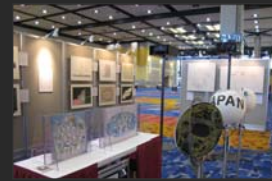
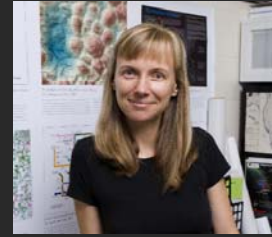


# Mapping Science

**Dr. Katy Börner**

Cyberinfrastructure for Network Science Center, Director  
Information Visualization Laboratory, Director  
School of Library and Information Science  
Indiana University, Bloomington, IN

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*Colloquium Talk*

*School of Informatics, IUPUI*

*IT – Informatics & Communications Technology Complex (ICTC), Room 252  
535 W. Michigan St., Indianapolis, IN 46202*

*November 20, 2009*

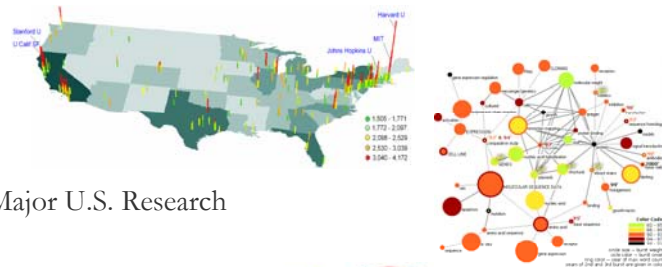


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## Overview

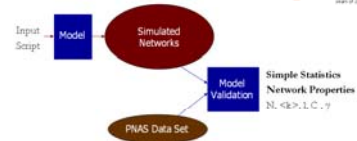
---

### Computational Scientometrics



#### Case Studies:

- Information Diffusion Among Major U.S. Research Institutions
- Identifying Research Topics and Trends
- Modeling the Co-Evolving Author-Paper Networks



#### Science of Science Cyberinfrastructures

- Scholarly Database (SDB)
  - Network Workbench (NWB) Tool
  - Science of Science (Sci<sup>2</sup>) Tool
- 
- Mapping Science Exhibit



# Computational Scientometrics: Studying Science by Scientific Means

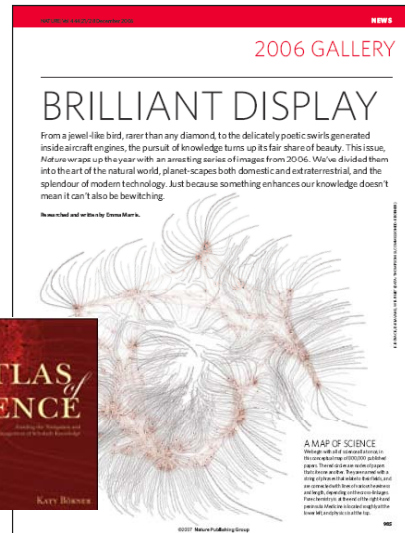
Börner, Katy, Chen, Chaomei, and Boyack, Kevin. (2003). **Visualizing Knowledge Domains**. In Blaise Cronin (Ed.), *ARIST*, Medford, NJ: Information Today, Inc./American Society for Information Science and Technology, Volume 37, Chapter 5, pp. 179-255.  
<http://ivl.slis.indiana.edu/km/pub/2003-borner-arist.pdf>



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/](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>



### Chart toppers

An exhibition explores the diverse ways of putting data on the map.

**Map of maps**  
How often do you see a map? Well, you see a map every day. But there are still a lot of people who don't know about the many different ways of putting maps on the map. This is the mission of the new exhibition, *Map of Maps*, which is on view at the National Academy of Sciences from February 22 to March 27. The exhibition is a celebration of the art and science of mapping, from the earliest maps to the most advanced digital maps. It features a variety of maps, including historical maps, modern maps, and interactive maps. The exhibition is a must-see for anyone interested in the history and future of mapping.

### How Scientific Paradigms Relate

Journal written by Allen54 (180860) and posted by kdawson on Tuesday March 20, 2007 in the connections dept.

There is a giant chart mapping relationships among scientific paradigms, as published in the journal Nature. This map was constructed by sorting roughly 800,000 published papers into 776 different scientific paradigms (shown as pale circular nodes) based on how often the papers were cited together by authors of other papers. Information Esthetics, an organization founded by map co-creator Bradford Paltridge, posted and analyzed the chart, which makes their analyses.

### 2006 GALLERY

## BRILLIANT DISPLAY

From a jewel-like bird, rarer than any diamond, to the delicately poetic swirls generated inside aircraft engines, the pursuit of knowledge turns up its fair share of beauty. This issue, Nature wraps up the year with an arresting series of images from 2006. We've divided them into the art of the natural world, planet-scapes both domestic and extraterrestrial, and the splendour of modern technology. Just because something enhances our knowledge doesn't mean it can't also be bewitching.

Researched and set into by Emma Mark.

**A MAP OF SCIENCE**  
We've got all of science at our fingertips. It's a vast, interconnected web of knowledge. This map shows the relationships between different scientific paradigms, based on how often they are cited together. The map is a complex network of nodes and edges, representing the interconnectedness of scientific knowledge. The nodes are colored and sized based on their frequency of citation, and the edges represent the relationships between different paradigms. This map is a powerful tool for understanding the structure and evolution of scientific knowledge.

### SCIENTIFIC METHOD: FROM AMONG SCIENTIFIC PARADIGMS

By KORY STAFF • Posted March 7, 2007 02:14 PM

To see the full map of relationships among scientific paradigms, click on the image below. Note: The map is a large (8.7 MB) file.

This map was constructed by sorting roughly 800,000 published papers into 776 different scientific paradigms (shown as pale circular nodes) based on how often the papers were cited together by authors of other papers. Labels (circled black lines) were made between paradigms that shared papers, then treated as rubber bands, holding similar paradigms nearer one another.

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### Mapping Science

Map shows how scientific paradigms relate.

<http://scimaps.org>

## General Process of Analyzing and Mapping Science

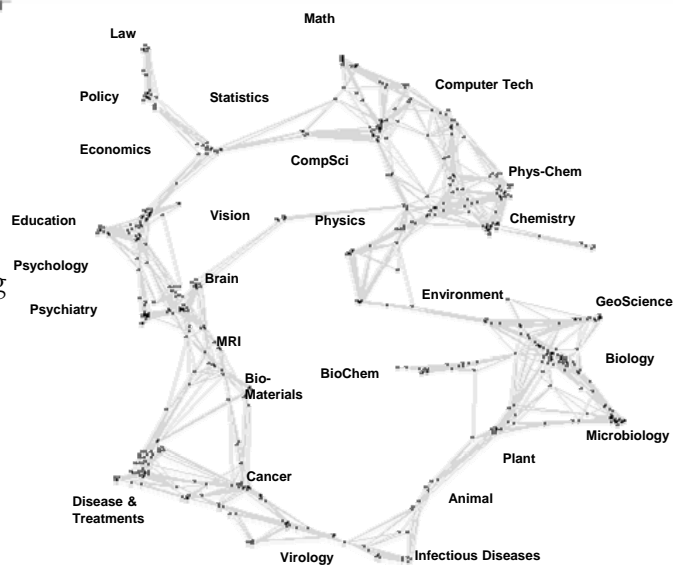
(1) Data Extraction	(2) Unit of Analysis	(3) Measures	Layout (often one code does both similarity and ordination steps)		(6) Display
			(4) Similarity	(5) Ordination	
<b>Searches</b> <i>WoS</i> <i>Scopus</i> <i>Google Scholar</i> <i>MEDLINE</i> <i>Patents</i> <i>Funding</i>  <b>Broadening</b> <i>By citation</i> <i>By terms</i>	<b>Common Choices</b> <i>Journal</i> <i>Document</i> <i>Author</i> <i>Term</i>	<b>Counts/ Frequencies</b> <i>Attributes (e.g. terms)</i> <i>Author citations</i> <i>Co-citations</i> <i>By year</i>  <b>Thresholds</b> <i>By counts</i>	<b>Scalar (unit by unit matrix)</b> <i>Direct citation</i> <i>Co-citation</i> <i>Combined linkage</i> <i>Co-word/co-term</i> <i>Co-classification</i>  <b>Vector (unit by attribute matrix)</b> <i>Vector Space Model (words/terms)</i> <i>Latent Semantic Analysis (LSA)</i> <i>Singular Value Decomposition (SVD)</i>  <b>Correlation (if desired)</b> <i>Pearson's R on any of above</i>	<b>Dimensionality Reduction</b> <i>Eigenvector/Eigenvalue Solutions</i> <i>Factor Analysis (FA)</i> <i>Principal Components Analysis (PCA)</i> <i>Multi-Dimensional Scaling (MDS)</i> <i>Pathfinder Networks (PFNet)</i> <i>Self-Organizing Maps (SOM)</i> <i>Topics Model</i>  <b>Cluster Analysis</b> <i>Partition</i> <i>Hierarchical</i>  <b>Spatial Placement</b> <i>Triangulation</i> <i>Force-Directed Placement (FDP)</i>	<b>Interaction</b> <i>Browse</i> <i>Pan</i> <i>Zoom</i> <i>Filter</i> <i>Query</i> <i>Detail on demand</i>  <b>Analysis &amp; Interpretation</b>

Börner, Katy, Chen, Chaomei, and Boyack, Kevin. (2003) *Visualizing Knowledge Domains*. In Blaise Cronin (Ed.), [Annual Review of Information Science & Technology, Volume 37](#), Medford, NJ: Information Today, Inc./ American Society for Information Science and Technology, chapter 5, pp. 179-255.

## 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.

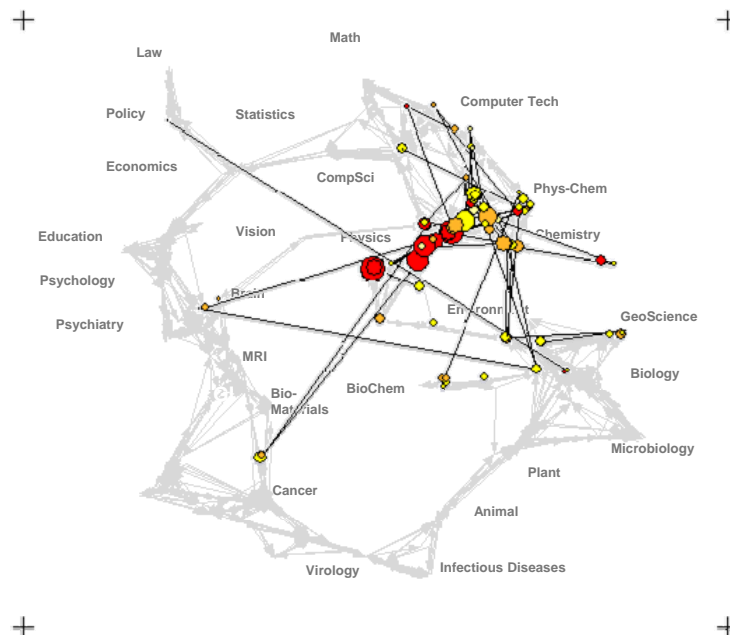
- Uses combined SCI/SSCI from 2002
  - 1.07M papers, 24.5M references, 7,300 journals
  - Bibliographic coupling of papers, aggregated to journals
- Initial ordination and clustering of journals gave 671 clusters
- Coupling counts were reaggregated at the journal cluster level to calculate the
  - (x,y)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

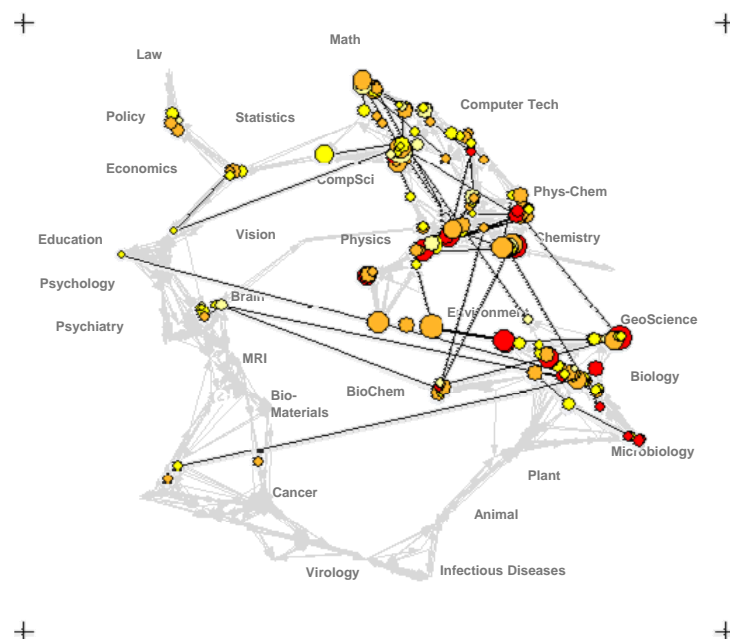
### Funding patterns of the US Department of Energy (DOE)



## Science map applications: Identifying core competency

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

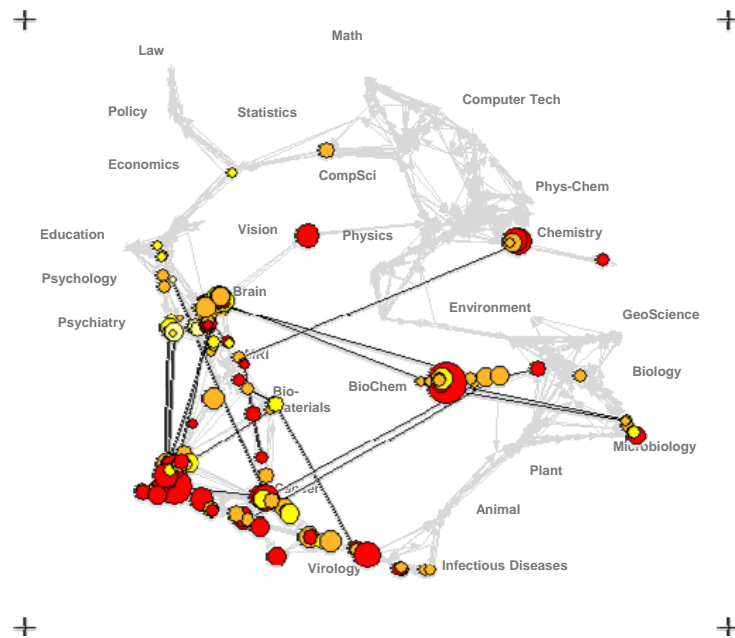
### Funding Patterns of the National Science Foundation (NSF)



## Science map applications: Identifying core competency

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

### Funding Patterns of the National Institutes of Health (NIH)



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## Opportunities

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### Advantages for Funding Agencies

- Supports monitoring of (long-term) money flow and research developments, evaluation of funding strategies for different programs, decisions on project durations, funding patterns.
- Staff resources can be used for scientific program development, to identify areas for future development, and the stimulation of new research areas.

### Advantages for Researchers

- Easy access to research results, relevant funding programs and their success rates, potential collaborators, competitors, related projects/publications (**research push**).
- More time for research and teaching.

### Advantages for Industry

- Fast and easy access to major results, experts, etc.
- Can influence the direction of research by entering information on needed technologies (**industry-pull**).

### Advantages for Publishers

- Unique interface to their data.
- Publicly funded development of databases and their interlinkage.

### For Society

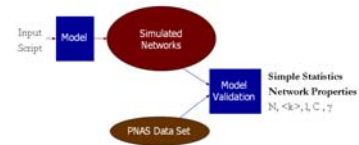
- Dramatically improved access to scientific knowledge and expertise.

# Overview

## Computational Scientometrics

### Case Studies:

- Information Diffusion Among Major U.S. Research Institutions
- Identifying Research Topics and Trends
- Modeling the Co-Evolving Author-Paper Networks



### Science of Science Cyberinfrastructures

- Scholarly Database (SDB)
- Network Workbench (NWB) Tool
- Science of Science (Sci<sup>2</sup>) Tool
- Mapping Science Exhibit



## Information Diffusion Among Major U.S. Research Institutions

Börner, Katy, Penumathy, Shashikant, Meiss, Mark & Ke, Weimao. (2006). Mapping the Diffusion of Information among Major U.S. Research Institutions. *Scientometrics*. Vol. 68(3), 415 - 426.

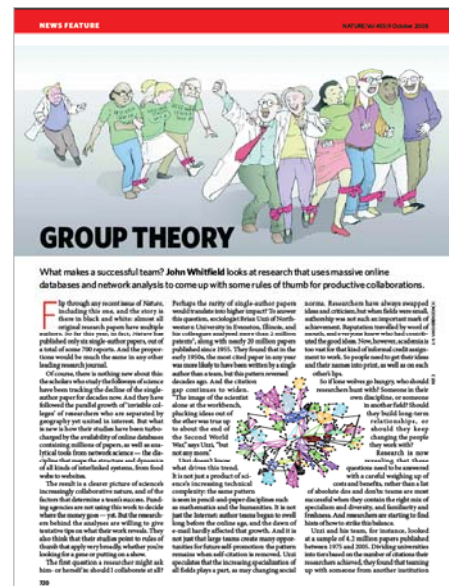
### Questions:

1. Does space still matter in the Internet age, i.e., does one still have to study and work at major research institutions in order to have access to high quality data and expertise and to produce high quality research?
2. Does the Internet lead to more global citation patterns, i.e., more citation links between papers produced at geographically distant research institutions?



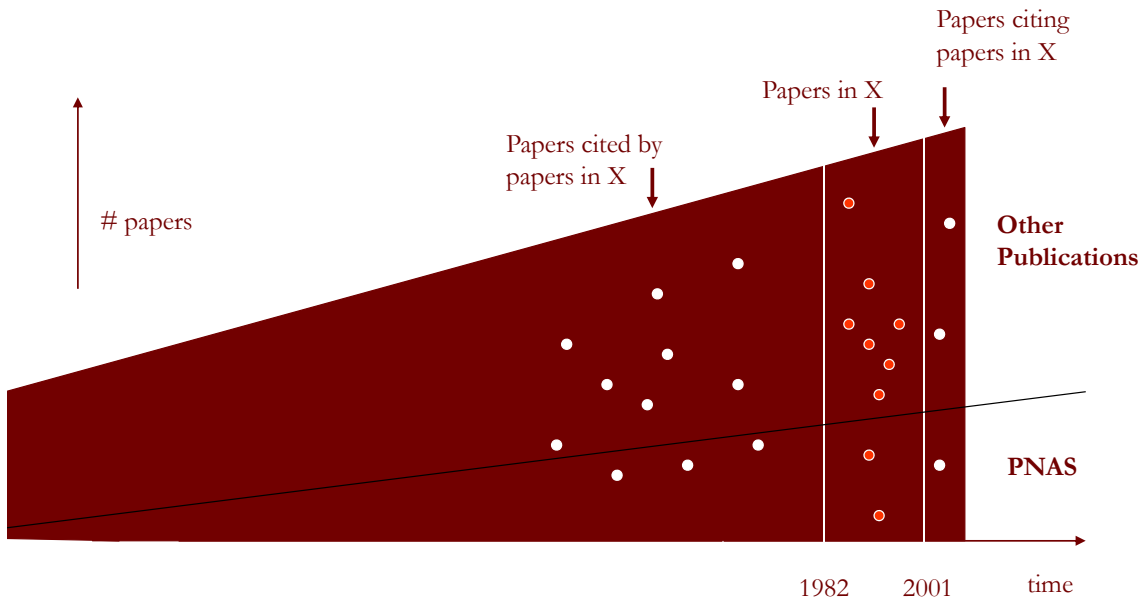
### Contributions:

- Answer to Q1 is YES.
- Answer to Q2 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.



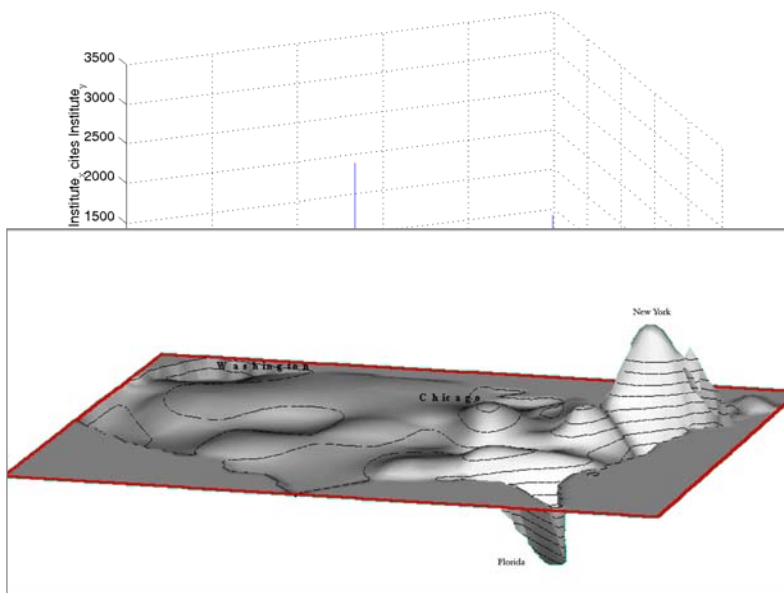
## 20-Year PNAS Dataset (1982-2001)

Coverage in terms of time span, total number of papers, and complete author's work



## Citation Matrix

Unsymmetrical direct citation linkage patterns among the top 500 institutions. High peak values in the diagonal reflect the high amount of self-citations for all institutions. Medium peak horizontal and vertical lines denote references from and citations to papers written at Harvard University.



### Information Sources (Export) and Sinks (Import)

Calculate ratio of the number of citations received by an institution divided by the sum of received citations and references made, multiplied by 100.

131 have a value between 0-40% acting mostly as information producers = information sources.

71 have a value between 60-100% and act mostly as information consumers – they reference a large number of papers but the number of citations they receive is comparably low = information sinks.

(Tobler, 1995)

## Geographic Location of Received Citations

Unsymmetrical direct citation linkage patterns among the top 500 institutions. High peak values in the diagonal reflect the high amount of self-citations for all institutions. Medium peak horizontal and vertical lines denote references from and citations to papers written at Harvard University.



## Information Flow Among the Top-5 Consumers and Their Top-10 Producers

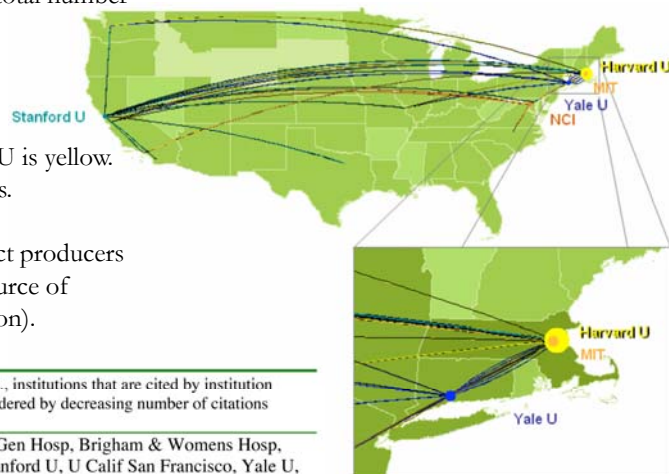
U.S. states are color coded based on the total number of citations received by their institutions (excluding self citations).

Dots indicate the five producers.

Each has a different color, e.g., Harvard U is yellow.

Dot area size depicts number of citations.

Lines represent citations that interconnect producers and consumers shaded from colored (source of information) to white (sink of information).



Consumers, i.e., citing institutions	# citations made	Top ten producers, i.e., institutions that are cited by institution listed in first column ordered by decreasing number of citations received.
Harvard U	13,552	MIT, Massachusetts Gen Hosp, Brigham & Womens Hosp, Johns Hopkins U, Stanford U, U Calif San Francisco, Yale U, Rockefeller U, U Washington, Washington U
U Calif SF	4,682	Harvard U, MIT, Stanford U, Johns Hopkins U, U Washington, Washington U, U Calif Berkeley, U Texas, U Calif SD, U Calif LA
MIT	4,655	Harvard U, Whitehead Inst Biomed Res, Johns Hopkins U, Stanford U, U Calif SF, Yale U, Rockefeller U, U Calif LA, Massachusetts Gen Hosp, U Calif Berkeley
NCI (zip: 20814)	4,519	Harvard U, NCI (zip: 20205), NCI (zip: 21701), MIT, Duke U, Johns Hopkins U, NIAID NICHD, Stanford U, U Calif SF
Yale U	4,464	Harvard U, MIT, Stanford U, Rockefeller U, Johns Hopkins U, Washington U, U Calif SF, U Washington, NCI, Massachusetts Gen Hosp

Paper also shows top-5 producers and their top-10 consumers.

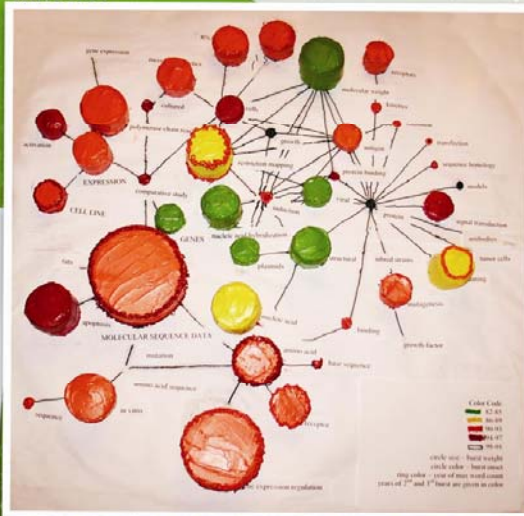




# Merry Christmas and Happy New Year! 2008

Jon Burgoyne Katy Börner  
Russell J. Duhon

Shravan Rajagopal  
Heng (Michael) Zhang  
Bruce W. Herr II  
Julie M. Smith  
Peter A. Hook  
Nanli Ma  
Chung-Yang (Kenneth) Lee



Kristin E. Reed  
Stacy Kowalevzk  
Micah Linnemeier  
Bryan J. Hook  
Nianli Ma  
Elisha F. Hardy  
Fileve Palmer  
Carol Walter  
Renpeng Hu  
Richard Pinapati  
Todd Holloway  
Heng (Michael) Zhang  
Peter A. Hook  
Renpeng Hu  
Gonzalez Jr  
Micah Lin

Weixia (Bonnie) Huang  
Elisha F. Hardy  
Fileve Palmer  
Bruce W. Herr II

Cake created by Kristin Reed and Lydia Nichols. They insisted on having a legend!

<http://ella.slis.indiana.edu/~katy>

<http://scimaps.org>

<http://ivl.slis.indiana.edu>

## Modeling the Co-Evolving Author-Paper Networks

Börner, Katy, Marin, Jeegar & Goldstone, Robert. (2004). *The Simultaneous Evolution of Author and Paper Networks*. PNAS. Vol. 101(Suppl. 1), 5266-5273.



### The TARL Model (Topics, Aging, and Recursive Linking) incorporates

- A partitioning of authors and papers into topics,
- Aging, i.e., a bias for authors to cite recent papers, and
- A tendency for authors to cite papers cited by papers that they have read resulting in a rich get richer effect.

The model attempts to capture the roles of authors and papers in the production, storage, and dissemination of knowledge.

### Model Assumptions

- Co-author and paper-citation networks co-evolve.
- Authors come and go.
- Papers are forever.
- Only authors that are 'alive' are able to co-author.
- All existing (but no future) papers can be cited.
- Information diffusion occurs directly via co-authorships and indirectly via the consumption of other authors' papers.
- Preferential attachment is modeled as an *emergent property* of the elementary, local networking activity of authors reading and citing papers, but also the references listed in papers.

Model Parameters (0=without, 1=with)

0/1 Topics  
 0/1 Co-Authors  
 0/1 Consider References  
 0 Aging Function

---

Model Initialization Values

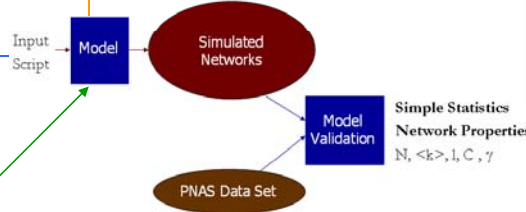
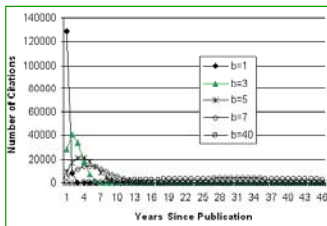
2 # Years  
 5 # Authors in Start Year  
 5 # Papers in Start Year  
 2 # Papers Consumed (Referenced) per Paper  
 1 # Papers Produced per Author each Year  
 5 # Topics  
 1 # Co-Author(s) per Author  
 1 # Levels References are Considered

```
// Initialization
generate #_papers papers and assign a random topic to each paper;
generate #_authors authors and assign a random topic to each author;
randomly assign #_coauthors+1 authors to papers of the same topic;
// Simulation
for each year do {
  add #_new_authors new authors, deactivate authors older than #_author_age;
  for each author_group {
    randomly partition set of authors into author_group of size #_coauthors+1;
    for each new_paper to be produced, do {
      generate new_paper;
      randomly select #_read_papers from existing papers;
      get all references of read_papers up to #_reference_path_length;
      for each new_paper_reference {
        select a time_slice from (start year to cur_year-1) with probability given in aging_function;
        randomly select a paper published or cited in this time_slice as a new_paper_reference;
        add the new_paper_reference to new_papers;
      }
    }
  }
  add all new papers to the set of existing papers;
  add new links to author and paper information;
}
```

Table 3 Statistics for SIM data

Year	#p	#a	#r	#c	altca
1981	1624	3953	0	756	8.21
1982	1040	5200	31200	112161	4
1983	1118	5590	33540	21397	4
1984	1197	5985	35910	10224	4
1985	1275	6375	38250	6184	4
1986	1353	6765	40590	4687	4
1987	1432	7160	42960	3573	4
1988	1510	7550	45300	2816	4
1989	1589	7945	47670	2219	4
1990	1667	8335	50010	1853	4
1991	1745	8725	52350	1634	4
1992	1824	9120	54720	1431	4
1993	1902	9510	57060	1167	4
1994	1981	9905	59430	1040	4
1995	2059	10295	61770	767	4
1996	2137	10685	64110	632	4
1997	2216	11080	66480	522	4
1998	2294	11470	68820	400	4
1999	2373	11865	71190	265	4
2000	2451	12255	73530	125	4
2001	2529	12645	75870	0	4
Total	37316		1070760	173853	

Aging function



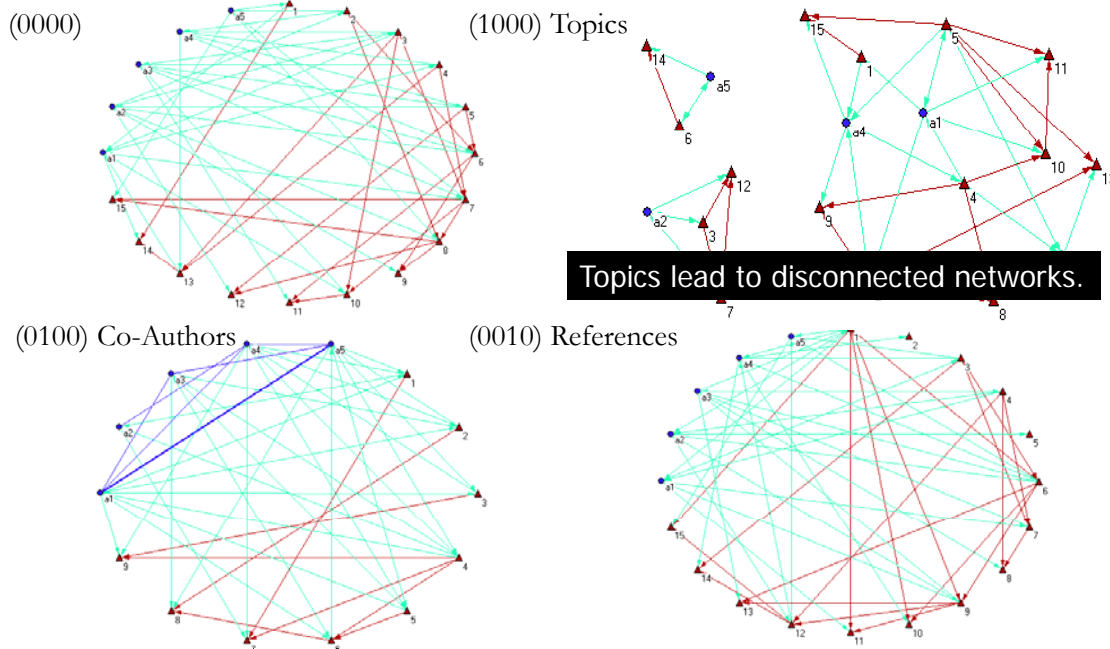
**Model Validation**

The properties of the networks generated by this model are validated against a 20-year data set (1982-2001) of documents of type article published in the Proceedings of the National Academy of Science (PNAS) – about 106,000 unique authors, 472,000 co-author links, 45,120 papers cited within the set, and 114,000 citation references within the set.

Table 2. PNAS Statistics

Year	#p	#a	#r	#c	altca
1982	1669	5201	46665	156690	3.92
1983	1611	5142	46685	161437	3.98
1984	1695	5583	49834	174161	4.22
1985	1846	6325	55662	191750	4.38
1986	2042	7209	64379	218229	4.76
1987	1924	7061	59110	207729	4.88
1988	2035	7471	63116	215227	4.8
1989	2088	7959	65883	215437	5.01
1990	2066	8031	66019	207138	5.15
1991	2382	9559	77740	223102	5.25
1992	2500	9812	80949	211238	5.29
1993	2413	9770	79848	193867	5.55
1994	2600	10656	86176	187353	5.56
1995	2476	10429	82021	151249	5.66
1996	2765	11803	99061	148622	5.96
1997	2618	11255	96788	122908	6.12
1998	2711	12328	100973	107764	6.48
1999	2603	12182	97018	76080	6.69
2000	2501	12201	94181	44131	7.6
2001	2575	13038	97450	16357	8.4
Total	45120		1509558	3250469	

**The TARL Model: The Effect of Parameters**



Topics lead to disconnected networks.

Co-authoring leads to fewer papers.

```

Model Parameters (0=without, 1=with)
-----
0/1 Topics
0/1 Co-Authors
0/1 Consider References
0 Aging Function
-----
Model Initialization Values
-----
2 # Years
5 # Authors in Start Year
5 # Papers in Start Year
2 # Papers Consumed (Referenced) per Paper
1 # Papers Produced per Author each Year
5 # Topics
1 # Co-Author(s) per Author
1 # Levels References are Considered

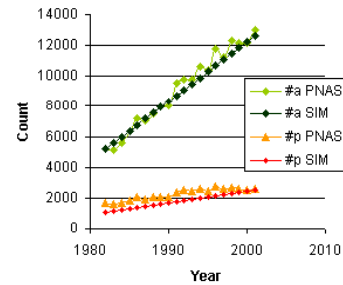
```

```

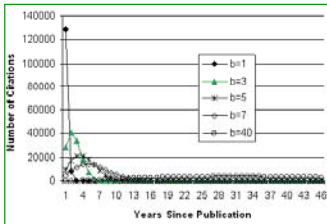
// Initialization
generate #_papers papers and assign a random topic to each paper;
generate #_authors authors and assign a random topic to each author;
randomly assign #_coauthors+J authors to papers of the same topic;
// Simulation
for each year do {
  add #_new_authors new authors, deactivate authors older than #_author_age;
  for each author_group do {
    randomly partition set of authors into author_group of size #_coauthors+J;
    for each author_group do {
      generate new_paper;
      randomly select #_read_papers from existing papers;
      get all references of read_papers up to #_reference_path_length;
      for each new_paper, reference do {
        select a time_slice from (start year to cur_year-1) with probability given in aging_function;
        randomly select a paper published or cited in this time_slice as a new_paper_reference;
        add the new_paper_reference to new_papers;
      }
    }
  }
  add all new papers to the set of existing papers;
  add new links to author and paper information;
}

```

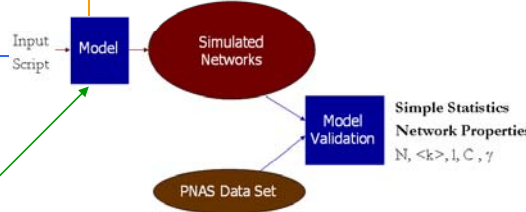
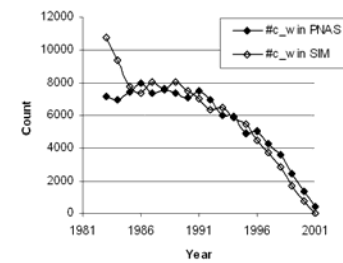
Counts for Papers and Authors



Aging function



Counts for Citations



```

Model Parameters (0=without, 1=with)
-----
0/1 Topics
0/1 Co-Authors
0/1 Consider References
0 Aging Function
-----
Model Initialization Values
-----
2 # Years
5 # Authors in Start Year
5 # Papers in Start Year
2 # Papers Consumed (Referenced) per Paper
1 # Papers Produced per Author each Year
5 # Topics
1 # Co-Author(s) per Author
1 # Levels References are Considered

```

```

// Initialization
generate #_papers papers and assign a random topic to each paper;
generate #_authors authors and assign a random topic to each author;
randomly assign #_coauthors+J authors to papers of the same topic;
// Simulation
for each year do {
  add #_new_authors new authors, deactivate authors older than #_author_age;
  for each author_group do {
    randomly partition set of authors into author_group of size #_coauthors+J;
    for each author_group do {
      generate new_paper;
      randomly select #_read_papers from existing papers;
      get all references of read_papers up to #_reference_path_length;
      for each new_paper, reference do {
        select a time_slice from (start year to cur_year-1) with probability given in aging_function;
        randomly select a paper published or cited in this time_slice as a new_paper_reference;
        add the new_paper_reference to new_papers;
      }
    }
  }
  add all new papers to the set of existing papers;
  add new links to author and paper information;
}

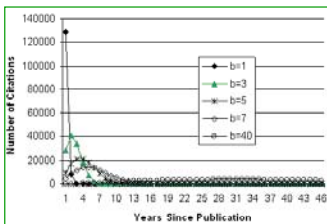
```

Table 2. Properties of co-author & paper citation networks comprising number of nodes n, average node degree <k>, path length l, cluster coefficient C, and power law exponent gamma. Source references are given in the left column.

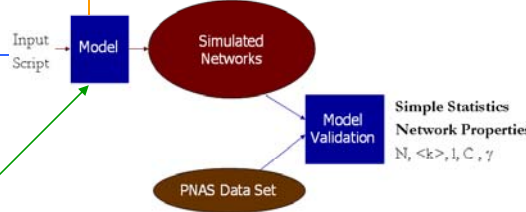
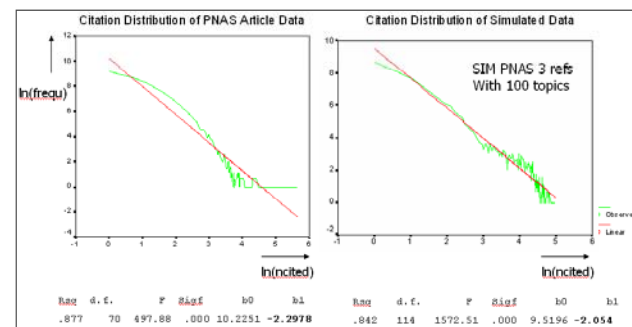
Network	n	<k>	l	C	gamma	Reference
<b>Co-authorship networks</b>						
LANL	52,909	9.7	5.9	0.43	--	Newman, (2001a; 2001b; 2001c)
MEDLINE	1,520,251	18.1	4.6	0.066	--	
SPIRES	56,627	1.73	4.0	0.726	1.2	
NCSTRL	11,994	3.59	9.7	0.496	--	
Math.	70,975	3.9	9.5	0.59	2.5	Barabasi et al., (2002)
Neurosci.	209,293	11.5	6	0.76	2.1	
PNAS	105,915	8.97	5.89	0.399	2.54	
<b>Paper-citation networks</b>						
ISI	783,339	8.57	--	--	3	Redner, (1998)
PhysRev	24,296	14.5	--	--	3	
PNAS	45,120	3.53	--	0.081	2.29	
SIM	37,114	2.13	--	0.074	2.05	

Co-Author and Paper-Citation Network Properties

Aging function



Power Law Distributions



log d.f.	F	Signif	b0	b1	log d.f.	F	Signif	b0	b1		
.877	70	697.88	.000	10.2251	-2.2978	.642	114	1572.51	.000	9.5196	-2.054

```

Model Parameters (0=without, 1=with)
-----
0/1 Topics
0/1 Co-Authors
0/1 Consider References
0 Aging Function
-----
Model Initialization Values
-----
2 # Years
5 # Authors in Start Year
5 # Papers in Start Year
2 # Papers Consumed (Referenced) per Paper
1 # Papers Produced per Author each Year
5 # Topics
1 # Co-Author(s) per Author
1 # Levels References are Considered

```

```

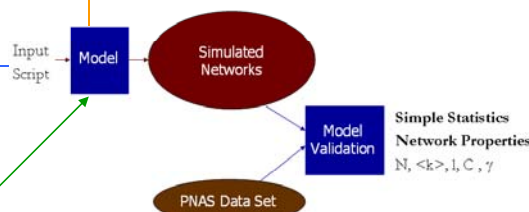
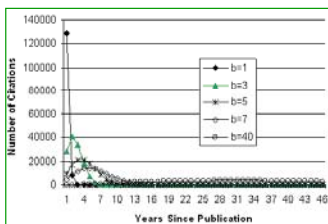
// Initialization
generate #_papers papers and assign a random topic to each paper;
generate #_authors authors and assign a random topic to each author;
randomly assign #_coauthors+1 authors to papers of the same topic;
// Simulation
for each year do {
  add #_new_authors new authors, deactivate authors older than #_author_age
  for each paperdo {
    randomly partition set of authors into author_groups of size #_coauthors+1;
    for each author_groupdo {
      for each new_paper to be produced, do {
        generate new_paper;
        randomly select #_read_papers from existing papers;
        get all references of read_papers up to #_reference_path_length;
        for each new_paper.reference do {
          select a time_slice from (start year to curr_year-1) with probability given in aging_function;
          randomly select a paper published or cited in this time_slice as a new_paper_reference;
          add the new_paper_reference to new_papers;
        }
      }
    }
  }
  add all new papers to the set of existing papers;
  add new links to author and paper information;
}

```

**Topics:** The number of topics is linearly correlated with the clustering coefficient of the resulting network:  $C = 0.000073 * \# \text{topics}$ . Increasing the number of topics increases the power law exponent as authors are now restricted to cite papers in their own topics area.

**Aging:** With increasing  $b$ , and hence increasing the number of older papers cited as references, the clustering coefficient decreases. Papers are not only clustered by topic, but also in time, and as a community becomes increasingly nearsighted in terms of their citation practices, the degree of temporal clustering increases.

Aging function



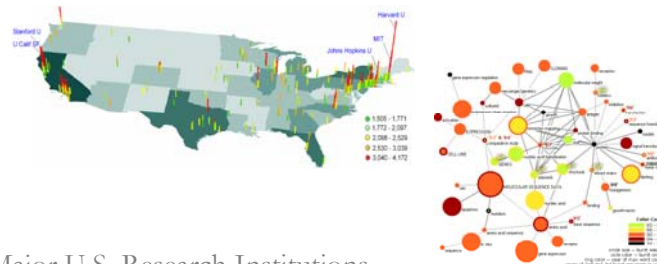
**References/Recursive Linking:** The length of the chain of paper citation links that is followed to select references for a new paper also influences the clustering coefficient. Temporal clustering is ameliorated by the practice of citing (and hopefully reading!) the papers that were the earlier inspirations for read papers.

## Overview

## Computational Scientometrics

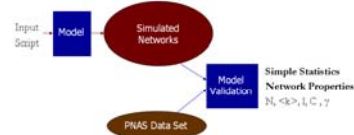
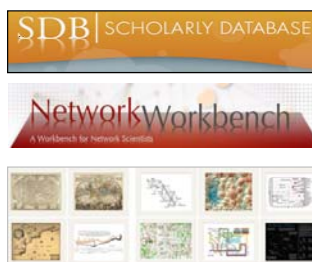
### Case Studies:

- Information Diffusion Among Major U.S. Research Institutions
- Identifying Research Topics and Trends
- Modeling the Co-Evolving Author-Paper Networks



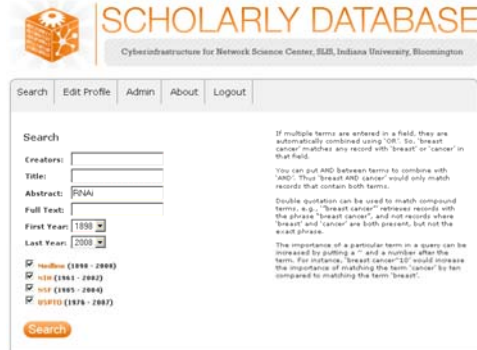
### Science of Science Cyberinfrastructures

- Scholarly Database (SDB)
- Network Workbench (NWB) Tool
- Science of Science (Sci<sup>2</sup>) Tool
- Mapping Science Exhibit

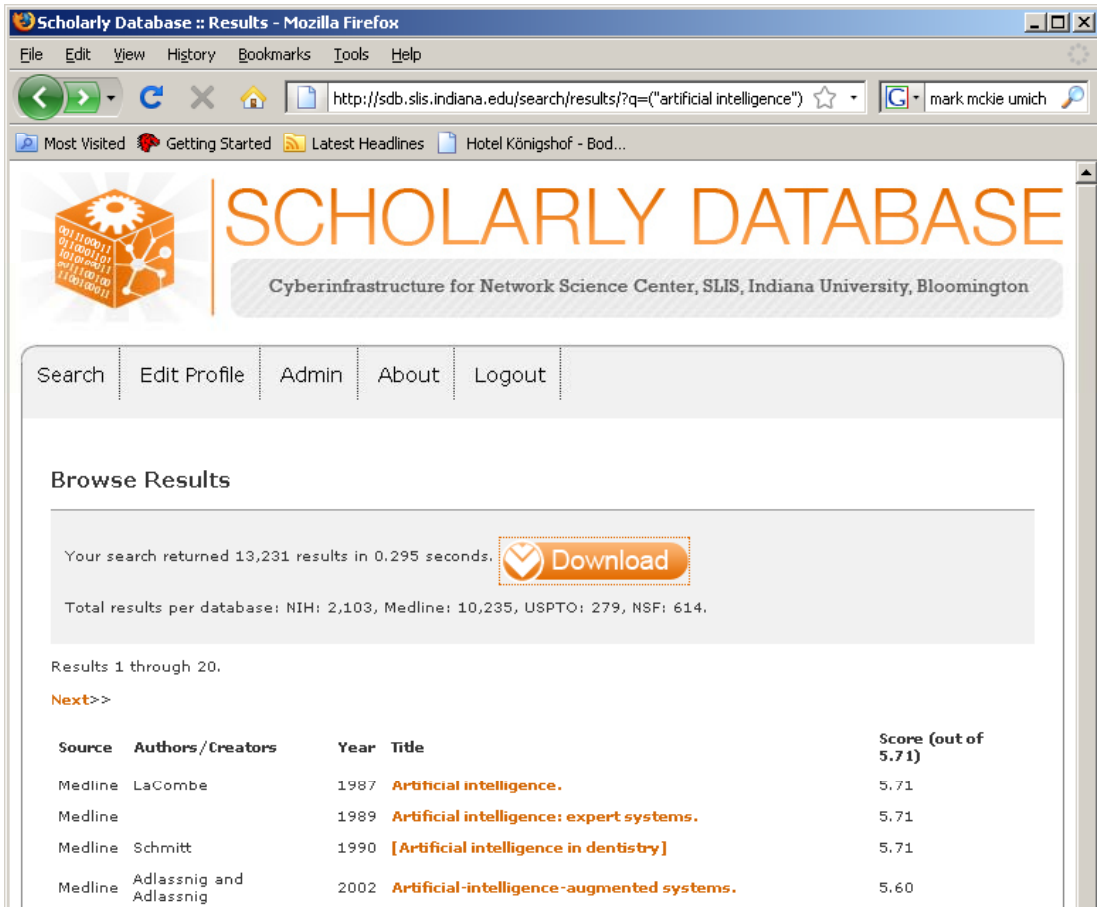


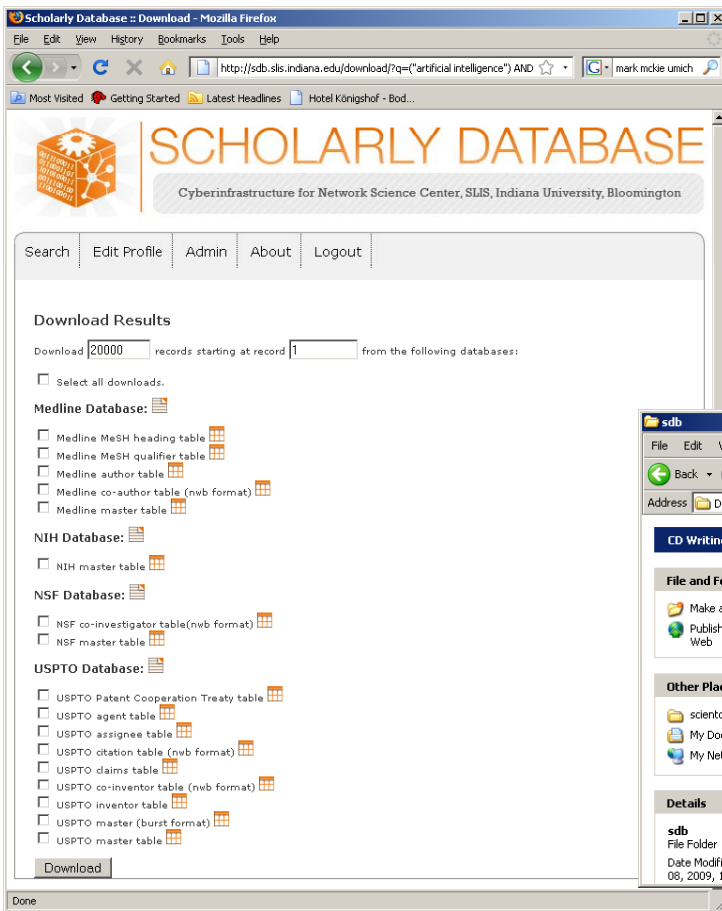
Search across publications, patents, grants.

Download records and/or (evolving) co-author, paper-citation networks.

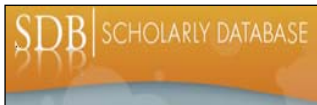
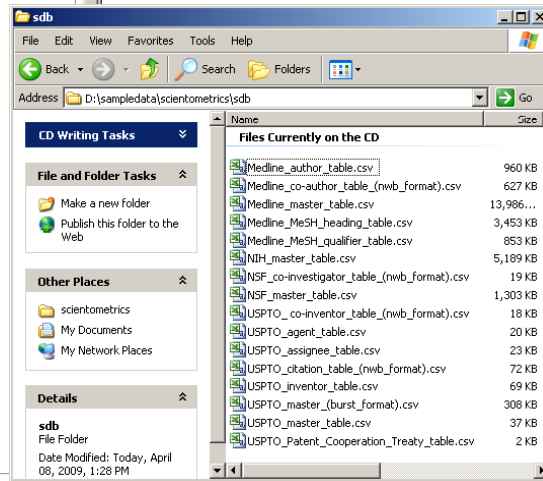


Register for free access at <http://sdb.slis.indiana.edu>





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)

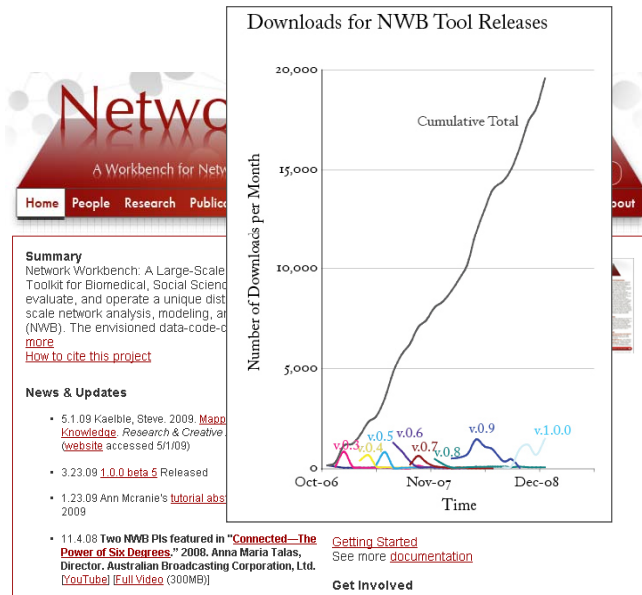
Dataset	# Records	Years Covered	Updated	Restricted Access
Medline	17,764,826	1898-2008	Yes	
PhysRev	398,005	1893-2006		Yes
PNAS	16,167	1997-2002		Yes
JCR	59,078	1974, 1979, 1984, 1989 1994-2004		Yes
USPTO	3, 875,694	1976-2008	Yes*	
NSF	174,835	1985-2002	Yes*	
NIH	1,043,804	1961-2002	Yes*	
<b>Total</b>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

Aim for comprehensive time, geospatial, and topic coverage.

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 Community Wiki: Home Page**

File Edit View History Bookmarks Tools Help

Address bar: <https://nwb.slis.indiana.edu/community>

Search:  Go

**NetworkWorkbench**  
A Workbench for Network Scientists

Main / Home Page

**Main**

- People
- NWB Tool
- Update Sites
- Tutorials
- Algorithms
- Datasets
- Data Formats
- Glossary
- FAQ
- Related Work
- Site Statistics

**About the Network Workbench Community Wiki**

The Network Workbench Community Wiki is the part of [Network Workbench \(NWB\)](#) project. It provides descriptions for algorithms and datasets that have been integrated in the [NWB Tool](#). It is also a place for users of the [NWB Tool](#), the [Cyberinfrastructure Shell](#), or any other CShell based program to get, upload, and request algorithms & datasets to be used in the tool. This site is a sounding board to be used by the community to work together and create a tool which will meet their needs and the needs of the scientific community at large.

Check out the lists of available [algorithms](#) and [datasets](#). Download the [NWB Tool](#) and play with it.

You are invited to add or edit your own dataset and algorithm descriptions (sign up [here](#)), or post wanted algorithms and datasets.

If you are interested in joining the NWB community, please sign up the [NWB mailing list](#), post your question there, or contact Weixia (Bonnie) Huang [huangb@indiana.edu](mailto:huangb@indiana.edu) for more information.

Recent Changes (All) | [Edit SideBar](#) | Page last modified on June 23, 2008, at 05:40 PM | [Upload files](#) | [Edit Page](#) | [Page History](#)

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Done | [nwb.slis.indiana.edu](http://nwb.slis.indiana.edu)



**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>

**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>

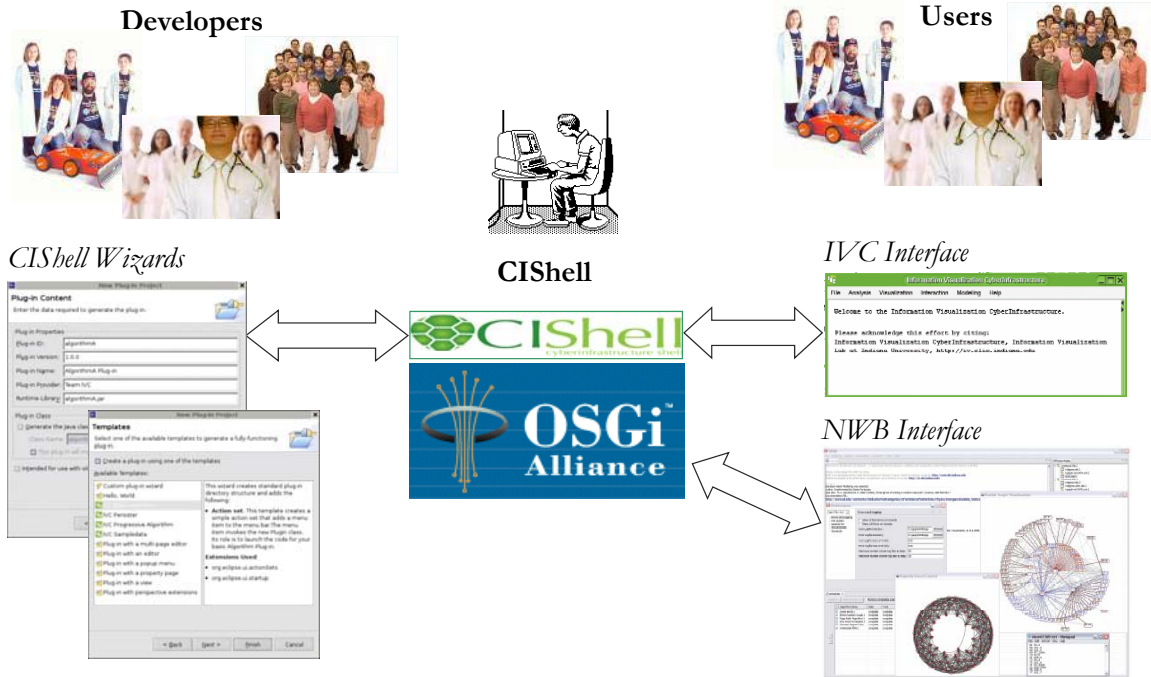
Tom Snijders, University of Groningen <http://stat.gamma.rug.nl/snijders/>

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 be 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.

### 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)

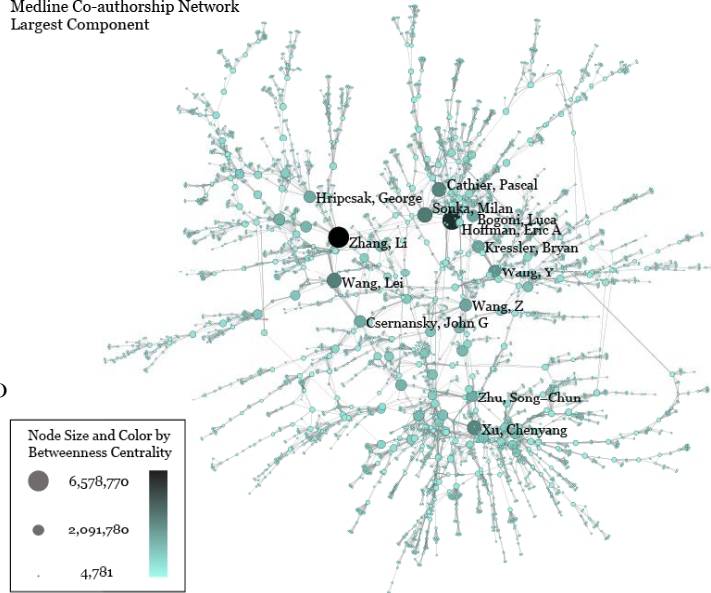
### Other Formats

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

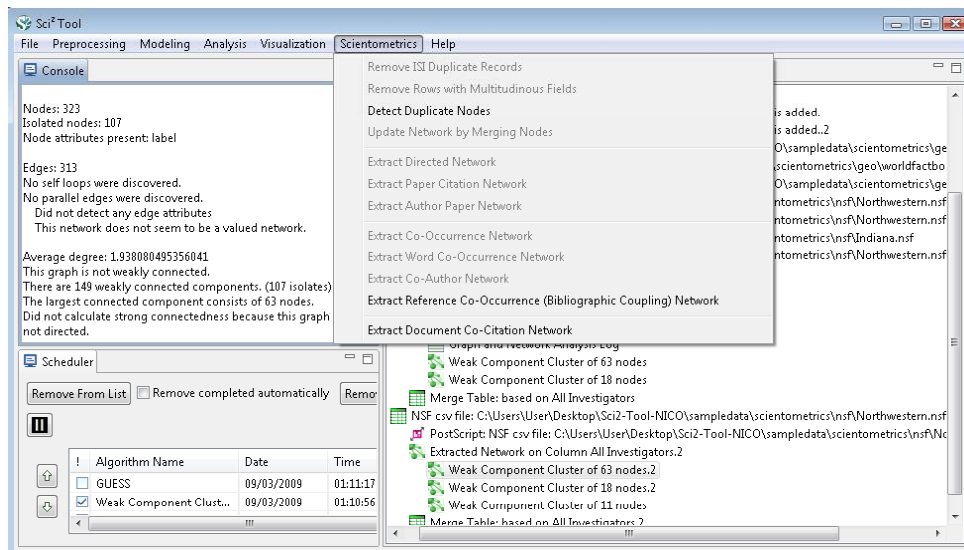
<p><b>Preprocessing</b> <small>Edit</small></p> <p><b>Remove Nodes</b></p> <ul style="list-style-type: none"> <li><a href="#">Extract Top Nodes</a></li> <li><a href="#">Extract Nodes Above or Below Val</a></li> <li><a href="#">Delete High Degree Nodes</a></li> <li><a href="#">Delete Random Nodes</a></li> <li><a href="#">Delete Isolates</a></li> </ul> <p><b>Remove Edges</b></p> <ul style="list-style-type: none"> <li><a href="#">Extract Top Edges</a></li> <li><a href="#">Extract Edges Above or Below Val</a></li> <li><a href="#">Remove Self Loops</a></li> <li><a href="#">Trim By Degree<sup>2</sup></a></li> <li><a href="#">Pathfinder Network Scaling</a></li> </ul> <p><b>Sampling</b></p> <ul style="list-style-type: none"> <li><a href="#">Snowball Sampling (n nodes)</a></li> <li><a href="#">Node Sampling</a></li> <li><a href="#">Edge Sampling</a></li> </ul> <p><b>Transformations</b></p> <ul style="list-style-type: none"> <li><a href="#">Symmetrize</a></li> <li><a href="#">Dichotomize</a></li> <li><a href="#">Multipartite Joining</a></li> </ul> <p><b>Modeling</b> <small>Edit</small></p> <p><b>General</b></p> <ul style="list-style-type: none"> <li><a href="#">Random Graph</a></li> <li><a href="#">Watts-Strogatz Small World</a></li> <li><a href="#">Barabási-Albert Scale-Free</a></li> </ul> <p><b>Structured</b></p> <ul style="list-style-type: none"> <li><a href="#">CAN</a></li> <li><a href="#">Chord</a></li> </ul> <p><b>Unstructured</b></p> <ul style="list-style-type: none"> <li><a href="#">Hypergrid</a></li> <li><a href="#">PRU</a></li> </ul> <p><b>Other</b></p> <ul style="list-style-type: none"> <li><a href="#">TARL</a></li> <li><a href="#">Discrete Network Dynamics</a></li> </ul>	<p><b>Analysis</b> <small>Edit</small></p> <p><b>General Purpose</b></p> <ul style="list-style-type: none"> <li><a href="#">Network Analysis Toolkit<sup>2</sup></a></li> </ul> <p><b>Unweighted &amp; Undirected</b></p> <ul style="list-style-type: none"> <li>Based on degree/</li> <li><a href="#">Node Degree</a></li> <li><a href="#">Node Distribution</a></li> </ul> <ul style="list-style-type: none"> <li>Based on clustering</li> <li><a href="#">k-Nearest Neighbor</a></li> <li><a href="#">Watts Strogatz Clustering Coefficient</a></li> <li><a href="#">Watts Strogatz Clustering Coefficient Over k</a></li> </ul> <ul style="list-style-type: none"> <li>Based on path</li> <li><a href="#">Diameter</a></li> <li><a href="#">Average Shortest Path</a></li> <li><a href="#">Shortest Path Distribution</a></li> <li><a href="#">Node Betweenness Centrality</a></li> </ul> <ul style="list-style-type: none"> <li>Based on components</li> <li><a href="#">Connected Components</a></li> <li><a href="#">Weak Component Clustering</a></li> </ul> <ul style="list-style-type: none"> <li><b>K-Core</b></li> <li><a href="#">Extract K-Core<sup>2</sup></a></li> <li><a href="#">Annotate K-Core<sup>2</sup></a></li> </ul> <p><b>Unweighted &amp; Directed</b></p> <ul style="list-style-type: none"> <li>Based on degree</li> <li><a href="#">Node Indegree</a></li> <li><a href="#">Node Outdegree</a></li> <li><a href="#">Indegree Distribution</a></li> <li><a href="#">Outdegree Distribution</a></li> </ul> <ul style="list-style-type: none"> <li>Based on local graph structure</li> <li><a href="#">k-Nearest Neighbor</a></li> <li><a href="#">Single Node In-Out Degree Correlations<sup>2</sup></a></li> </ul> <ul style="list-style-type: none"> <li>Unnamed Category?</li> <li><a href="#">Page Rank</a></li> </ul> <ul style="list-style-type: none"> <li>Based on local graph structure #2</li> <li><a href="#">Dyad Reciprocity<sup>2</sup></a></li> <li><a href="#">Arc Reciprocity<sup>2</sup></a></li> </ul>	<p><b>tion</b> <small>Edit</small></p> <p><b>Tools</b></p> <ul style="list-style-type: none"> <li><a href="#">GUESS</a></li> <li><a href="#">GnuPlot<sup>2</sup></a></li> </ul> <p><b>Predefined Positions Layout</b></p> <ul style="list-style-type: none"> <li><a href="#">DrL (VxOrd)</a></li> <li><a href="#">Pre-defined Positions (prefuse beta)<sup>2</sup></a></li> </ul> <p><b>Move</b></p> <ul style="list-style-type: none"> <li><a href="#">Circular</a></li> </ul> <p><b>Tree Layouts</b></p> <ul style="list-style-type: none"> <li><a href="#">Radial Tree (prefuse alpha)</a></li> <li><a href="#">Radial Tree with Annotations (prefuse beta)<sup>2</sup></a></li> <li><a href="#">Tree Map</a></li> <li><a href="#">Tree View</a></li> <li><a href="#">Balloon Graph (prefuse alpha)<sup>2</sup></a></li> </ul> <p><b>Network Layouts</b></p> <ul style="list-style-type: none"> <li><a href="#">Force Directed with Annotation (prefuse beta)</a></li> <li><a href="#">Kamada-Kawai (JUNG)</a></li> <li><a href="#">Fruchterman-Reingold (JUNG)</a></li> <li><a href="#">Fruchterman-Reingold with Annotation (prefuse beta)</a></li> <li><a href="#">Spring (JUNG)</a></li> <li><a href="#">Small World (prefuse alpha)</a></li> </ul> <p><b>Other Layouts</b></p> <ul style="list-style-type: none"> <li><a href="#">Parallel Coordinates (demo)<sup>2</sup></a></li> <li><a href="#">LaNet (k-Core Decomposition)</a></li> </ul> <p><b>etrics</b> <small>Edit</small></p> <p><b>Extract Network From Table</b></p> <ul style="list-style-type: none"> <li><a href="#">Extract Co-Authorship Network</a></li> <li><a href="#">Extract Co-Occurrence Network From Table<sup>2</sup></a></li> <li><a href="#">Extract Directed Network From Table<sup>2</sup></a></li> </ul> <p><b>Extract Network From Another Network</b></p> <ul style="list-style-type: none"> <li><a href="#">Extract Bibliographic Coupling Similarity Network</a></li> <li><a href="#">Extract Co-Citation Similarity Network<sup>2</sup></a></li> </ul> <p><b>Cleaning</b></p> <ul style="list-style-type: none"> <li><a href="#">Remove ISI Duplicate Records</a></li> </ul>
---	--	--

- 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.

Medline Co-authorship Network  
Largest Component



## Sci² Tool for Science of Science Research and Practice

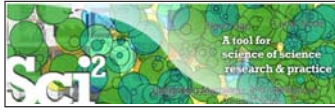


Algorithm Name	Date	Time
GUESS	09/03/2009	01:11:17
Weak Component Clust...	09/03/2009	01:10:56

### 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.





## Sci<sup>2</sup> 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-Coreeness

-----  
HTTS

### 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

### HTTS

### Unweighted & Directed

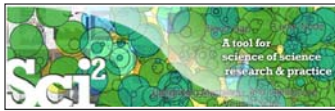
Node Indegree  
Node Outdegree  
Indegree Distribution  
Outdegree Distribution

-----  
K-Nearest Neighbor  
Single Node in-Out Degree Correlations

-----  
Dyad Reciprocity  
Arc Reciprocity  
Adjacency Transitivity

-----  
Weak Component Clustering  
Strong Component Clustering

41



## Sci<sup>2</sup> Tool: Algorithms cont.

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

-----  
Extract K-Core  
Annotate K-Coreeness

-----  
HTTS  
PageRank  
Weighted & Directed  
HTTS  
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

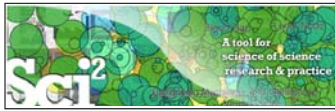
Extract Word Co-Occurrence Network  
Extract Co-Author Network  
Extract Reference Co-Occurrence  
(Bibliographic Coupling) Network

-----  
Extract Document Co-Citation Network

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

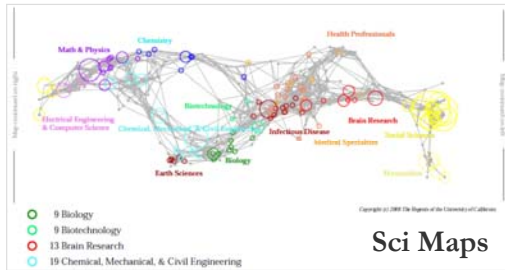
[General Network extraction](#)

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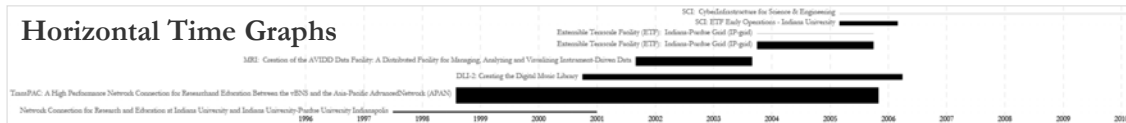


# Sci² Tool

Plugins that render into Postscript files:



## Horizontal Time Graphs



Börner, Katy, Huang, Weixia (Bonnie), Linnemeier, Micah, Dubon, 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

**Horizontal Line Graph**

Takes tabular data and generates PostScript for a horizontal line graph.

Label: Full Project Number (including subproject ID)

Start Date: Project start date

End Date: Project end date

Size By: FY Total Costs

Date Format: Month-Day-Year Date Format (U.S., e.g. 10/15/2010)

Page Width: 8.5

Page Height: 11.0

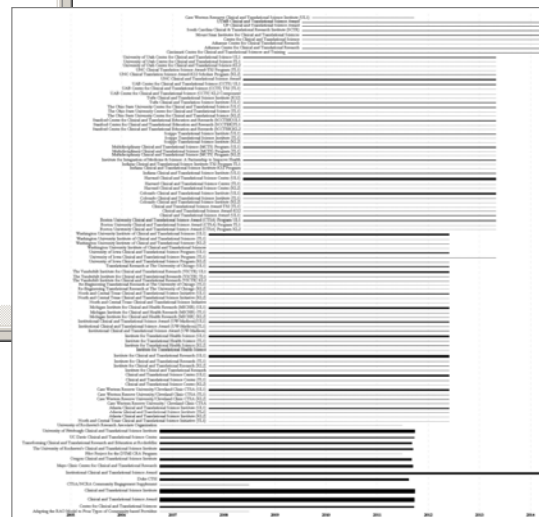
Scale Output?

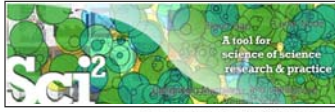
OK Cancel

Area size equals numerical value, e.g., award amount.

Text, e.g., title [ ]

Start date      End date

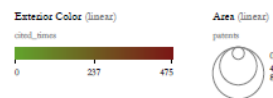




## USPTP Patent Influenza Data – Geo Map (circle)



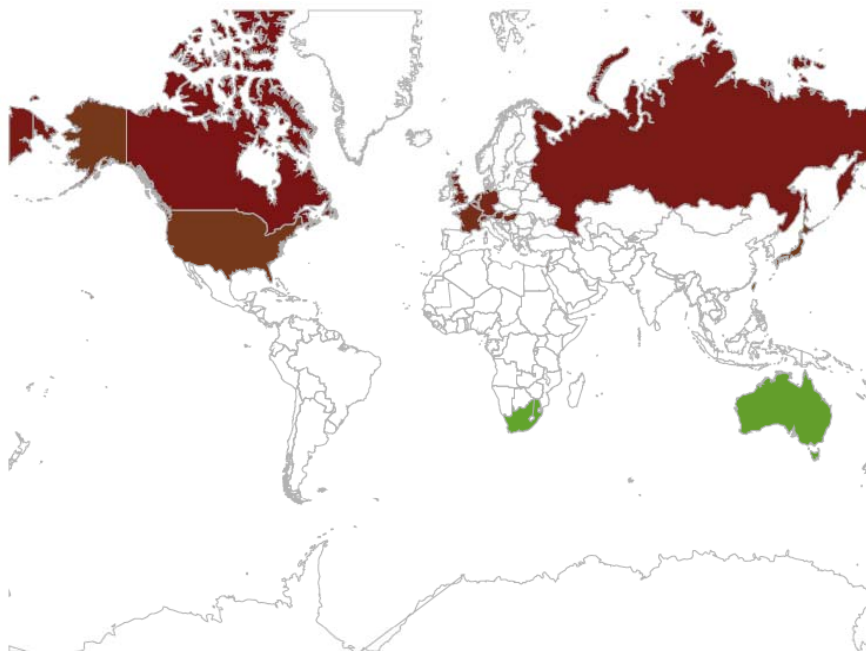
Geo Map (Circle Annotation Style)  
Mercator Projection  
Sep 03, 2009 | 12:25:24 AM  
Katy Bonner



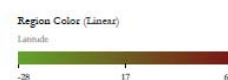
45



## USPTP Patent Influenza Data – Geo Map (region)



Geo Map (Colored-Region Annotation Style)  
Mercator Projection  
Oct 19, 2009 | 09:28:22 PM  
Katy Bonner



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# 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.



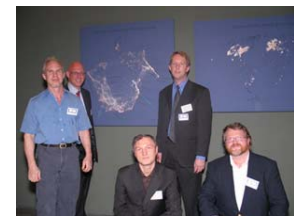
## Illuminated Diagram Display

W. Bradford Paley, Kevin W. Boyack, Richard Kalvans, and Katy Börner (2007)

Mapping, Illuminating, and Interacting with Science. SIGGRAPH 2007.

### Questions:

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

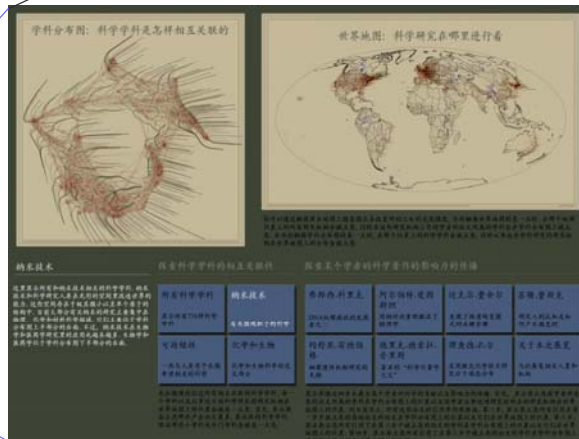


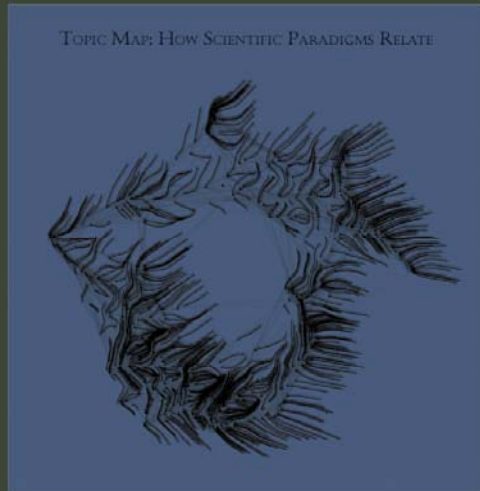
Large-scale, high resolution prints illuminated via projector or screen.

Interactive touch panel.

### Contributions:

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





You may run your finger over each of these maps to control the lighting on the other: touching a place on the world map will light up topics studied in that place; touching a paradigm on the topic map will light up the places that study that topic.

### Nanotechnology

This overlay shows the distribution of nanotechnology within the paradigms of science. The majority of current work in nanotechnology takes place in physics, chemistry, and materials science, at the upper right portion of the map. However, an increasing amount of nanotechnology is being applied in the biological and medical sciences, at the lower right.

<b>All Topics</b> <i>Sweep through all 776 scientific paradigms</i>	<b>Nanotechnology</b> <i>Science on the tiny scale of molecules</i>	<b>Francis H. C. CRICK</b> <i>Co-discovered DNA's double helix</i>	<b>Albert EINSTEIN</b> <i>Revitalized physics with Relativity theories</i>	<b>Michael E. FISHER</b> <i>Models critical phase transitions of matter</i>	<b>Susan T. FISKE</b> <i>Connects perception and stereotypes</i>
<b>Sustainability</b> <i>The science behind our long-term hopes</i>	<b>Biology &amp; Chemistry</b> <i>The interface between these two vital fields</i>	<b>Joshua LEDERBERG</b> <i>Pioneer in bacterial genetic mechanisms</i>	<b>Derek J. de Solla PRICE</b> <i>Known as the "Father of Scientometrics"</i>	<b>Richard N. ZARE</b> <i>Uses laser chemistry in molecular dynamics</i>	<b>About this display</b> <i>People &amp; organizations that helped create it</i>

We sweep slowly through adjoining related topics, lighting up the places in the world that study each topic. You may select a subset of the topics that deal with these three interesting subjects by touching it.

A single person's spreading influence is shown as a series of four snapshots. First, we light only topics and places relating to that person's papers—papers that are still highly cited today. The second lights everything that cites that original work. Note that this first-generation impact extends to far more topics than did the original work. The third snapshot lights science that cites the second, and the fourth lights science that cites the third.



Science Maps in "Expedition Zukunft" science train visiting 62 cities in 7 months 12 coaches, 300 m long. Opening was on April 23<sup>rd</sup>, 2009 by German Chancellor Merkel

<http://www.expedition-zukunft.de>

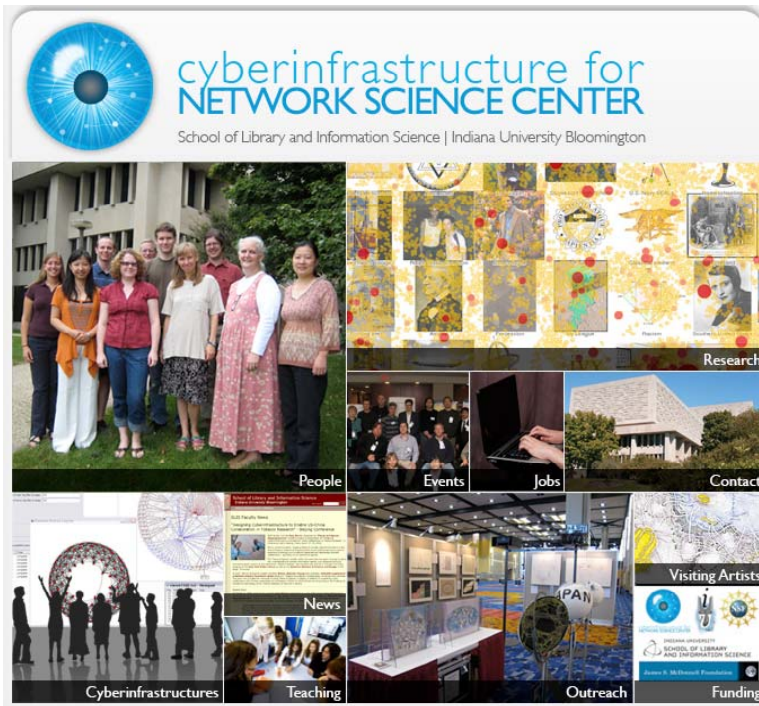


Debut of 5<sup>th</sup> Iteration of Mapping Science Exhibit at MEDIA X was on May 18, 2009 at Wallenberg Hall, Stanford University, <http://mediax.stanford.edu>, <http://scaleindependentthought.typepad.com/photos/scimaps>

This is the only mockup in this slide show.

Everything else is available today.





<http://cns.slis.indiana.edu>