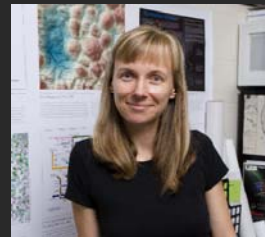


Communicating the Structure and Evolution of Science

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

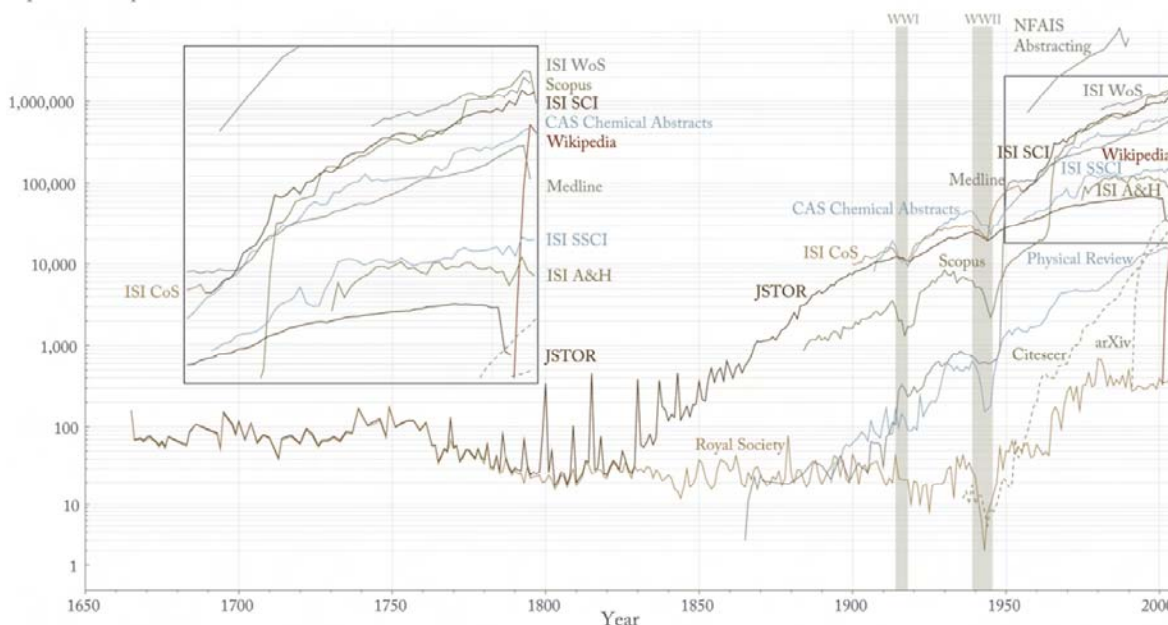


*SEED, New York City
 February 23, 2009*



Growth of Scientific Knowledge, 1665 to 2006

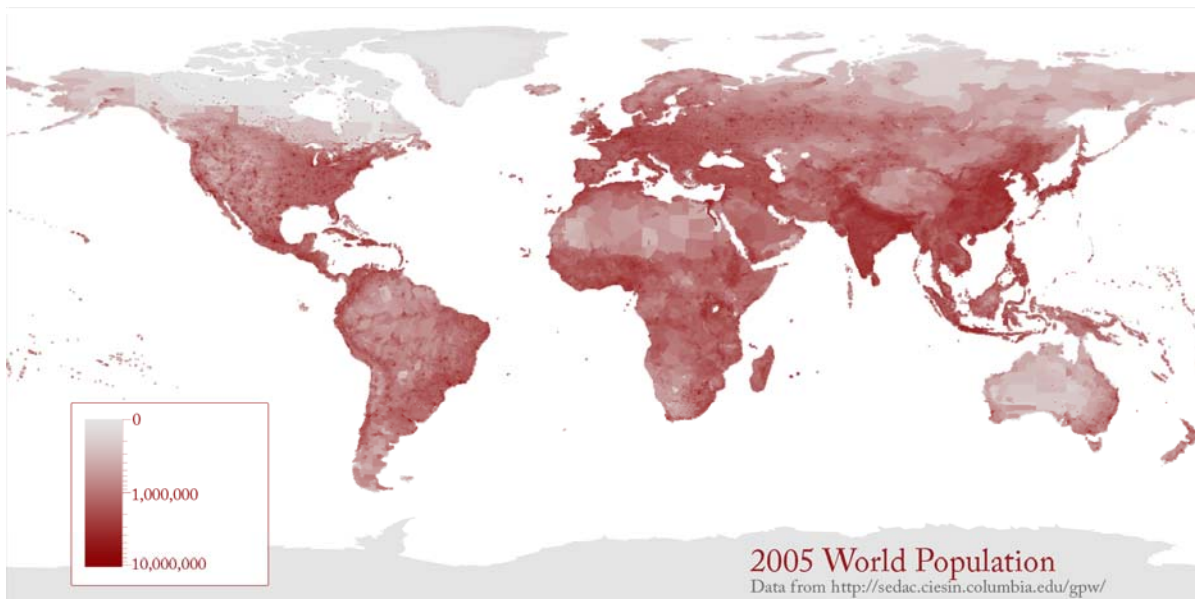
Papers & Wikipedia Entries



'Atlas of Science: Guiding the Navigation and Management of Scholarly Knowledge', Part I: The Rise of Science and Technology. Chart showing the number of papers/wikipedia entries for different databases and publication years. Contact Katy Börner <katy@indiana.edu> or Elisha Hardy <ehardy@indiana.edu> for details.

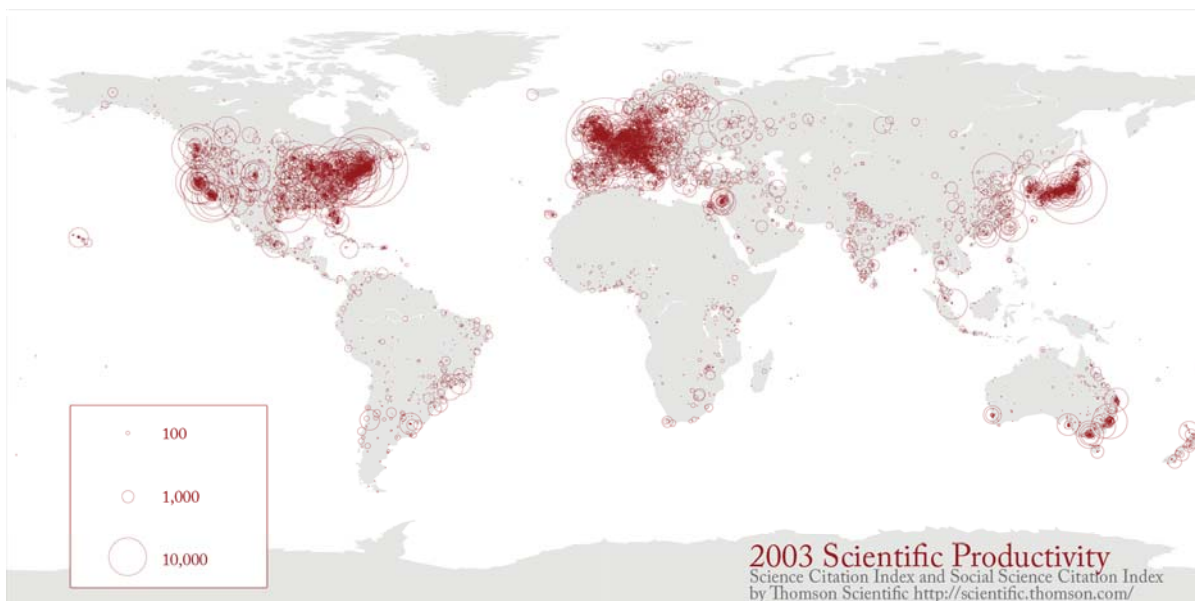
2005 World Population

The population map uses a quarter degree box resolution. Boxes with zero people are given in white. Darker shades of red indicate higher population counts per box using a logarithmic interpolation. The highest density boxes appear in Mumbai, with 11,687,850 people in the quarter degree block, Calcutta (10,816,010), and Shanghai (8,628,088).



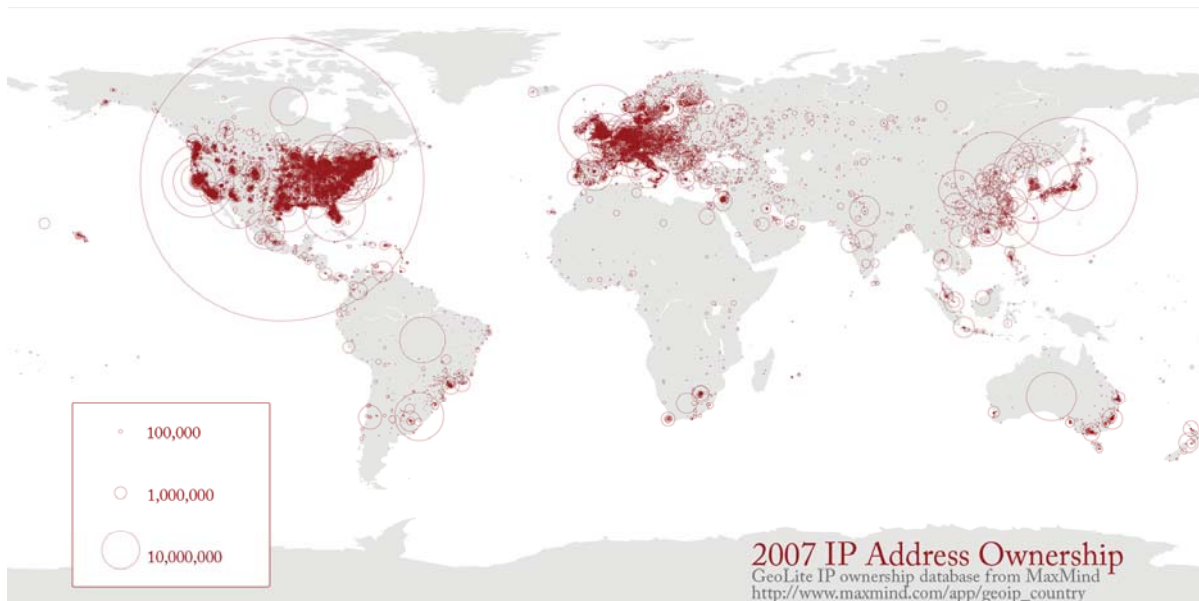
2003 Scientific Productivity

Shown is where science is performed today. Each circle indicates a geographic location at which scholarly papers are published. The larger the circle the more papers are produced. Boston, MA, London, England, and New York, NY are the top three paper production areas. Note the strong resemblance with the Night on Earth and the IP Ownership maps and the striking differences to the world population map.



2007 IP Address Ownership

This map shows IP address ownership by location. Each owner is represented by a circle and the area size of the circle corresponds to the number of IP addresses owned. The largest circle denotes MIT's holdings of an entire class A subnet, which equates to 16,581,375 IP addresses. The countries that own the most IP addresses are US (560 million), Japan (130 million), Great Britain (47 million).



"Human history becomes more and more a race between education and catastrophe."

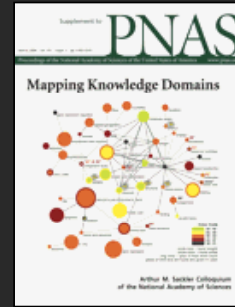
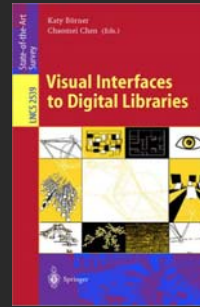
Herman G. Wells (1938) World Brain

* * *

In the 1960's, *Richard Buckminster Fuller* proposed the "World Peace Game" or "World Game", a comprehensive, anticipatory, design science approach to the problems of the world. The playing of World Game was intended to

"make the world work for 100% of humanity in the shortest possible time through spontaneous cooperation without ecological damage or disadvantage to anyone."

Computational Scientometrics: Studying Science by Scientific Means



- Börner, Katy, Chen, Chaomei, and Boyack, Kevin. (2003). *Visualizing Knowledge Domains*. In Blaise Cronin (Ed.), *Annual Review of Information Science & Technology*, 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.), *Annual Review of Information Science & Technology*, Medford, NJ, Volume 41, Chapter 12, pp. 537-607. <http://ivl.slis.indiana.edu/km/pub/2007-borner-arist.pdf>
- *Places & Spaces: Mapping Science* exhibit, see also <http://scimaps.org>.

Chart toppers

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

Map of Maps
How often do you see the geography we habit map, and how do you do it? But there are an almost infinite number of ways to map the world — from a simple map of the world to a map of the world as seen from space. This is the theme of the exhibition 'Map of Maps' at the National Academy of Sciences, which runs from February 27 to May 1, 2007. The exhibition is a collaboration between the National Academy of Sciences and the National Geographic Society.

Map of Maps
The exhibition is a collaboration between the National Academy of Sciences and the National Geographic Society. It features a variety of maps, including a map of the world as seen from space, a map of the world as seen from the ground, and a map of the world as seen from the sea.

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, is the organization behind the chart. The chart makes these connections.

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 splendor of modern technology. Just because something enhances our knowledge doesn't mean it can't also be bewitching.

Researched and set by Emma Miskell.

A MAP OF SCIENCE
This map is a visualization of the relationships between scientific paradigms. It is based on the citation patterns of approximately 800,000 scientific papers. The nodes represent different scientific paradigms, and the lines represent the relationships between them. The map is a complex network of nodes and edges, with some nodes being larger and more prominent than others. The map is titled 'A MAP OF SCIENCE' and is described as a 'map of relationships among scientific paradigms'.

SCIENTIFIC METHOD: FROM AMONG SCIENTIFIC PARADIGMS

by KORT STAFF • Posted March 7, 2007 12:14 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. Lines (colored black lines) were made between the paradigms that shared papers, then treated as rubber bands, holding similar paradigms near one another.

<http://scimaps.org>

Sandia National Laboratories
SECURING A PEACEFUL AND FREE WORLD THROUGH
Mapping Science
Map shows how scientific paradigms relate.

Computational Scientometrics Opportunities

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.

Process of Computational Scientometrics

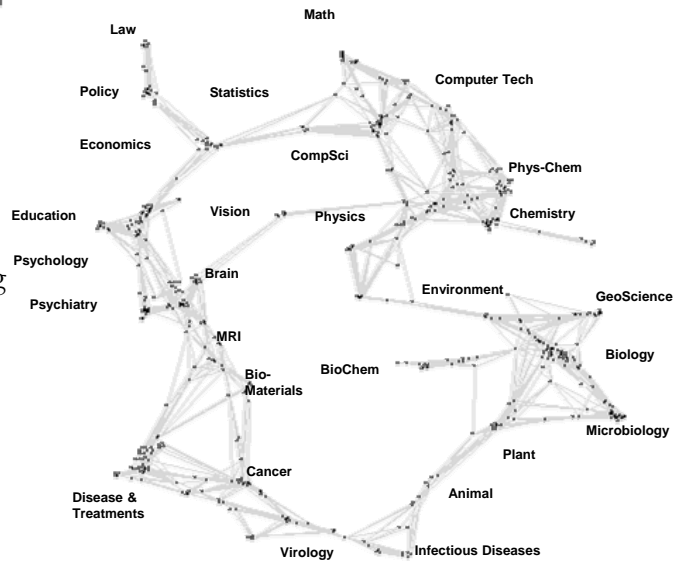
DATA EXTRACTION	UNIT OF ANALYSIS	MEASURES	LAYOUT (often one code does both similarity and ordination steps)		DISPLAY
			SIMILARITY	ORDINATION	
SEARCHES ISI INSPEC Eng Index Medline ResearchIndex Patents etc.	COMMON CHOICES Journal Document Author Term	COUNTS/FREQUENCIES Attributes (e.g. terms) Author citations Co-citations By year THRESHOLDS By counts	SCALAR (unit by unit matrix) Direct citation Co-citation Combined linkage Co-word / co-term Co-classification VECTOR (unit by attribute matrix) Vector space model (words/terms) Latent Semantic Analysis (words/terms) incl. Singular Value Decomposition (SVD) CORRELATION (if desired) Pearson's R on any of above	DIMENSIONALITY REDUCTION Eigenvector/ Eigenvalue solutions Factor Analysis (FA) and Principal Components Analysis (PCA) Multi-dimensional scaling (MDS) LSA, Topics Pathfinder networks (PFNet) Self-organizing maps (SOM) includes SOM, ET-maps, etc.	INTERACTION Browse Pan Zoom Filter Query Detail on demand ANALYSIS
BROADENING By citation By terms				CLUSTER ANALYSIS SCALAR Triangulation Force-directed placement (FDP)	

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.

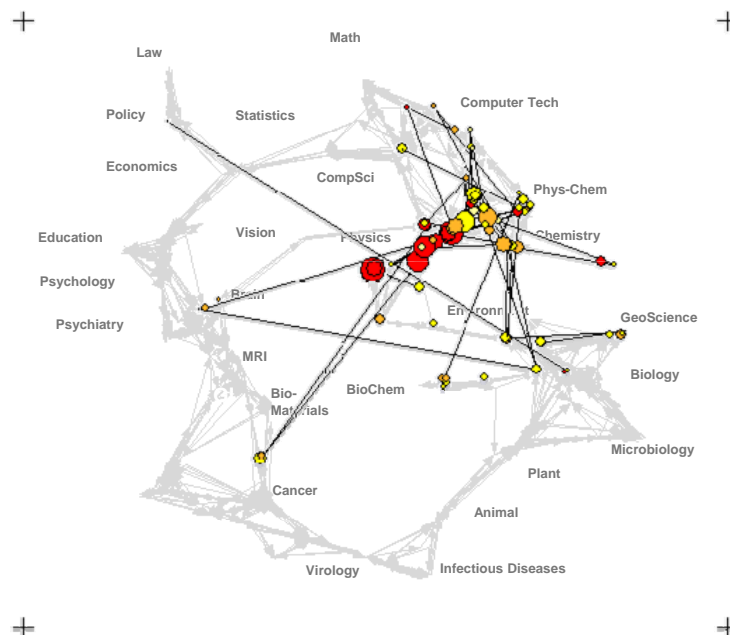
- Uses combined SCI/SSCI from 2002
 - 1.07M papers, 24.5M references, 7,300 journals
 - Bibliographic coupling of papers, aggregated to journals
- Initial ordination and clustering of journals gave 671 clusters
- Coupling counts were reaggregated at the journal cluster level to calculate the
 - (x,y)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

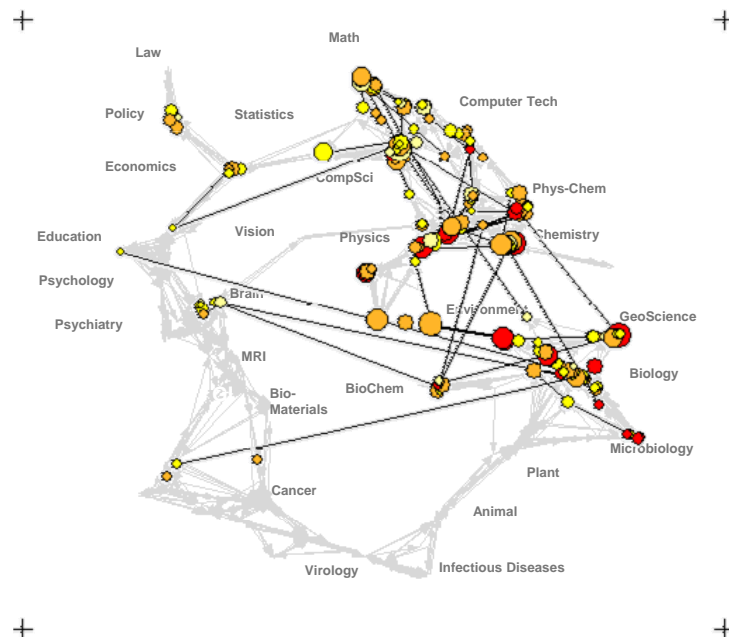
Funding patterns of the US Department of Energy (DOE)



Science map applications: Identifying core competency

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

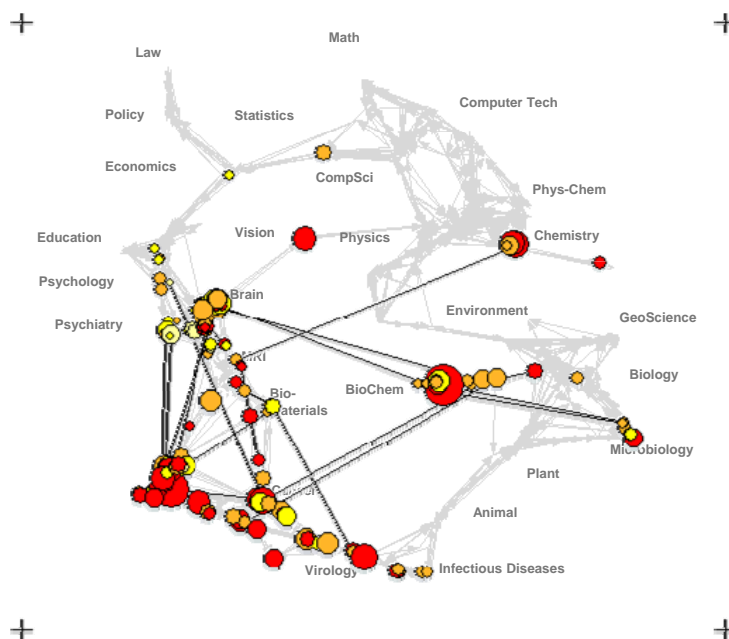
Funding Patterns of the National Science Foundation (NSF)



Science map applications: Identifying core competency

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

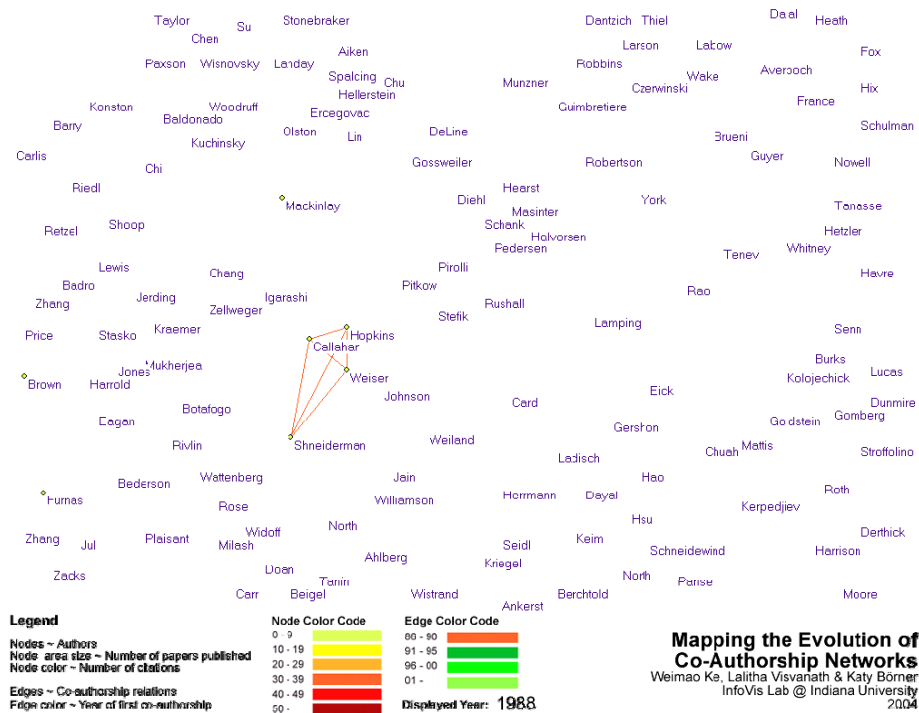
Funding Patterns of the National Institutes of Health (NIH)



Sample Science Studies

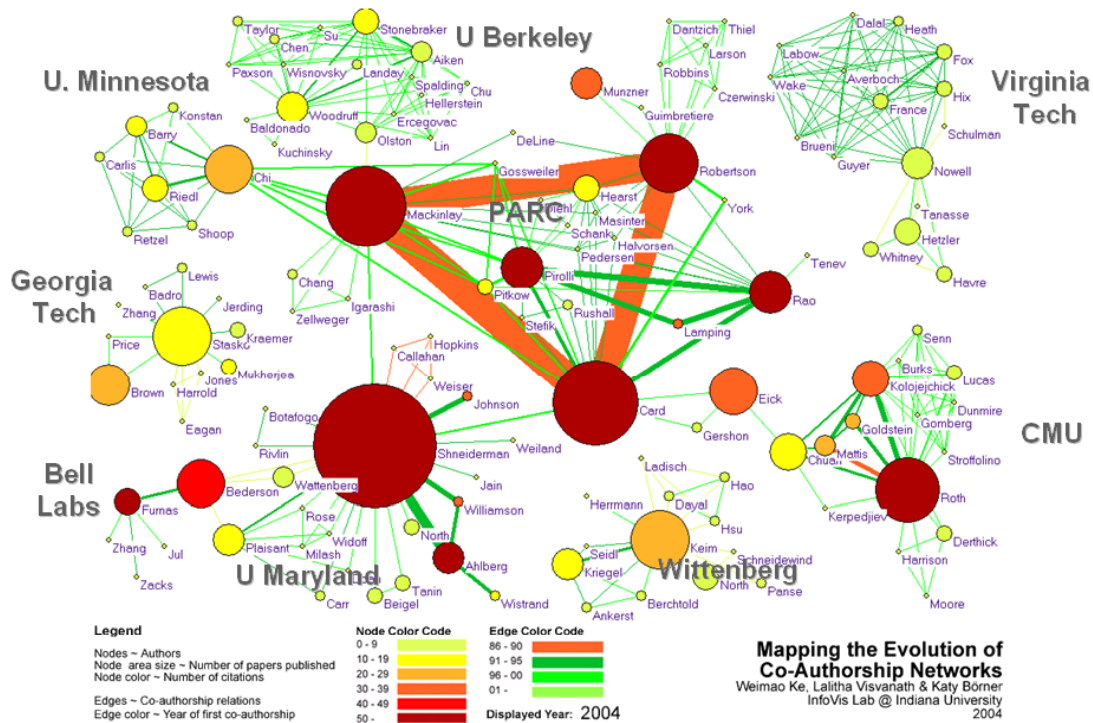
Mapping the Evolution of Co-Authorship Networks

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



Mapping the Evolution of Co-Authorship Networks

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



17

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

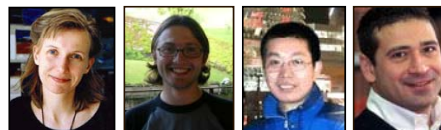
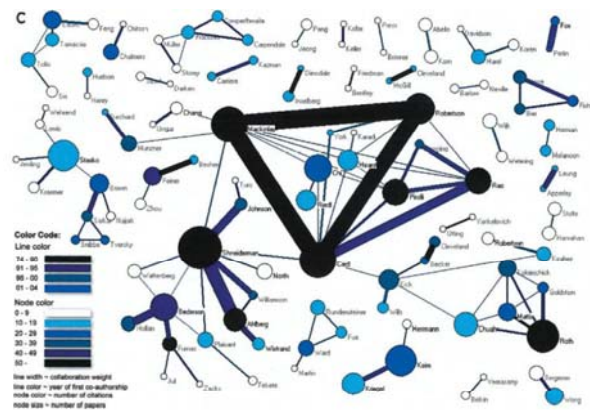
Börner, Dall'Asta, Ke & Vespignani (2005) *Complexity*, 10(4):58-67.

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 graph representation.
- Visualization of the growth of weighted co-author network.
- Centrality measures to identify author impact.
- Global statistical analysis of paper production and citations in correlation with co-authorship team size over time.
- Local, author-centered entropy measure.

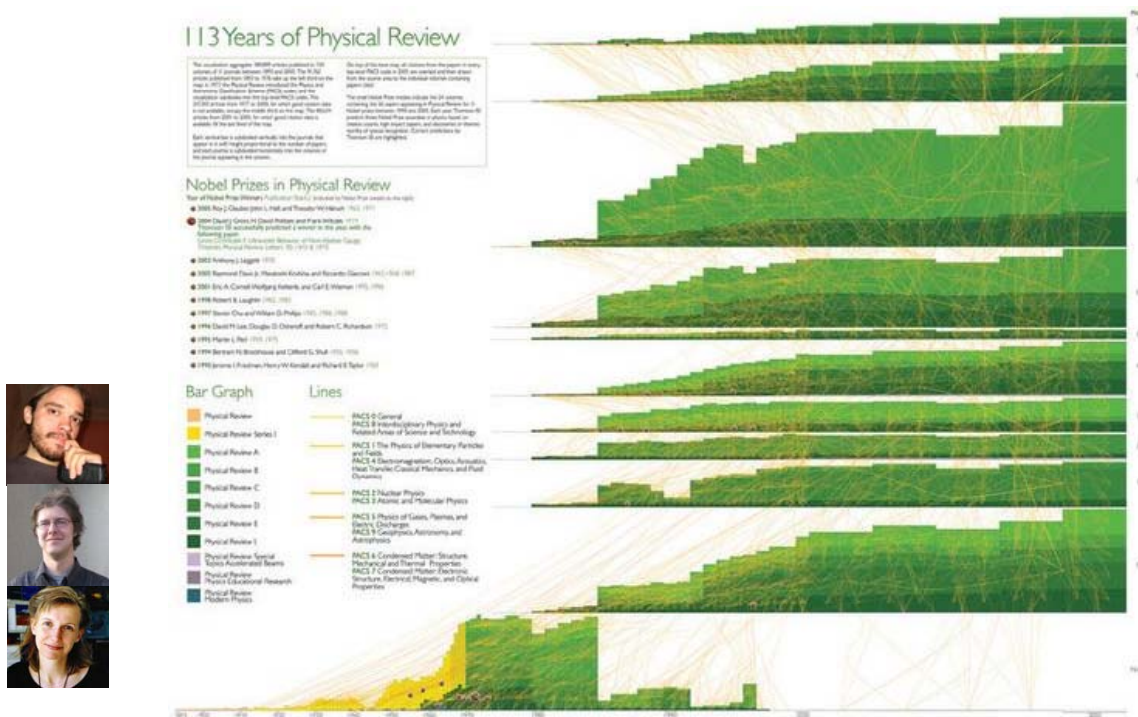


18

113 Years of Physical Review

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

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



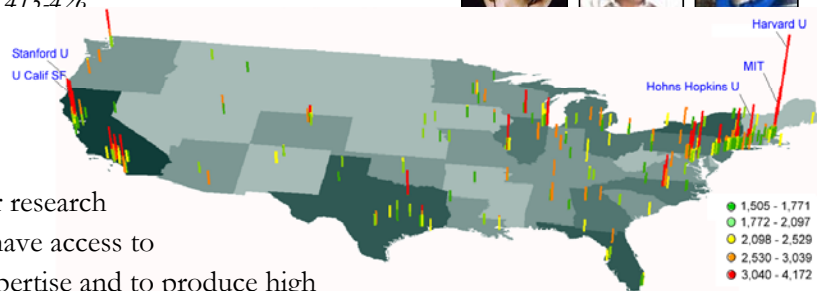
Spatio-Temporal Information Production and Consumption of Major U.S. Research Institutions

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*



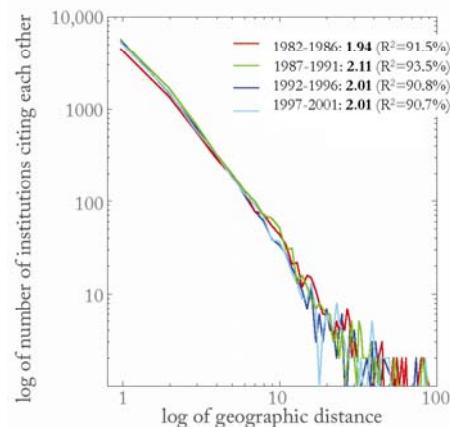
Research questions:

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 have access to high quality data and expertise and to produce high quality research?
3. Does the Internet lead to more global citation patterns, i.e., more citation links between papers produced at geographically distant research institutions?



Contributions:

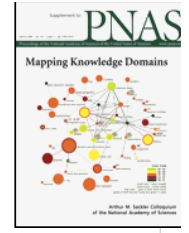
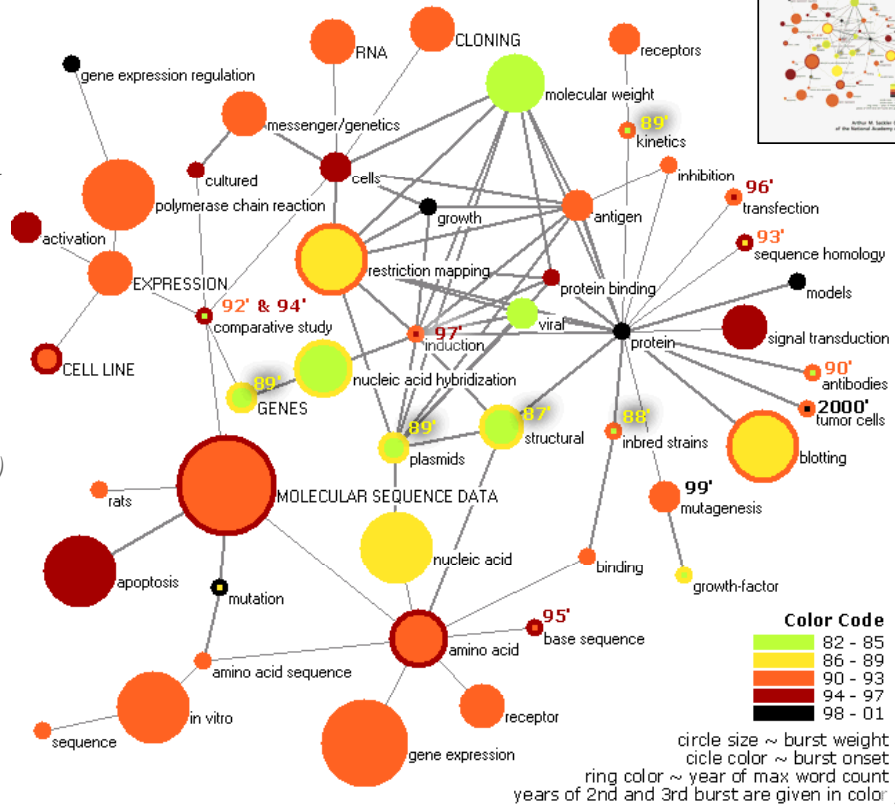
- Answer to Qs 1 + 2 is YES.
- Answer to Qs 3 is NO.
- Novel approach to analyzing the dual role of institutions as information producers and consumers and to study and visualize the diffusion of information among them.



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.

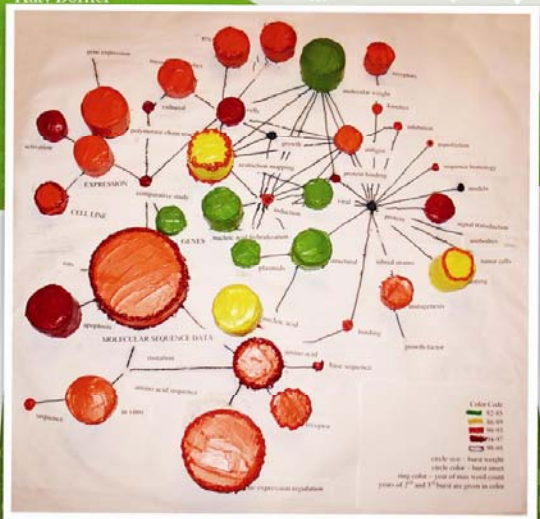
Mane & Börner. (2004) PNAS, 101(Suppl. 1): 5287-5290.



Merry Christmas and Happy New Year! 2008

Jon Burgoyne, Katy Börner, Russell J. Duhon, Shriram Rajagopal, Heng (Michael) Zhang, Bruce W. Herr II, Julie M. Smith, Peter A. Hook, Nianli Ma, Chung Yang (Kenneth) Lee

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



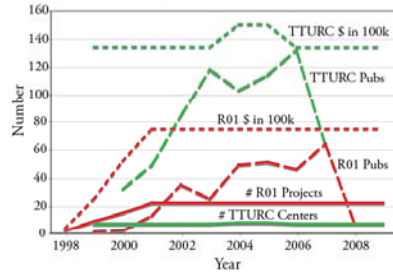
Cake created by Kristin Reed and Lydia Nichols. They insisted on having a legend!

Mapping Transdisciplinary Tobacco Use Research Centers Publications

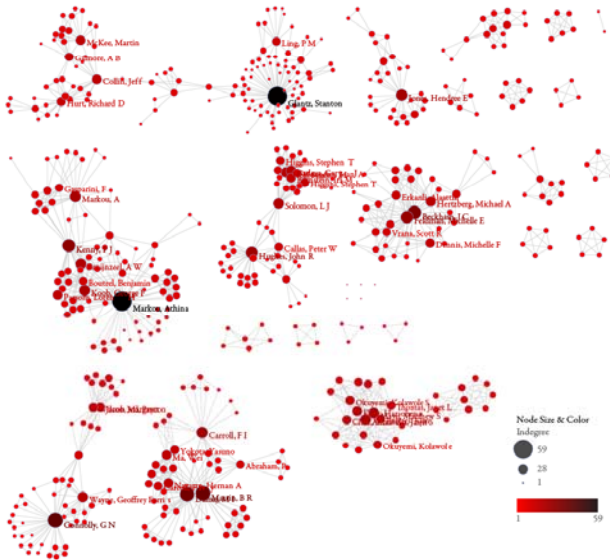
Compare R01 investigator based funding with TTURC Center awards in terms of number of publications and evolving co-author networks.

Zoss & Börner, forthcoming.

R01 & TTURC Project Information



R01 Co-Author Network

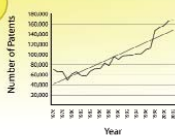


TTURC Co-Author Network



Examining the Evolution and Distribution of Patent Classifications

1 Patents Granted Over the Last 20 Years



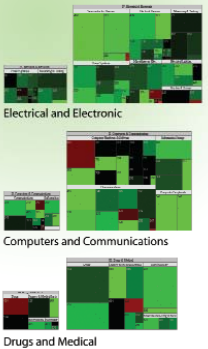
Class	Title	Patents
2801	Chemistry of Carbon Compounds	13,348
4307	English Writing and Body Training Compositions	10,527
2414	Compositions	9,148
4306	Language	8,984
6708	Stock Market or Miscellaneous Articles	8,051
751	Manufacturing and Testing	6,971
232	Internal-Combustion Engines	6,162
340	Communications/Chemical	5,283
2344	Electrical Components and Circuits/Power Systems	3,789
27	Metal Working	2,684
Total		35,078

Class	Title	Patents
311	Drug Bio/Writing and Body Training Compositions	28,041
4306	Chemistry of Carbon Compounds	13,348
4307	Chemistry of Carbon Compounds	13,348
4308	Chemistry of Carbon Compounds	13,348
4309	Chemistry of Carbon Compounds	13,348
4310	Chemistry of Carbon Compounds	13,348
4311	Chemistry of Carbon Compounds	13,348
4312	Chemistry of Carbon Compounds	13,348
4313	Chemistry of Carbon Compounds	13,348
4314	Chemistry of Carbon Compounds	13,348
4315	Chemistry of Carbon Compounds	13,348
4316	Chemistry of Carbon Compounds	13,348
4317	Chemistry of Carbon Compounds	13,348
4318	Chemistry of Carbon Compounds	13,348
4319	Chemistry of Carbon Compounds	13,348
4320	Chemistry of Carbon Compounds	13,348
4321	Chemistry of Carbon Compounds	13,348
4322	Chemistry of Carbon Compounds	13,348
4323	Chemistry of Carbon Compounds	13,348
4324	Chemistry of Carbon Compounds	13,348
4325	Chemistry of Carbon Compounds	13,348
4326	Chemistry of Carbon Compounds	13,348
4327	Chemistry of Carbon Compounds	13,348
4328	Chemistry of Carbon Compounds	13,348
4329	Chemistry of Carbon Compounds	13,348
4330	Chemistry of Carbon Compounds	13,348
4331	Chemistry of Carbon Compounds	13,348
4332	Chemistry of Carbon Compounds	13,348
4333	Chemistry of Carbon Compounds	13,348
4334	Chemistry of Carbon Compounds	13,348
4335	Chemistry of Carbon Compounds	13,348
4336	Chemistry of Carbon Compounds	13,348
4337	Chemistry of Carbon Compounds	13,348
4338	Chemistry of Carbon Compounds	13,348
4339	Chemistry of Carbon Compounds	13,348
4340	Chemistry of Carbon Compounds	13,348
4341	Chemistry of Carbon Compounds	13,348
4342	Chemistry of Carbon Compounds	13,348
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4350	Chemistry of Carbon Compounds	13,348
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4353	Chemistry of Carbon Compounds	13,348
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4360	Chemistry of Carbon Compounds	13,348
4361	Chemistry of Carbon Compounds	13,348
4362	Chemistry of Carbon Compounds	13,348
4363	Chemistry of Carbon Compounds	13,348
4364	Chemistry of Carbon Compounds	13,348
4365	Chemistry of Carbon Compounds	13,348
4366	Chemistry of Carbon Compounds	13,348
4367	Chemistry of Carbon Compounds	13,348
4368	Chemistry of Carbon Compounds	13,348
4369	Chemistry of Carbon Compounds	13,348
4370	Chemistry of Carbon Compounds	13,348
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4393	Chemistry of Carbon Compounds	13,348
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4395	Chemistry of Carbon Compounds	13,348
4396	Chemistry of Carbon Compounds	13,348
4397	Chemistry of Carbon Compounds	13,348
4398	Chemistry of Carbon Compounds	13,348
4399	Chemistry of Carbon Compounds	13,348
4400	Chemistry of Carbon Compounds	13,348
Total		1,000,000

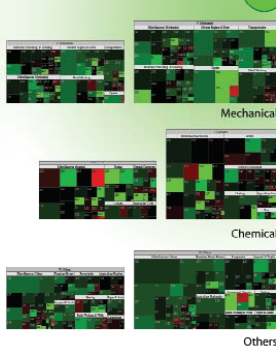
In the United States, each patent gets assigned to one out of more than 450 classes covering broad application domains. An examination of the size and growth of patent classes provides insight about patenting trends.

Treemaps, a space-filling technique developed in the HCI Lab at the University of Maryland, are used to communicate major results. Treemaps represent a tree structure as nested rectangles with each rectangle representing a node. A rectangular area is first allocated to hold the representation of the tree, and this area is then subdivided into a set of rectangles that represent the top level of the tree. This process continues recursively on the resulting rectangles to represent each lower level of the tree. The parent-child relationship is indicated by enclosing the child rectangle by its parent rectangle. Typically, the size of each rectangle corresponds to the size of the node. Additional information about a node, e.g., its age or value, can be represented by the color of the respective rectangle.

2 Fast Growth Domains 1983 - 1987 / 1998 - 2002

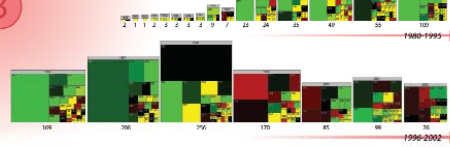


2 Slow Growth Domains 1983 - 1987 / 1998 - 2002



Shown is a comparison of the patent class space for 1983 to 1987 and 1998 to 2002. There is a predominance of growth in the 1998 to 2002 patent space, which correlates to the increase in patent grants during this period. By comparing the growth in categories, one can distinguish between domains that have been receiving a larger amount of patent grants.

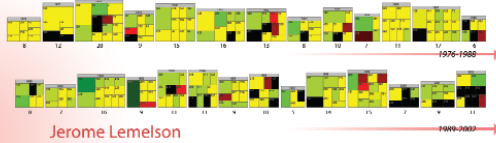
3 Apple Computer

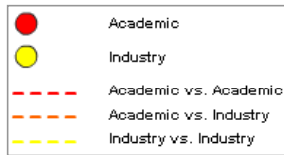
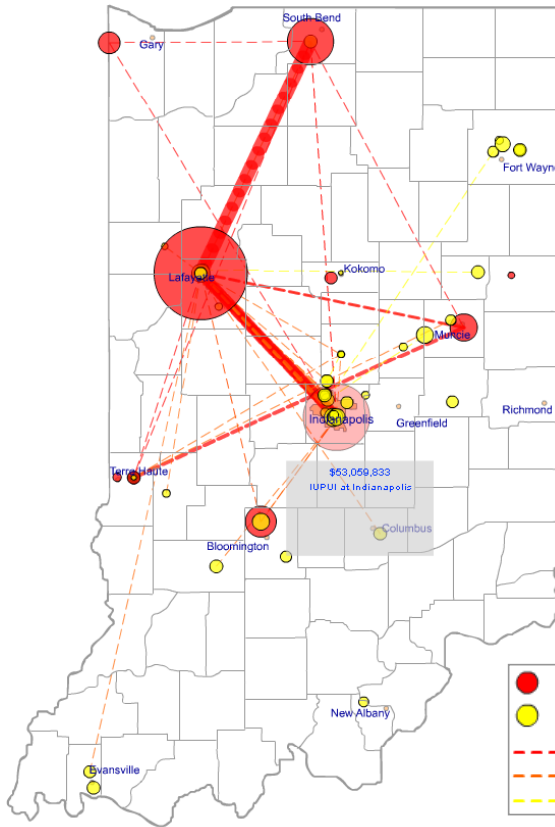


Depicted above is how Apple Computers' portfolio has changed in yearly increments from 1980 to 2002.

Legend:
Green = Increase in number of patent grants in particular class.
Red = Decrease in number of patent grants in particular class.
Yellow = No patents granted in that class in the past five years.
Size = Number of patent grants in a particular class.

Lemelson's patent holdings below show a more even distribution over multiple classes. No class dominates over a majority of the years for granted patents; instead they are distributed more broadly over the intellectual space.





Mapping Indiana's Intellectual Space

Identify

- Pockets of innovation
- Pathways from ideas to products
- Interplay of industry and academia

Wikipedian Activity

Studying large scale social networks such as Wikipedia

Vizzards 2007 Entry

Second Sight: An Emergent Mosaic of Wikipedian Activity, The NewScientist, May 19, 2007

Rendered as Google Map:

<http://scimaps.org/maps/wikipedia>

Jan 8th, 2008 Data Version on Gigapan:

<http://gigapan.org/vienGigapan.php?id=5042>



Second sight

Image: Bruce W. Herr and Todd M. Holloway

Power struggle



To spot where arguments are taking place, Herr suggests. If rival contributors are repeatedly changing each other's entries, for example, a page could be locked until the mood cools (locked pages at the time of writing include entries on Sheffield Wednesday football club, Mikhail Gorbachev and pigs). The mosaic has been commended in a competition for images that visualise network dynamics, coinciding with this week's International Workshop and Conference on Network Science in Bloomington.

www.newscientist.com

19 May 2007 | NewScientist | 95

Science Related Wikipedian Activity

http://scimaps.org/dev/map_detail.php?map_id=165

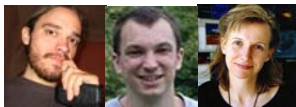
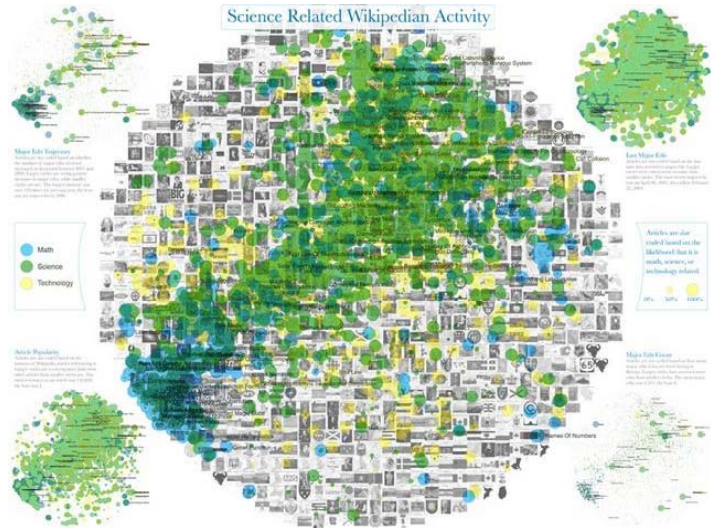
Same base map.

Overlaid are 3,599 math (blue), 6,474 science (green), and 3,164 technology relevant articles (yellow).

All other articles are given in grey.

Corners show articles size coded according to

- article edit activity (top left),
- number of major edits (top right),
- number of bursts in edit activity (bottom, right)
- indegree (bottom left).



**Society for Neuroscience, 2006
Visual Browser**

Click to start a bounding box, then click again to end it. A listing of all nodes in the bounding box will be shown. Click once again to clear the bounding box.

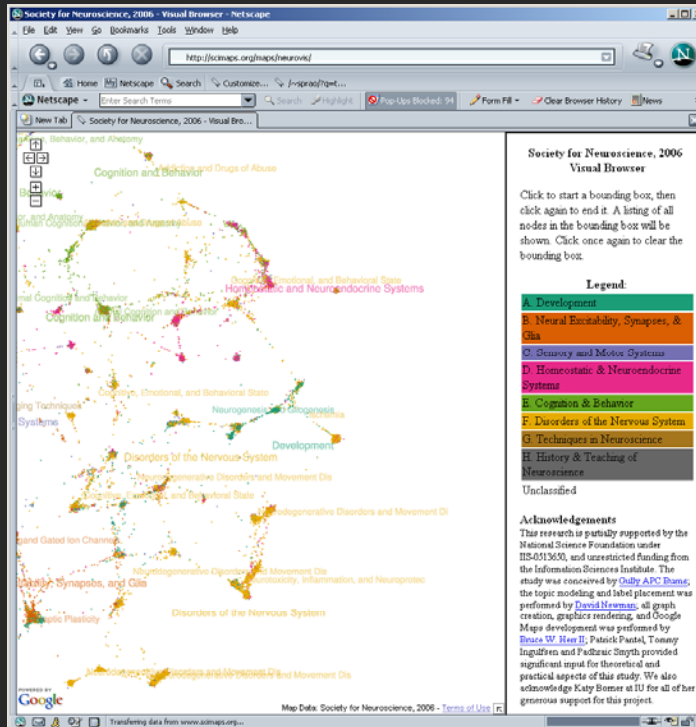
Legend

- A. Development
- B. Neural Excitability, Synapses, & Glia
- C. Sensory and Motor Systems
- D. Homeostatic & Neuroendocrine Systems
- E. Cognition & Behavior
- F. Disorders of the Nervous System
- G. Techniques in Neuroscience
- H. History & Teaching of Neuroscience
- Unclassified

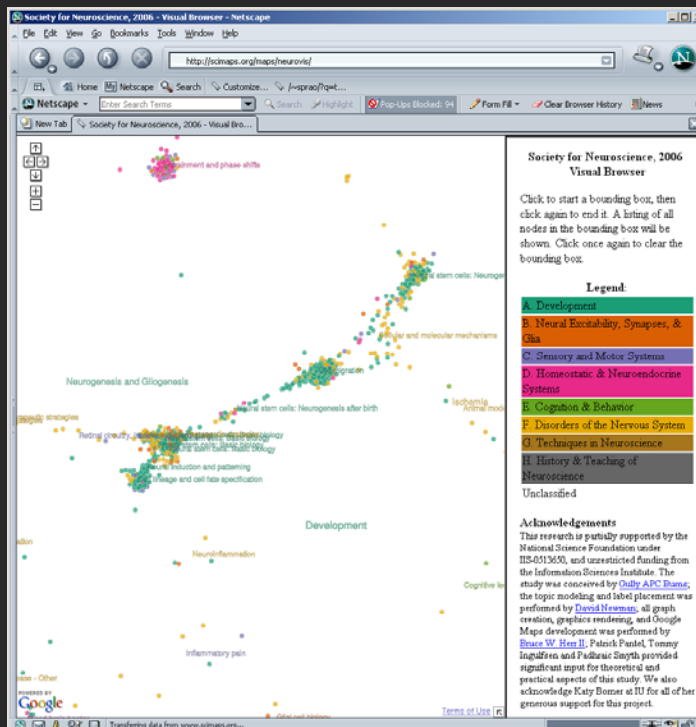
Acknowledgements
This research is partially supported by the National Science Foundation under IIS-0513650, and unrestricted funding from the Information Sciences Institute. The study was conceived by Gully APC Burns, the topic modeling and label placement was performed by David Newman, all graph creation, graphics rendering, and Google Maps development was performed by Bruce W. Herr II, Patrick Paudel, Tommy Ingulfsen and Padraic Smyth provided significant input for the theoretical and practical aspects of this study. We also acknowledge Katy Bonner at UI for all of her generous support for this project.

Map Data: Society for Neuroscience, 2006 - Terms of Use

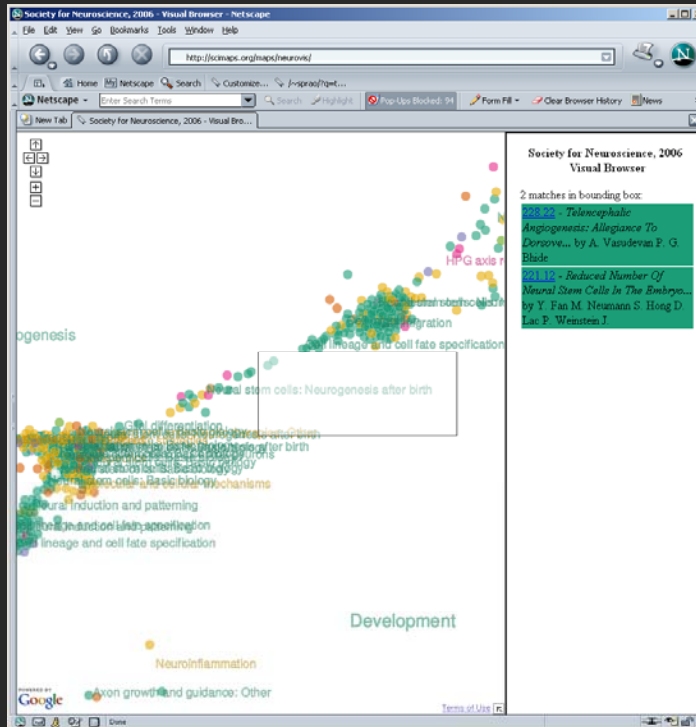
Bruce W. Herr II, Gully Burns (USC), David Newman (UCI), Society for Neuroscience, 2006
Visual Browser, 2007, <http://scimaps.org/maps/neurovis/>



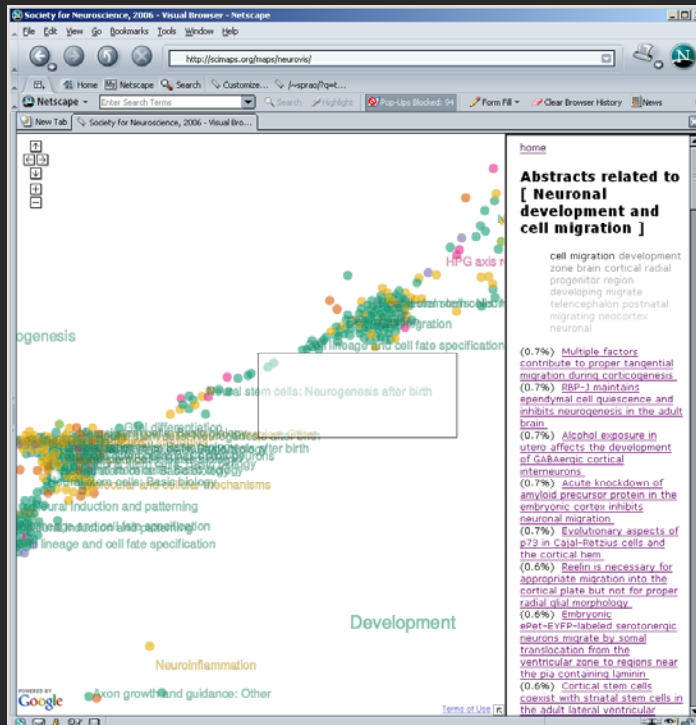
Bruce W. Herr II, Gully Burns (USC), David Newman (UCI), Society for Neuroscience, 2006
 Visual Browser, 2007, <http://scimaps.org/maps/neurovis/>



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/>



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

Information Visualization CyberInfrastructure

The InfoV's CyberInfrastructure provides access to data, software code and learning modules as well as computing resources in support of the analysis, modeling and visualization of diverse data sets.

DATABASES

An Oracle database provides access to publications, patents, grants and grant opportunities. The database is continuously and automatically updated.

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

SOFTWARE

An open source IIC framework was designed to facilitate the integration of diverse data analysis, modeling and visualization algorithms. New algorithms, data provenance methods, back and forth for the interface and even entire toolkits can be easily "plugged in" or "unplugged".

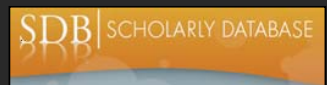
<http://slis.indiana.edu/cis/>

COMPUTING RESOURCES

The InfoV's CyberInfrastructure is hosted at Indiana University's Research Computing Center, comprising of over 5000 servers with 12,000 CPU processors and 16 TB of memory cache. 5 TB fiber channel disks are attached to both servers. A Sun V900 system with 4 CPUs and 8GB memory serves as the web front end for the database servers.

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

InfoV's
INDIANA LIBRARY, SCHOOL OF LIBRARY AND INFORMATION SCIENCE, INDIANA UNIVERSITY (2006) This material is based upon work supported by the National Science Foundation under Grant No. IRI-0730611 and IRI-0730612



Scholarly Database
<http://sdb.slis.indiana.edu>


CAREER: Visualizing Knowledge Domains. NSF IIS-0238261 award (Katy Börner, \$451,000) Sept. 03-Aug. 08.
<http://in.slis.indiana.edu/>



SEI: Network Workbench: A Large-Scale Network Analysis, Modeling and Visualization Toolkit for Biomedical, Social Science and Physics Research. NSF IIS-0513650 award (Katy Börner, Albert-László Barabási, Santiago Schnell, Alessandro Vespignani & Stanley Wasserman, Eric Wernert (Senior Personnel), \$1,120,926) Sept. 05 - Aug. 09.
<http://nwb.slis.indiana.edu>



Mapping Science Exhibit




places & spaces

Cartography of the Physical and the Abstract

An exhibition created for the conference "Mapping Humanity's Knowledge and Expertise in the Digital Domain" at the 2005 Meeting of the American Association of Geographers that is updated regularly with new maps and explanations.

Home Browse Maps Compare & Contrast Maps Connect



Places & Spaces: Mapping Science

a science exhibit that introduces people to maps of sciences, their makers and users.

<http://scimaps.org>

Exhibit Curators: Dr. Katy Börner & Elisha F. Hardy

Home













Exhibit Purpose and Goals




The Places & Spaces exhibit has been created to demonstrate the power of maps.

An initial theme of this exhibit is to compare and contrast first maps of our entire planet with the first maps of all of science as we know it.

Come see with your own eyes the extent to which maps can be employed to help make sense of the flood of information we are confronted with and how domain maps can be used to locate complex and beautiful information.

This online part of the exhibit provides links to a selected series of maps and their makers along with detailed explanations of why these maps work. The physical counterpart supports the close inspection of high quality reproductions for display at conferences and education centers. It is meant to inspire cross-disciplinary discussion on how to best track and communicate human activity and scientific progress on a global scale.



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 49 venues on four continents. Also at
- NSF, 10th Floor, 4201 Wilson Boulevard, Arlington, VA, permanent display.
 - National Science Library of the Chinese Academy of Sciences, Beijing, China, 2008.
 - University of Alberta, Edmonton, Alberta, Canada, Nov 10-Feb 31, 2009.
 - The Institute for Research Information and Quality Assurance, Bonn, Germany, permanent display.



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:

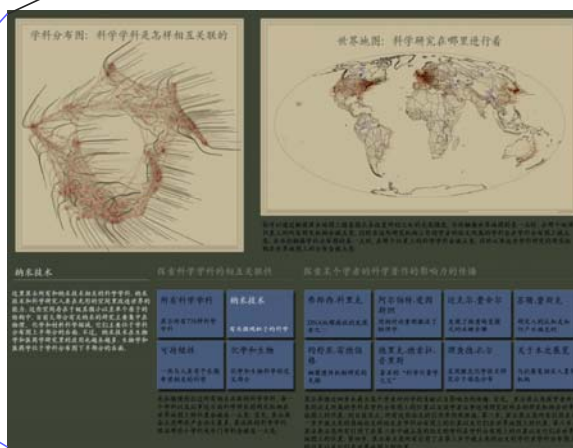
- Who is doing research on what topic and where?
- What is the 'footprint' of interdisciplinary research fields?
- What impact have scientists?



Interactive touch panel.

Contributions:

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



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

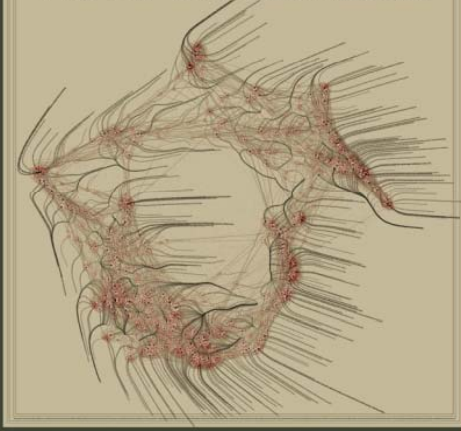
This overlay shows the distribution of nanotechnology within the paradigms of science. The majority of current work in nanotechnology takes place in physics, chemistry, and materials science, at the upper right portion of the map. However, an increasing amount of nanotechnology is being applied in the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

<p>All Topics</p> <p><i>Sweep through all 376 scientific paradigms</i></p>	<p>Nanotechnology</p> <p><i>Science on the tiny scale of molecules</i></p>	<p>Francis H. C. CRICK</p> <p><i>Co-discovered DNA's double helix</i></p>	<p>Albert EINSTEIN</p> <p><i>Revitalized physics with Relativity theories</i></p>	<p>Michael E. FISHER</p> <p><i>Models critical phase transitions of matter</i></p>	<p>Susan T. FISKE</p> <p><i>Connects perception and stereotypes</i></p>
<p>Sustainability</p> <p><i>The science behind our long-term hopes</i></p>	<p>Biology & Chemistry</p> <p><i>The interface between these two vital fields</i></p>	<p>Joshua LEDERBERG</p> <p><i>Pioneer in bacterial genetic mechanisms</i></p>	<p>Derek J. de Solla PRICE</p> <p><i>Known as the "Father of Scientometrics"</i></p>	<p>Richard N. ZARE</p> <p><i>Uses laser chemistry in molecular dynamics</i></p>	<p>About this display</p> <p><i>People & organizations that helped create it</i></p>

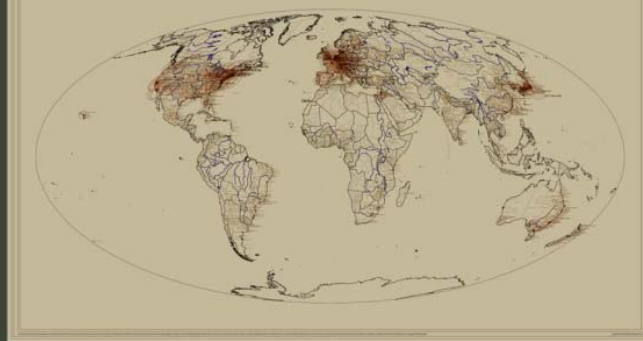
We sweep slowly through adjoining related topics, lighting up the places in the world that study each topic. You may select a subset of the topics that deal with these three interesting subjects by touching it.

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.

学科分布图：科学学科是怎样相互关联的



世界地图：科学研究在哪里进行着



你可以通过触摸屏在地图上随意指点来改变所到之处的光亮强度。当你触摸世界地图的某一点时，在那个地理位置上的所有研究机构会被点亮。同时在这些研究机构工作的学者的论文所属的学科会在学科分布图上被点亮。而当你触摸学科分布图的某一点时，在那个位置上的科学学科会被点亮，同时从事这些学科研究的研究机构在世界地图上的分布会被点亮。

纳米技术

这里显示所有和纳米技术相关的科学学科。纳米技术和科学研究人类在无形的空间里改造世界的的能力。这些空间存在于极其微小以至单个原子的结构中。目前大部分有关纳米的研究主要集中在物理、化学和材料科学领域。它们主要位于学科分布图上半部分的右面。不过，纳米技术在生物学和医药学研究里的应用也越来越多。生物学和医药学位于学科分布图下半部分的右面。



探索科学学科的相互关联性

所有科学学科 显示所有776种科学学科	纳米技术 有关微观粒子的科学
可持续性 一些与人类寄予长期希望相关的科学	化学和生物 化学和生物科学的交叉部分

光标缓慢的扫过所有相互关联的科学学科，每一个学科以及从事这方面科学研究的研究机构在世界地图上的位置会被逐一点亮。首先，显示屏会点亮那些产出论文最多、最活跃的科学学科，然后那些小学科或冷门学科会被逐一点亮。

探索某个学者的科学著作的影响力的传播

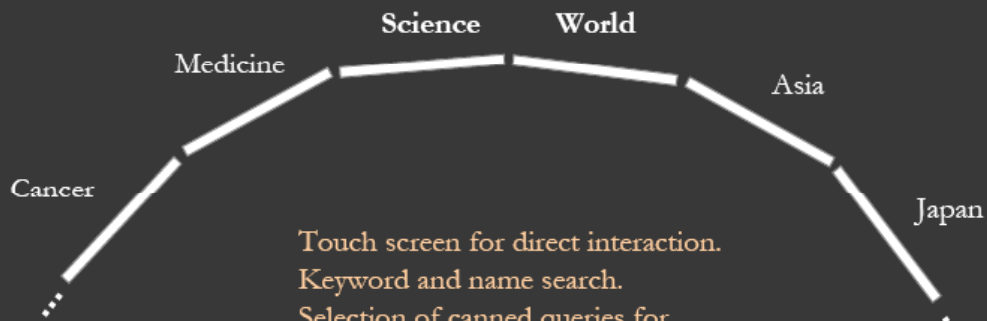
弗郎西·科里克 DNA双螺旋结构的发现者之一	阿尔伯特·爱因斯坦 用相对论重新激活了物理学	迈克尔·费舍尔 发现了物质转变模式的关键步骤	苏珊·费斯克 研究人的认知是如何产生偏见的
约舒亚·雷德伯格 细菌遗传机制研究先驱	德里克·德索拉·普里斯 著名的“科学计量学之父”	理查德·扎尔 采用激光化学技术研究分子动态分布	关于本次展览 与此展览相关人员和机构

显示屏通过四步来展示某个学者对科学的贡献以及影响力的传播。首先，显示屏点亮该学者所发表的论文所属的学科在学科分布图上的位置以及该学者从事这项研究所在的研究机构在世界地图上的位置。到目前为止，所有这些论文的引用率仍然很高。第二步，显示屏点亮所有引用在第一步中被点亮的原始论文的论文在学科分布图上的位置以及它们在世界地图上的位置。第三步，显示屏点亮所有引用了在第二步中被点亮的论文的论文在学科分布图上的位置以及它们在世界地图上的位置。第四步，显示屏点亮所有引用了在第三步中被点亮的论文的论文在学科分布图上的位置以及它们在世界地图上的位置。

Re-implementation of Illuminated Diagram Software

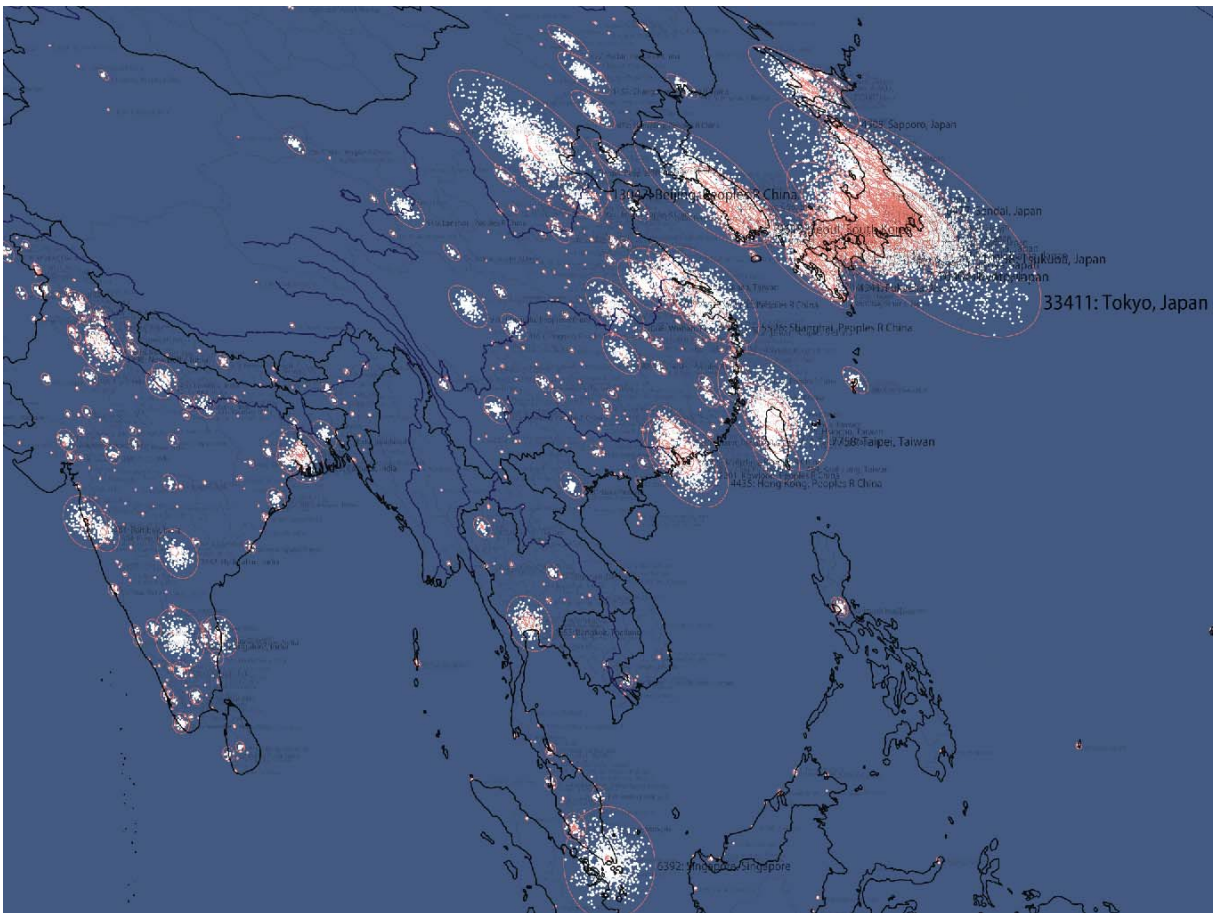
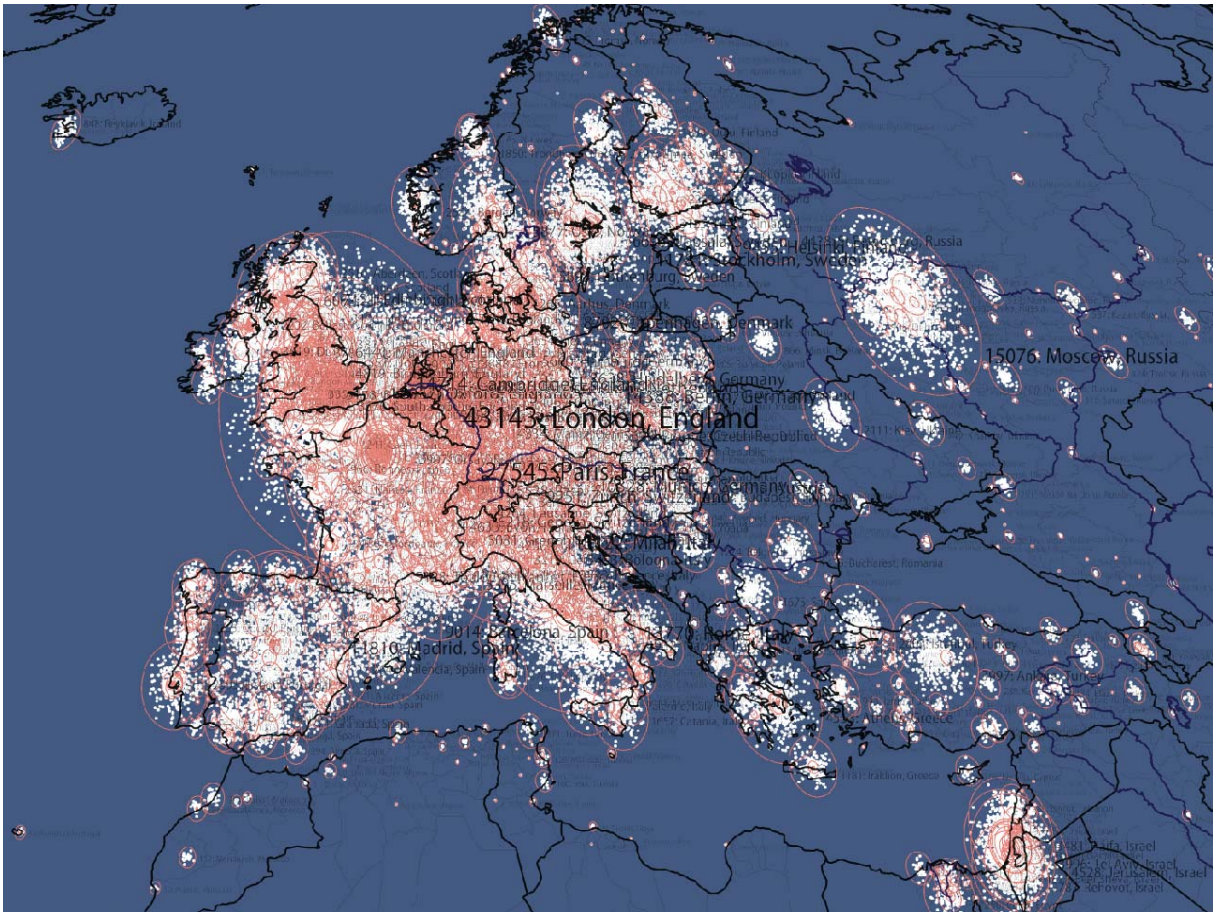
by Advanced Visualization Lab, Indiana University

Drives unlimited number of ID screens.



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









Science Puzzle Map for Kids by Filene Palmer, Julie Smith, Elisha Hardy and Katy Börner, Indiana University, 2006. (Base map taken from Illuminated Diagram display by Kevin Boyack, Richard Klavans, and W. Bradford Paley.)

Inventors



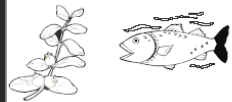
Hands-On Science Maps for Kids, by Filipe Palmer (Painting), Julia Smith (Data Acquisition), Eksha Hardy and Kitty Elmer (Graphic Design), BLOOMINGTON, IN, 2006. Courtesy of Indiana University. Learn more at www.scmmaps.org. This map plots the locations of where scientific papers were published; each light green dot represents 10 or fewer papers; they are scattered around the exact location for visibility, within a labeled green circle whose size is proportional to the number of papers published in that place. The base map is part of an "illuminated diagram" display which used a computer and two projectors, projecting spots of light on the panel to highlight different kinds of scientific research on a sliding map of scientific paradigms and the areas in the world where such science was performed. Base map: research by Kevin Baksh and Dik Kikstra, cartography by John Deacon, data from Thompson ISI graphics and typography by its Bradford Philp. Copyright © 2006 by Bradford Philp, all rights reserved.





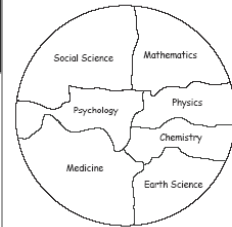
My Science Story

By _____



For more information about the map of science for kids or this exercise, please contact Katy Borvan (katy@indiana.edu) or Nikki Roberg (nroberg@indiana.edu) at the School of Library and Information Science, Indiana University. These materials were compiled by Nikki Roberg in 2006.

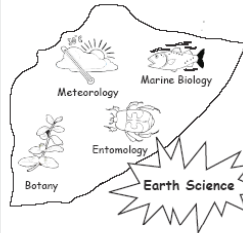
There are seven main fields of science. They are...



social science, mathematics, physics, chemistry, earth science, medicine, and psychology. I like to study earth science.

Color earth science green.

Earth scientists study the weather, plants and trees, marine life, insects, and much more.

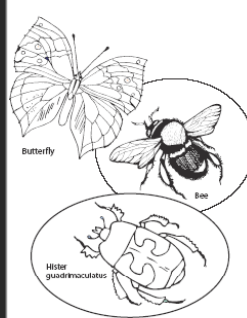


I like insects. They are interesting to look at and study.

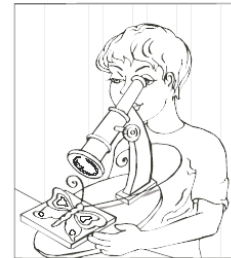
Color in the insect.

Activities:

- Solve the puzzle.
- Navigate to 'Earth Science'.
- Identify major inventions.
- Place major inventors.
- Find your dream job on the map.
- Why is mathematics important?



There are many types of insects in the world. Bees, butterflies, and beetles are just a few.



I want to be an entomologist when I grow up. Then I can study insects all the time.

What is Science? KIDS DRAWING CONTEST

WHAT

What is Science? Who does Science? What is Science to you? Design a picture of your favorite scientist or science experiment and tell us about it!

WHEN

October 1st - 30th: Submit entries
November 5th: Winners notified
November 5th - 30th: Winning entries and Top 50 on display at the American Museum of Science and Energy.

Judging Criteria

- 25% Appropriate use of contest theme
- 25% Creativity and quality of drawing
- 25% Originality of the story
- 25% Sensitivity of drawing and story

Requirements

Kids ages 4-15 are invited to submit their hand-drawn illustrations on 8.5 x 11 paper with a typed story of 25-100 words explaining their drawing and discussing their favorite scientist or experiment.

PRIZES

1 year family membership & Science Kit from AMSE

Science Kit from the AMSE Discovery Shop

Science Book from the AMSE Discovery Shop

Bring in your contest submission and get into AMSE for FREE

Consent

Required: Parental signature granting consent for child to enter contest and agreement that the submitted material will not be returned and will become the property of the Places & Spaces-Museum Science exhibit.

Submitting

Mail submissions to: The American Museum of Science and Energy, 600 S. Tulane Ave., Oak Ridge, TN 37830. You may also bring in your submission to The American Museum of Science and Energy.

QUESTIONS? Ask Kim Poyes (kimpoyes@amse.org) | Phone 865-574-9584

Please attach this form to the back of submission



Artist's Name _____ Age _____ Parent's Name _____ Phone Number _____

Winners @ AMSE

JoHanna Sanders, age 12, a picture of someone enjoying nature and a theme that science is all around us.
Sascha Richey, age 8, drew a picture of her mother and explained why her mother is her favorite scientist.

My Favorite Scientist



Observe
Discover
Understand
Learn
Science
Explore
Hypothesis
Experiment
Win or Lose

Science of Science Cyberinfrastructure



Science of Science Cyberinfrastructure — P O R T A L —

Provided by the [Cyberinfrastructure for Network Science Center](#) at Indiana University.

Introduction
E. O. Wilson writes in *Consilience: The Unity of Knowledge* (1998): "Features that distinguish science from pseudoscience are repeatability, economy, mensuration, heuristics, and consilience."
Please see Börner's [recent presentation](#) at the *A Deeper Look at the Visualization of Scientific Discovery* NSF Workshop for a general introduction of the needs and the resources provided here.

Needs Analysis
As part of the "TLS: Towards a Macroscopic for Science Policy Decision Making" NSF SBE-0738111 award, interviews with science policy makers are conducted to identify what science of science research results and tools might be most desirable and effective. So far, 30 formal, one-hour interviews have been conducted with science policy makers at university campus level, program officer level, and division director level for governmental, state, and private foundations. Data compilation will start in October 2008 and resulting report can be ordered by sending a request to Mark Price (maaprice@indiana.edu).

Conceptualization of Science
A science of science requires a theoretically grounded and practically useful conceptualization of the structure and evolution of science. A special journal issue entitled "*Science of Science: Conceptualizations and Models of Science*" edited by [Katy Börner](#), Indiana University & [Andrea Scharnhorst](#), Royal Netherlands Academy of Arts and Sciences invites contributions on this topic. It will be published in the *Journal of Informetrics* 3(1) in January 2009.

Scholarly Database
The [Scholarly Database \(SDB\)](#) at Indiana University aims to serve researchers and practitioners interested in the analysis, modeling, and visualization of large-scale scholarly datasets. The database currently provides access to over 20 million papers, patents and grants. Resulting datasets can be downloaded in bulk. Register for free access at <https://sdb.slis.indiana.edu/>.

Cyberinfrastructures
The Scientometrics filling of the [Network Workbench \(NWB\) Tool](#) provides a unique distributed, shared resources environment for large-scale network analysis, modeling, and visualization. Thomson Scientific/ISI, Scopus and Google Scholar data, EndNote and Bibtext files, or NSF awards can be read and diverse networks can be extracted and studied. Download [User Manual with focus on Scientometrics](#).

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

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>

Datasets available via the Scholarly Database

Dataset	#Records	Years Coverage	updated	Restricted Access
Medline	16,053,495	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	3,710,952	1976-2007	Yes	
NSF	174,835	1985-2003	Yes	
NIH	1,043,804	1972-2002	Yes	
Total	21,456,336	1893-2008	4	3

Aim for comprehensive temporal, geospatial, and topic coverage.

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

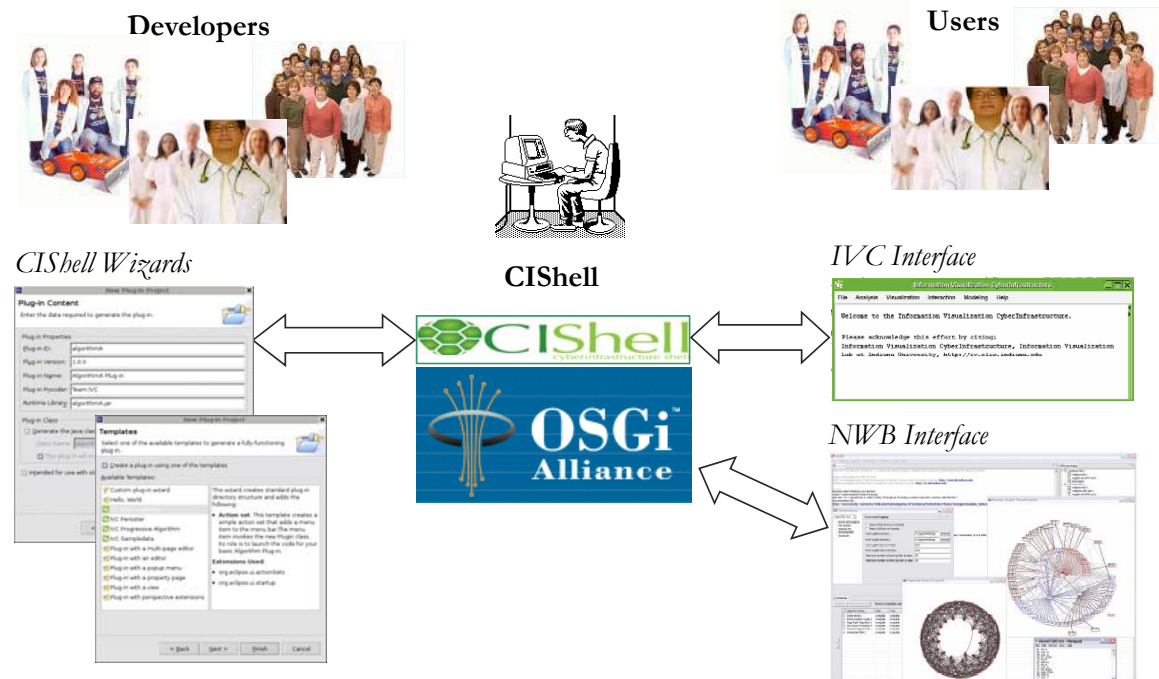


Software Team: Lead: Micah Linnemeier
 Members: Patrick Phillips, Russell Duhon, Tim Kelley & Ann McCranie
 Previous Developers: Weixia (Bonnie) Huang, Bruce Herr, Heng Zhang, Duygu Balcan, Bryan Hook, Ben Markines, Santo Fortunato, Felix Terkhorn, Ramya Sabbineni, Vivek S. Thakre & Cesar Hidalgo



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>



Preprocessing [Edit](#)

- Remove Nodes**
 - [Extract Top Nodes](#)
 - [Extract Nodes Above or Below Val](#)
 - [Delete High Degree Nodes](#)
 - [Delete Random Nodes](#)
 - [Delete Isolates](#)
- Remove Edges**
 - [Extract Top Edges](#)
 - [Extract Edges Above or Below Val](#)
 - [Remove Self Loops](#)
 - [Trim By Degree²](#)
 - [Pathfinder Network Scaling](#)
- Sampling**
 - [Snowball Sampling \(n nodes\)](#)
 - [Node Sampling](#)
 - [Edge Sampling](#)
- Transformations**
 - [Symmetrize](#)
 - [Dichotomize](#)
 - [Multipartite Joining](#)

Modeling [Edit](#)

- General**
 - [Random Graph](#)
 - [Watts-Strogatz Small World](#)
 - [Barabási-Albert Scale-Free](#)
- Structured**
 - [CAN](#)
 - [Chord](#)
- Unstructured**
 - [Hypergrid](#)
 - [PRU](#)
- Other**
 - [TARL](#)
 - [Discrete Network Dynamics](#)

Analysis [Edit](#)

- General Purpose**
 - [Network Analysis Toolkit²](#)
- Unweighted & Undirected**
 - Based on degree/**
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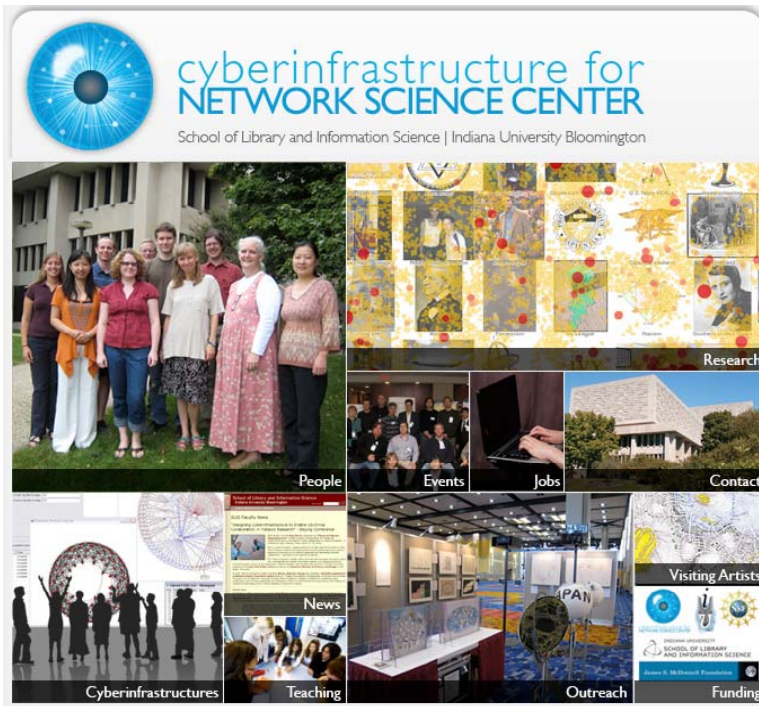
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