
Center for Research and Development Strategy (CRDS), Tokyo, Japan

March 9-10, 2010

The Need.

The Changing Scientific Landscape

Star Scientist -> Research Teams: In former times, science was driven by key scientists. Today, science is driven by effectively collaborating co-author teams often comprising expertise from multiple disciplines and several geospatial locations (Börner, Dall'Asta, Ke, & Vespignani, 2005; Shneiderman, 2008).

Users -> Contributors: Web 2.0 technologies empower anybody to contribute to Wikipedia and to exchange images and videos via Fickr and YouTube. WikiSpecies, WikiProfessionals, or WikiProteins combine wiki and semantic technology in support of real time community annotation of scientific datasets (Mons et al., 2008).

Cross-disciplinary: The best tools frequently borrow and synergistically combine methods and techniques from different disciplines of science and empower interdisciplinary and/or international teams of researchers, practitioners, or educators to fine-tune and interpret results collectively.

One Specimen -> Data Streams: Microscopes and telescopes were originally used to study one specimen at a time. Today, many researchers must make sense of massive streams of multiple types of data with different formats, dynamics, and origin.

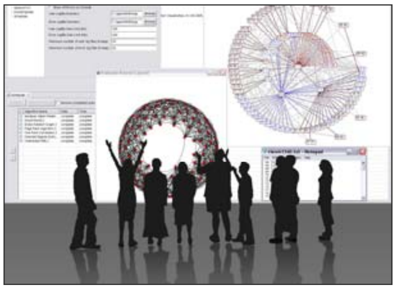
Static Instrument -> Evolving Cyberinfrastructure (CI): The importance of hardware instruments that are rather static and expensive decreases relative to software infrastructures that are highly flexible and continuously evolving according to the needs of different sciences. Some of the most successful services and tools are decentralized increasing scalability and fault tolerance.

Modularity: The design of software modules with well defined functionality that can be flexibly combined helps reduce costs, makes it possible to have many contribute, and increases flexibility in tool development, augmentation, and customization.

Standardization: Adoption of standards speeds up development as existing code can be leveraged. It helps pool resources, supports interoperability, but also eases the migration from research code to production code and hence the transfer of research results into industry applications and products.

Open data and open code: Lets anybody check, improve, or repurpose code and eases the replication of scientific studies.

Microscopes, Telescopes, and Macrocopes



Just as the **microscope** empowered our naked eyes to see cells, microbes, and viruses thereby advancing the progress of biology and medicine or the **telescope** opened our minds to the immensity of the cosmos and has prepared mankind for the conquest of space, **macroscopes** promise to help us cope with another infinite: the infinitely complex. Macroscopes give us a 'vision of the whole' and help us 'synthesize'. They let us detect patterns, trends, outliers, and access details in the landscape of science. Instead of making things larger or smaller, macroscopes let us observe what is at once too great, too slow, or too complex for our eyes.

Desirable Features of Plug-and-Play Macroscopes

Division of Labor: Ideally, labor is divided in a way that the expertise and skills of computer scientists are utilized for the design of standardized, modular, easy to maintain and extend "core architecture". Dataset and algorithm plugins, i.e., the "filling", are initially provided by those that care and know most about the data and developed the algorithms: the domain experts.

Ease of Use: As most plugin contributions and usage will come from non-computer scientists it must be possible to contribute, share, and use new plugins without writing one line of code. Wizard-driven integration of new algorithms and data sets by domain experts, sharing via email or online sites, deploying plugins by adding them to the 'plugin' directory, and running them via a Menu driven user interfaces (as used in Word processing systems or Web browsers) seems to work well.

Plugin Content and Interfaces: Should a plugin represent one algorithm or an entire tool? What about data converters needed to make the output of one algorithm compatible with the input of the next? Should those be part of the algorithm plugin or should they be packaged separately?

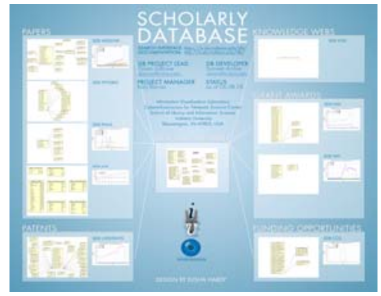
Supported (Central) Data Models: Some tools use a central data model to which all algorithms conform, e.g., Cytoscape, see Related Work section. Other tools support many internal data models and provide an extensive set of data converters, e.g., Network Workbench, see below. The former often speeds up execution and visual rendering while the latter eases the integration of new algorithms. In addition, most tools support an extensive set of input and output formats.

Core vs. Plugins: As will be shown, the "core architecture" and the "plugin filling" can be implemented as sets of plugin bundles. Answers to questions such as: "Should the graphical user interface (GUI), interface menu, scheduler, or data manager be part of the core or its filling?" will depend on the type of tools and services to be delivered.

Supported Platforms: If the software is to be used via Web interfaces then Web services need to be implemented. If a majority of domain experts prefers a stand-alone tool running on a specific operating system then a different deployment is necessary.

A Solution.

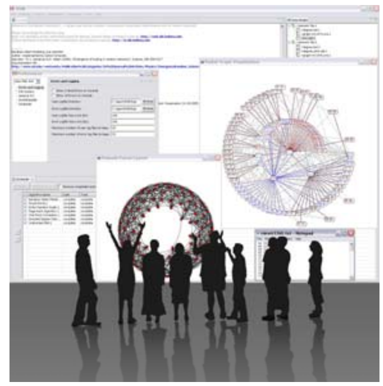
CI for a Science of Science Studies



Scholarly Database: 23 million scholarly records
http://sdb.slis.indiana.edu

James S. McDonnell Foundation

Information Visualization Cyberinfrastructure
http://iv.slis.indiana.edu



Network Workbench Tool + Community Wiki
http://nwb.slis.indiana.edu

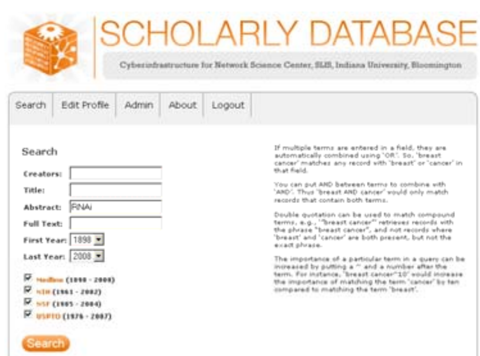
Sci^2 Tool and Science of Science CI Portal
http://sci.slis.indiana.edu

Epidemics Cyberinfrastructure
http://epic.slis.indiana.edu/

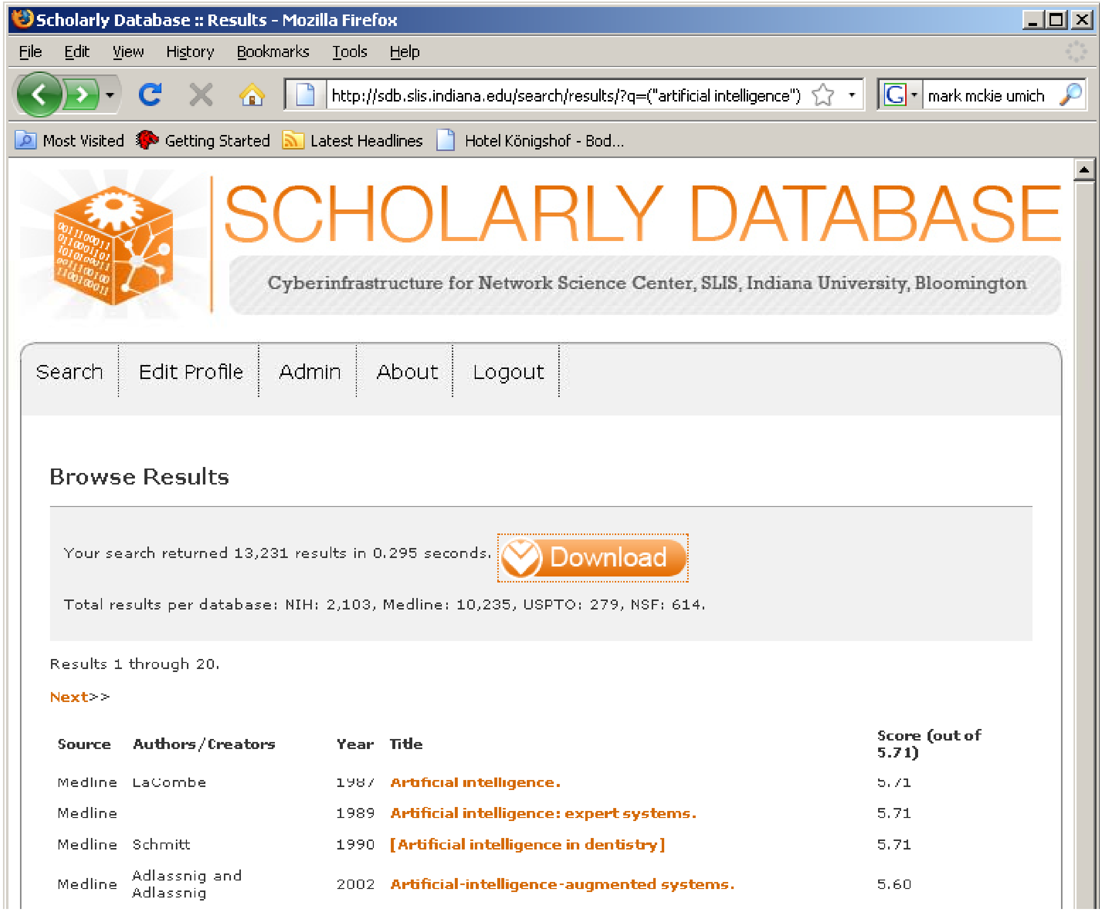
SDB | SCHOLARLY DATABASE

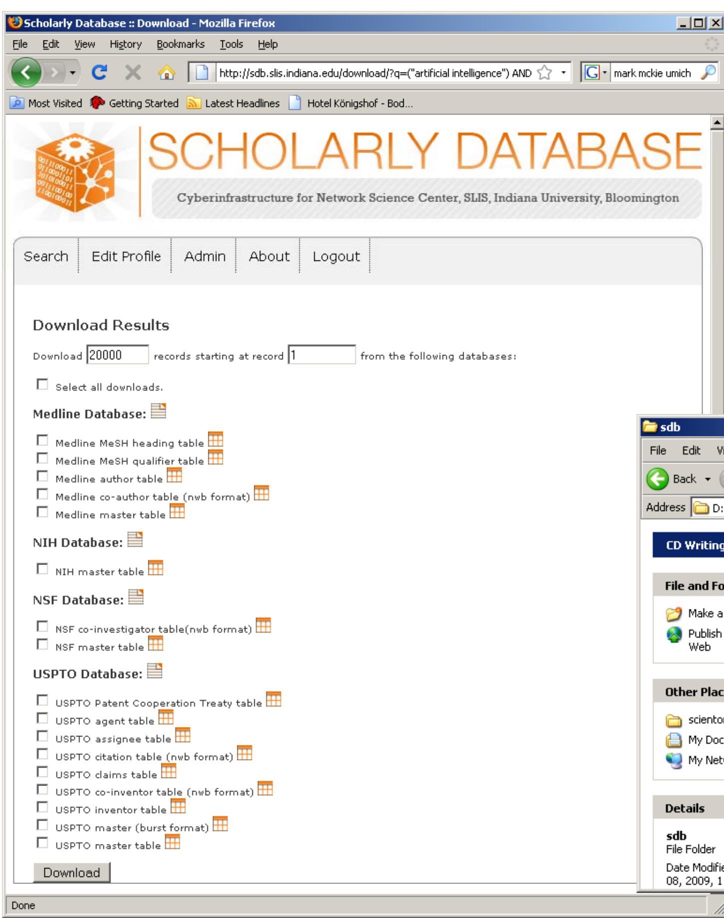
Scholarly Database: Web Interface

Search across publications, patents, grants.
Download records and/or (evolving) co-author, paper-citation networks.

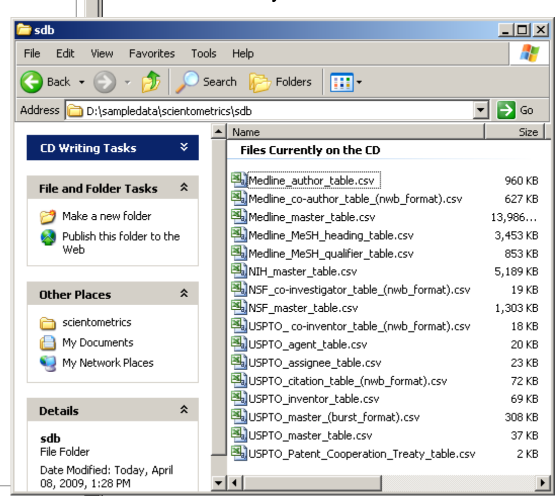


Register for free access at http://sdb.slis.indiana.edu





Since March 2009:
Users can download networks:
- Co-author
- Co-investigator
- Co-inventor
- Patent citation
and tables for
burst analysis in NWB.



Scholarly Database: # Records, Years Covered

Datasets available via the Scholarly Database (* internally)

Dataset	# Records	Years Covered	Updated	Restricted Access
Medline	17,764,826	1898-2008	Yes	
PhysRev	398,005	1893-2006		Yes
PNAS	16,167	1997-2002		Yes
JCR	59,078	1974, 1979, 1984, 1989 1994-2004		Yes
USPTO	3, 875,694	1976-2008	Yes*	
NSF	174,835	1985-2002	Yes*	
NIH	1,043,804	1961-2002	Yes*	
Total	**23,167,642**	**1893-2006**	**4**	**3**

Aim for comprehensive time, geospatial, and topic coverage.

Network Workbench Tool

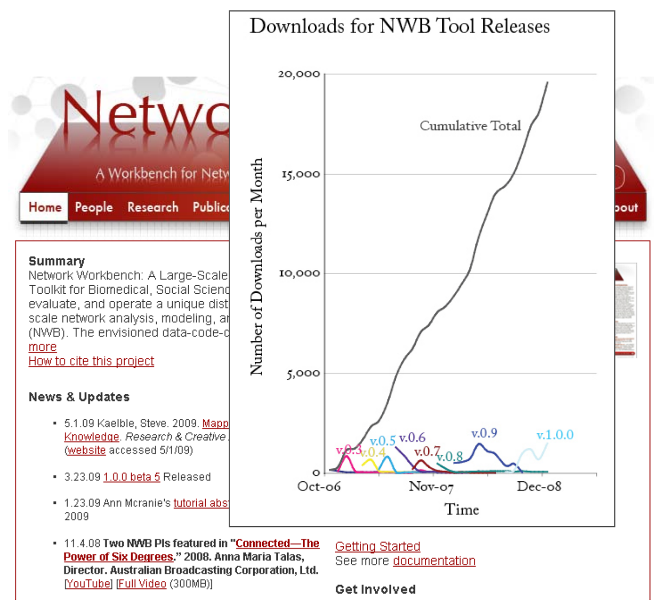
http://nwb.slis.indiana.edu

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 February 2009, the tool provides more 169 plugins that support the preprocessing, analysis, modeling, and visualization of networks.

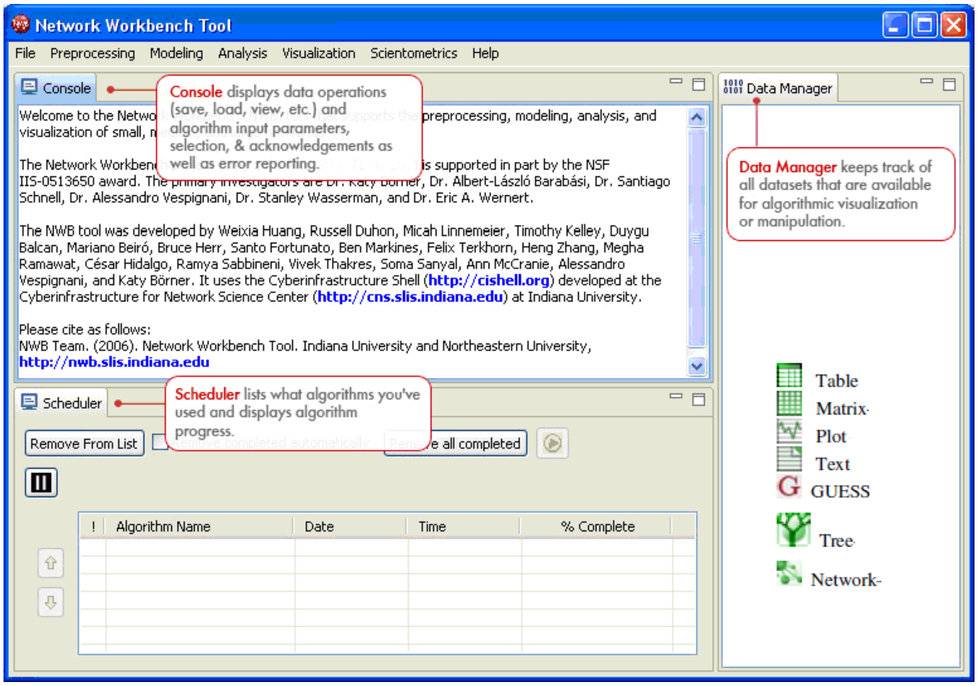
More than 50 of these plugins can be applied or were specifically designed for S&T studies.

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



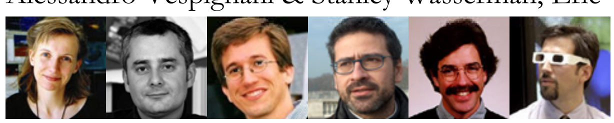
Herr II, Bruce W., Huang, Weixia (Bonnie), Penumarthy, Shashikant & Börner, Katy. (2007). Designing Highly Flexible and Usable Cyberinfrastructures for Convergence. In Bainbridge, William S. & Roco, Mihail C. (Eds.), Progress in Convergence - Technologies for Human Wellbeing (Vol. 1093, pp. 161-179),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

NWB Tool Interface Components



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

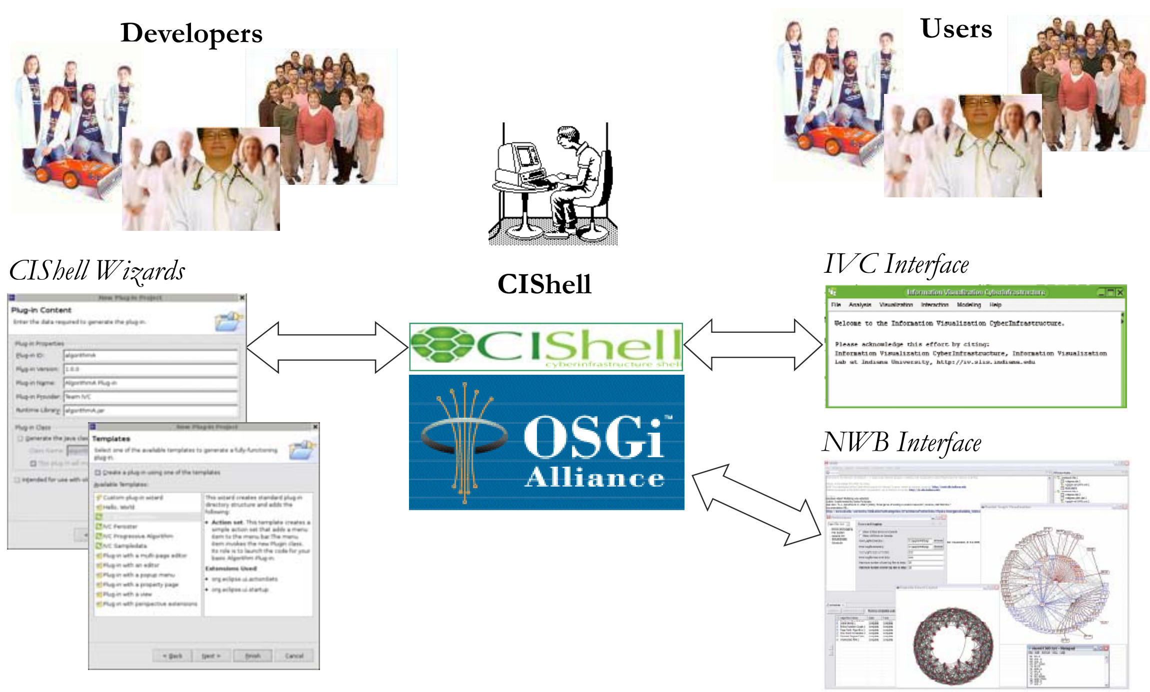
Website: http://nwb.slis.indiana.edu

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

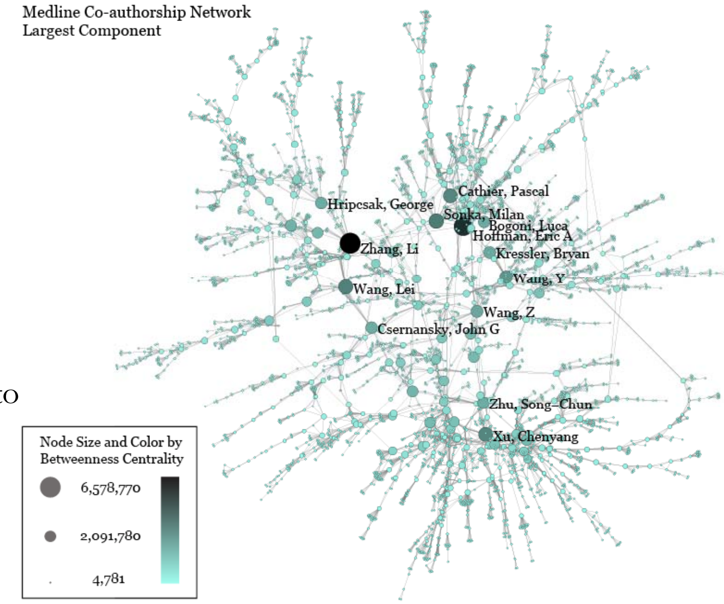
- CSV (.csv)
- Edgelist (.edge)
- Pajek (.mat)
- TreeML (.xml)

NWB Tool: Output Formats

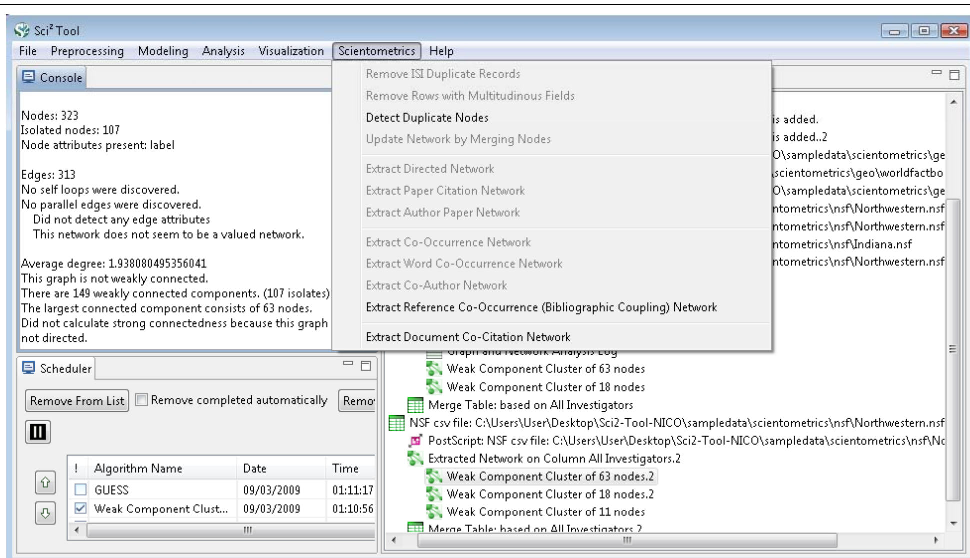
- NWB tool can be used for data conversion. Supported output formats comprise:
- CSV (.csv)
- NWB (.nwb)
- Pajek (.net)
- Pajek (.mat)
- GraphML (.xml or .graphml)
- XGMML (.xml)

- 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.

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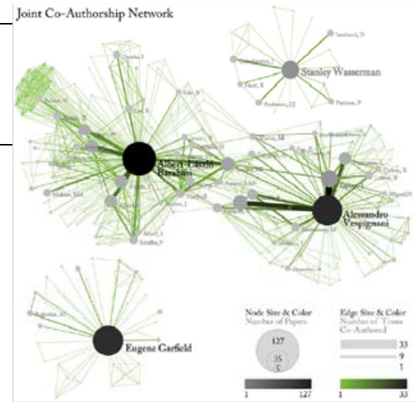
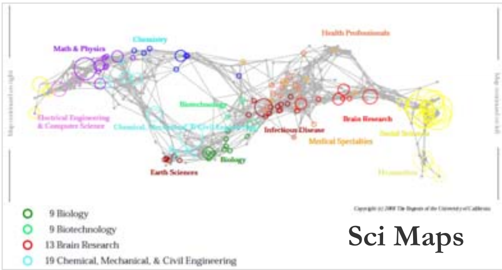
James S. McDonnell Foundation

Sci² Tool
http://sci.slis.indiana.edu



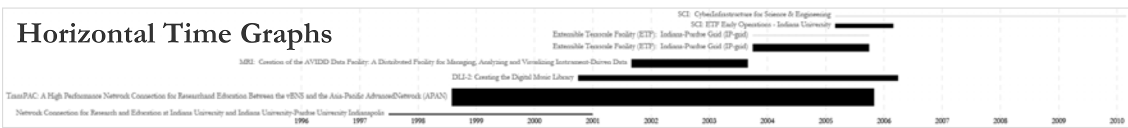
GUESS Network Vis

"Open Code for S&T Assessment"
Branded OSGi/CIShell based tool with NWB plugins and many new plugins.



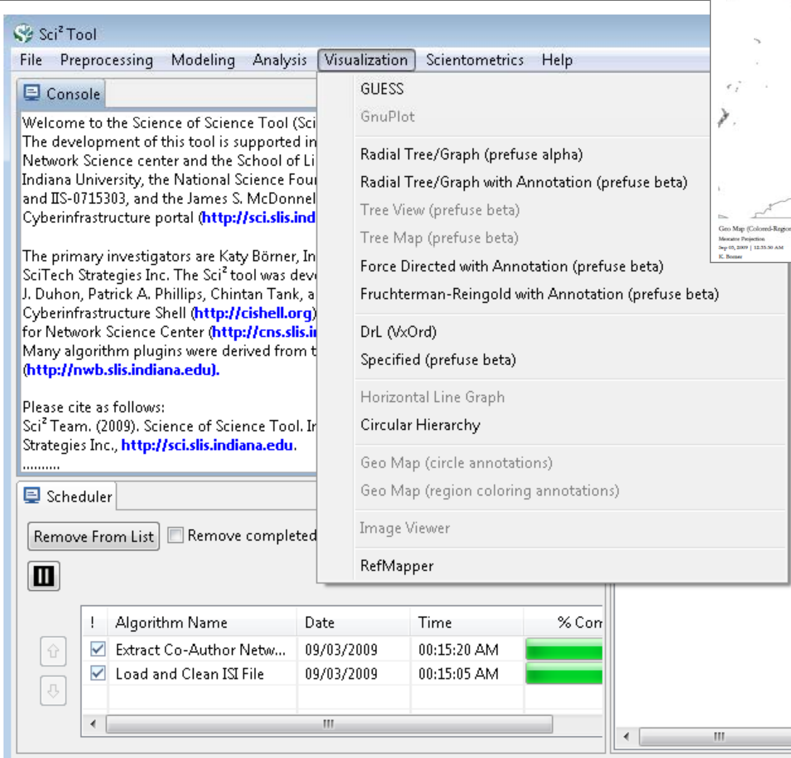
Sci Maps

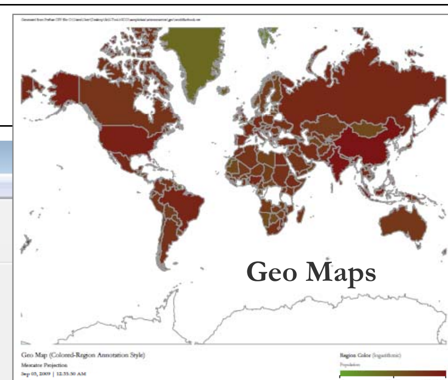
Horizontal Time Graphs



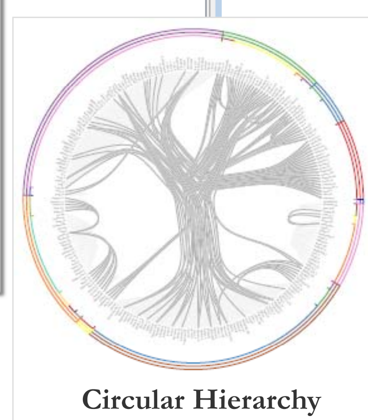
Börner, Katy, Huang, Weixia (Bonnie), Linnemeier, Micah, Duhon, Russell Jackson, Phillips, Patrick, Ma, Nianli, Zoss, Angela, Guo, Hanning & Price, Mark. (2009). Rete-Netzwerk-Red: Analyzing and Visualizing Scholarly Networks Using the Scholarly Database and the Network Workbench Tool. Proceedings of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

Sci² Tool





Geo Maps



Circular Hierarchy

Sci² Tool: Algorithms

See [*https://nwb.slis.indiana.edu/community*](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*](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

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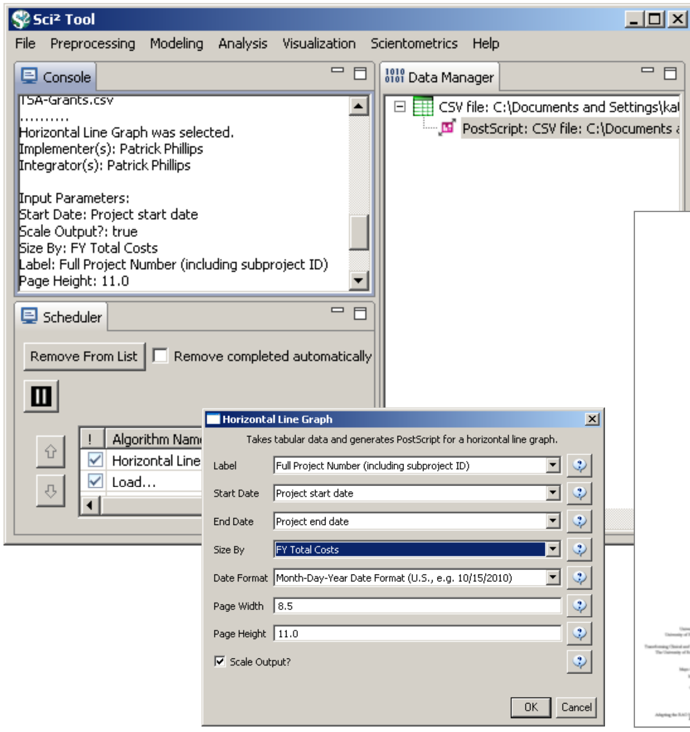
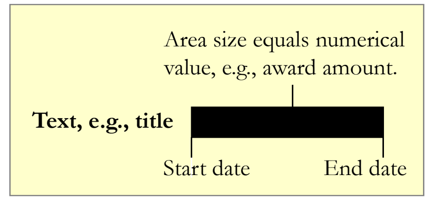
Extract Document Co-Citation Network

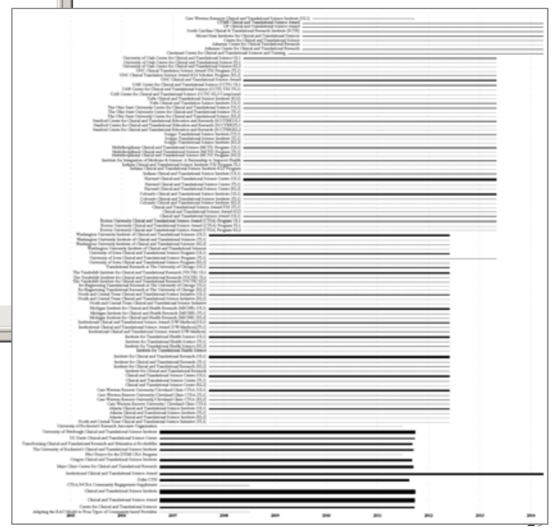
* Requires permission from UCSD
All four+ save into Postscript files.

General Network extraction

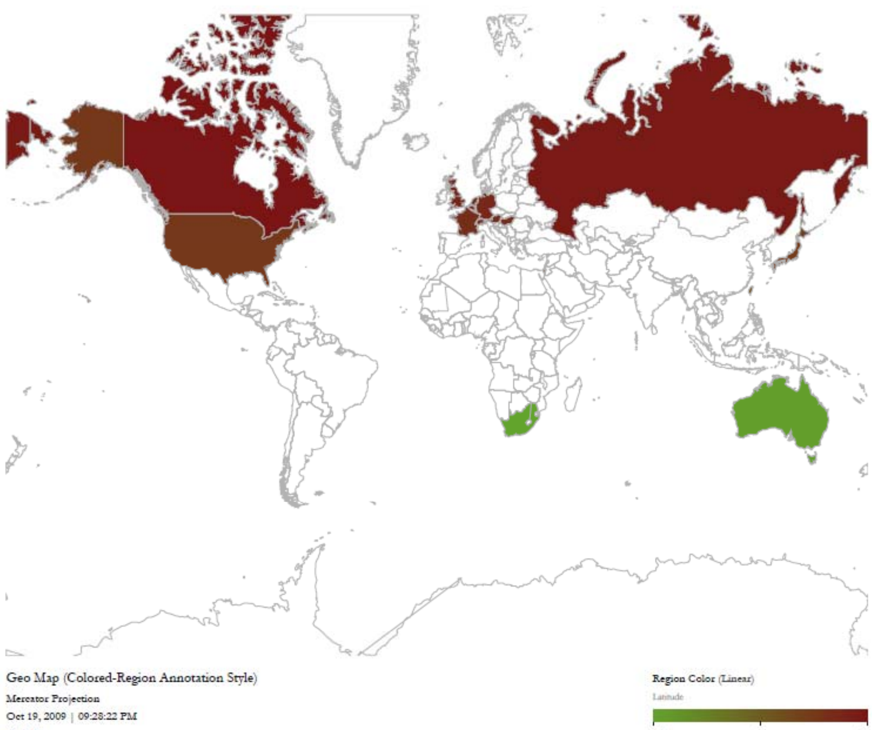
Temporal: Horizontal Bargraphs







USPTP Patent Influenza Data – Geo Map (region)

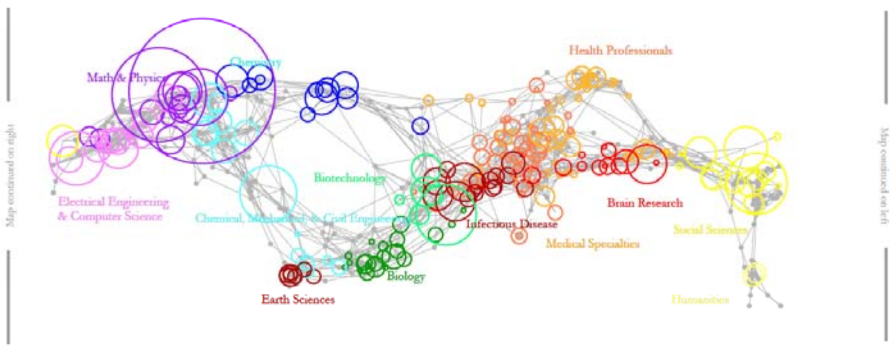


Topic Mapping: UCSD Science Map

Journal locations for FourNetSciResearchers.isi

342 journal references matched out of 361 found.

These 342 references are associated with 13 of 13 disciplines of science and 238 of 554 research specialties in the UCSD Map of Science.



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 (Sci² 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.

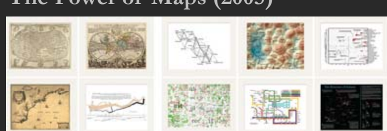
As the functionality of OSGi-based software frameworks improves and the number and diversity of dataset and algorithm plugins increases, the capabilities of custom tools will expand.

Outreach.

Mapping Science Exhibit – 10 Iterations in 10 years

http://scimaps.org

The Power of Maps (2005)



The Power of Reference Systems (2006)

The Power of Forecasts (2007)

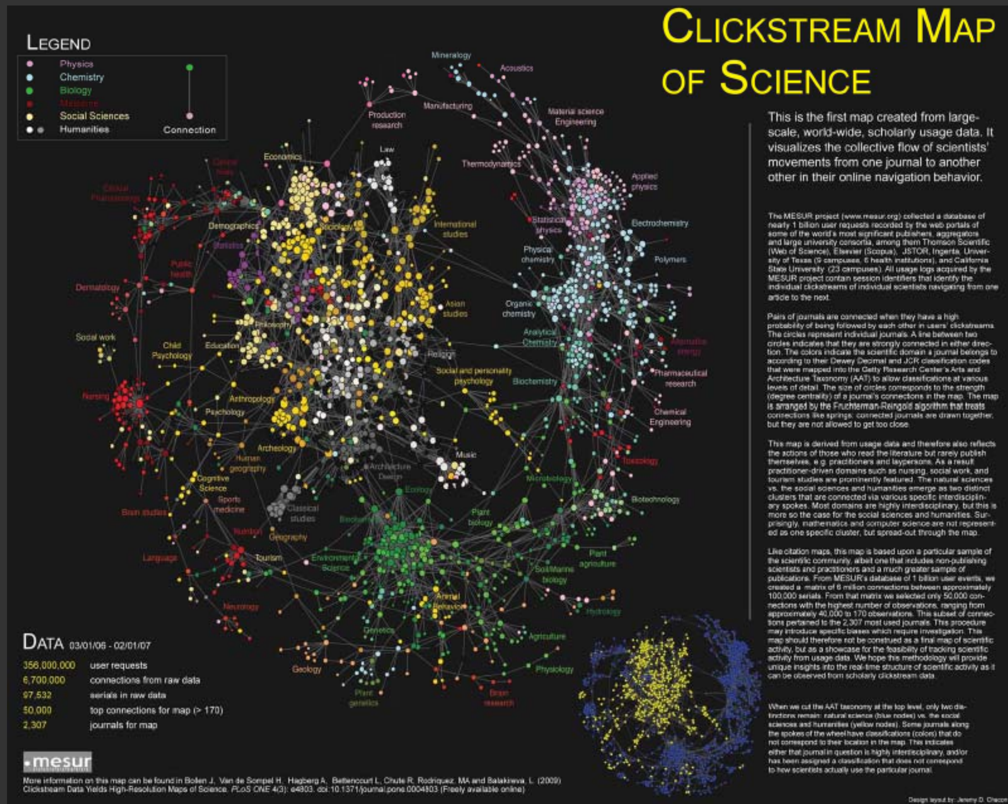
Science Maps for Economic Decision Makers (2008)

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)

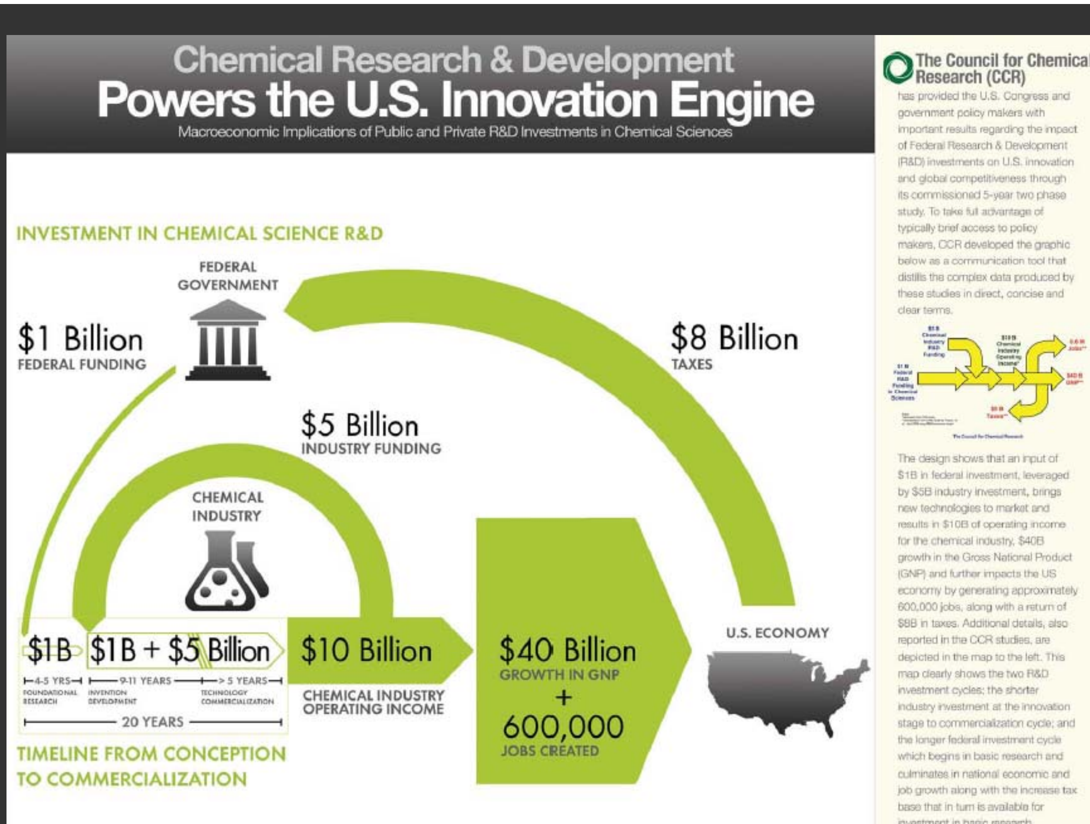
How to Lie with Science Maps (2014)

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.

ORDER MAPS



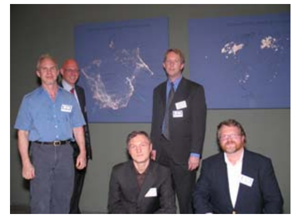
Bollen, Johan, Herbert Van de Sompel, Aric Hagberg, Luis M.A. Bettencourt, Ryan Chute, Marko A. Rodriquez, Lyudmila Balakireva. 2008. A Clickstream Map of Science.



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

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.

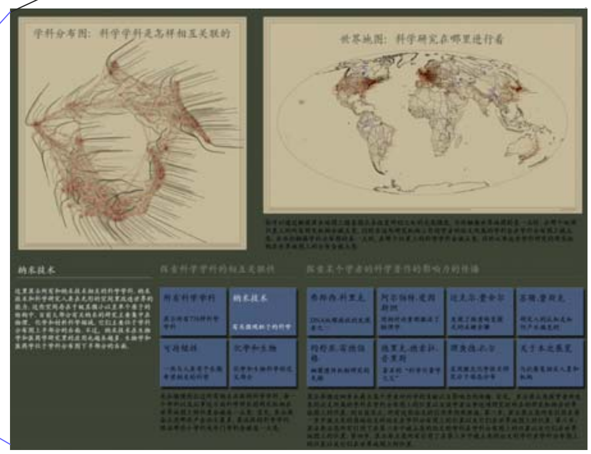
Questions:

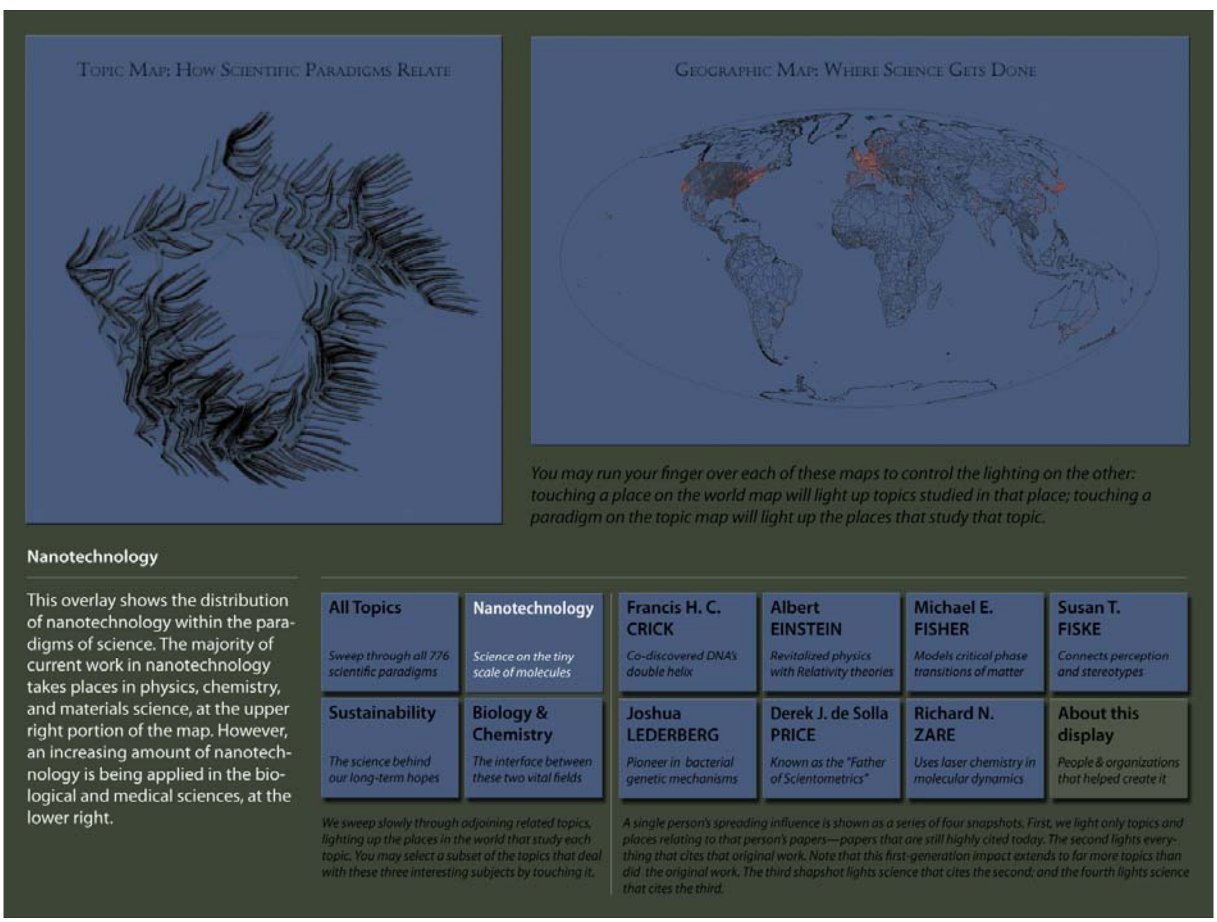
- Who is doing research on what topic and where?
- What is the 'footprint' of interdisciplinary research fields?
- What impact have scientists?

Interactive touch panel.

Contributions:

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





Re-implementation of Illuminated Diagram Software
by Advanced Visualization Lab, Indiana University

Drives unlimited number of ID screens.

Science World
Medicine Asia
Cancer Japan

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.

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

Computational Scientometrics References

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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.

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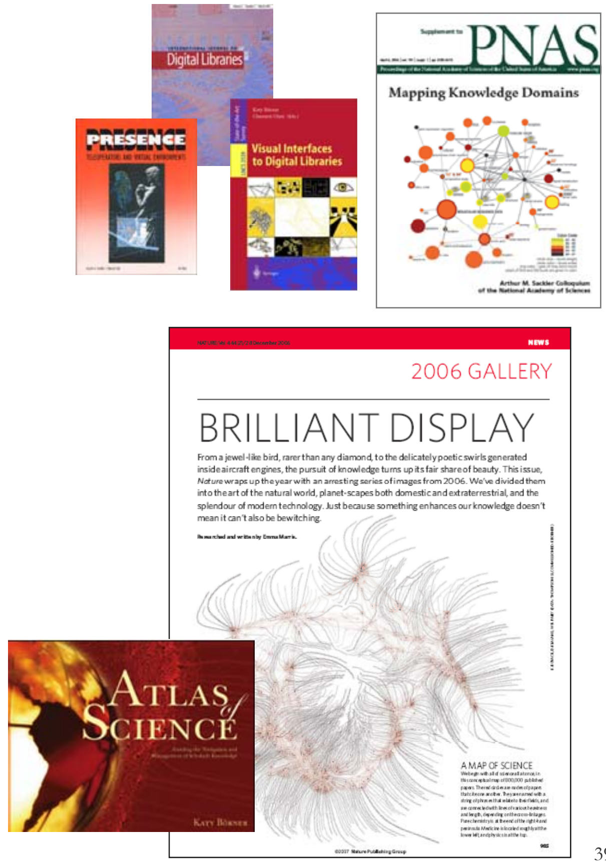
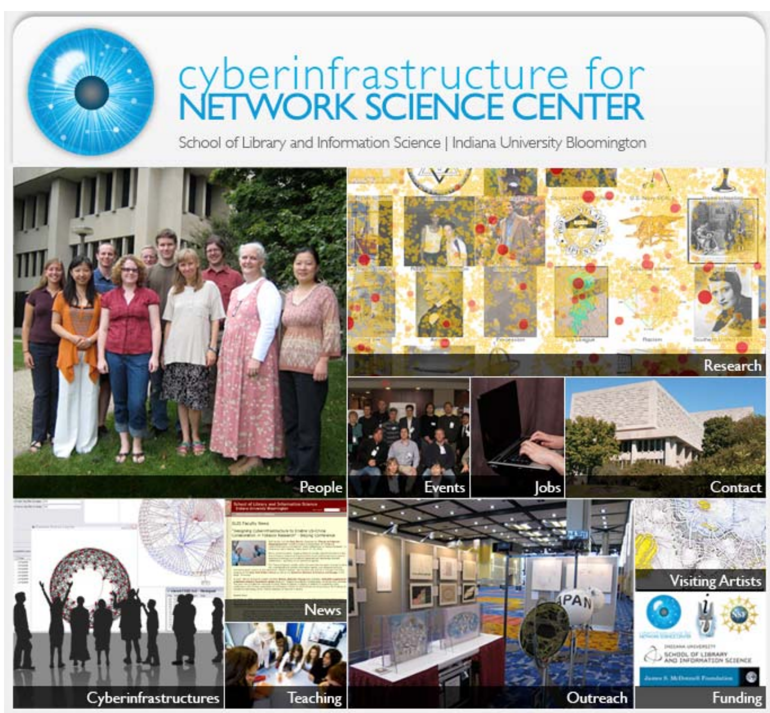
Börner, Katy (2010) Atlas of Science. MIT Press. http://scimaps.org/atlas





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