Mapping, Illuminating, and Interacting with Science (sap_0116)

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SIGGRAPH2007

Mapping, Illuminating, and Interacting with Science (sap_0116)

Mapping Science

The power of maps to guide explorations in physical and topic space.

Maps of science can guide our scholarly endeavors at multiple levels:

- **locally:** identify major authors/institutions/ nations, publications, patents, awards, businesses.
- **subnetwork/area level:** see major areas, their size, and internal structure.
- **globally:** get a birds-eye, holistic view of how areas of science are interrelated.


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Illuminated Diagram Display

Combines the incredibly high data density of two large prints: a map of the world and a map of science with the flexibility of an interactive program driving a touch panel display and two projectors that illuminate the maps.

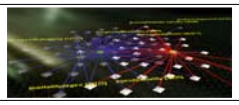
Interacting with Science

Using the touch panel display the viewer can study 'where in the world papers on a topic are published' and 'what topics are studied in a specific eographic location'.

Mapping Science

- 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.
- 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).
- Börner, Katy, Sanyal, Soma and Vespignani, Alessandro (in press). **Network Science.** In Blaise Cronin (Ed.), Annual Review of Information Science & Technology, Information Today, Inc./American Society for Information Science and Technology, Medford, NJ.

- **Places & Spaces: Mapping Science** exhibit, see also http://scimaps.org.



Process of Analyzing and Mapping Science

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. BROADENING By citation By terms	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 Decomp (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. CLUSTER ANALYSIS SCALAR Triangulation Force-directed placement (FDP)	INTERACTION Browse Pan Zoom Filter Query Detail on demand ANALYSIS

Börner, Chen & Boyack. (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.

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Places & Spaces: Mapping Science

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

Scimaps.org

Exhibit Curators:

Dr. Katy Börner &
Julie Smith

10 iterations in 10 years

1st Iteration in 2005:
The Power of Maps

2nd Iteration in 2006:
The Power of Reference Systems

3rd Iteration in 2007:
The Power of Forecasts

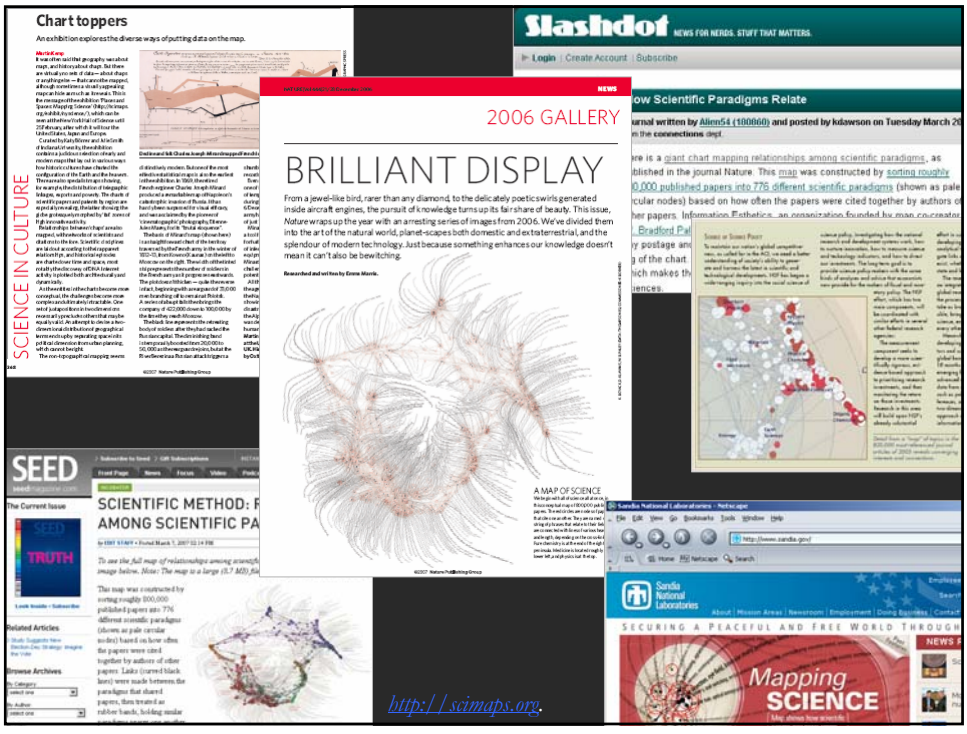
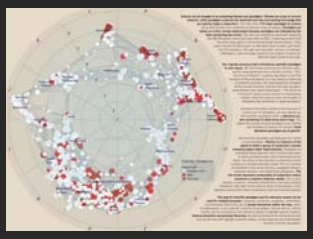
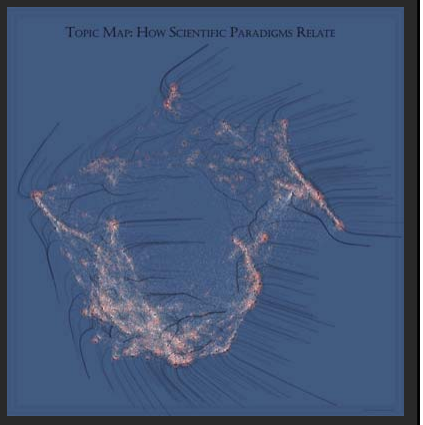


Chart toppers
An exhibition explores the diverse ways of putting data on the map.
SCIENCE IN CULTURE
Slashdot
NEWS FOR NERDS. STUFF THAT MATTERS.
2006 GALLERY
BRILLIANT DISPLAY
From a jewel-like bird, rarer than any diamond, to the delicately poetic swirls generated inside aircraft engines, the pursuit 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.
A MAP OF SCIENCE
SEED
SCIENTIFIC METHOD:
AMONG SCIENTIFIC PA
Mapping SCIENCE
http://scimaps.org.

Map of Scientific Paradigms(2nd Iteration)
by Kevin W. Boyack and Richard Klavans



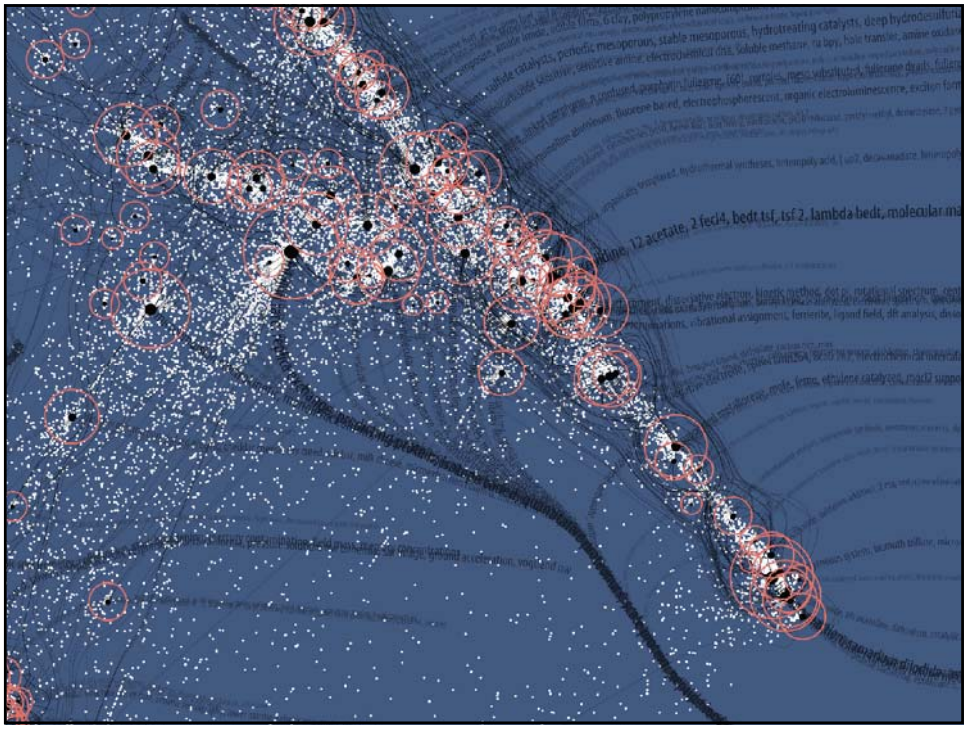


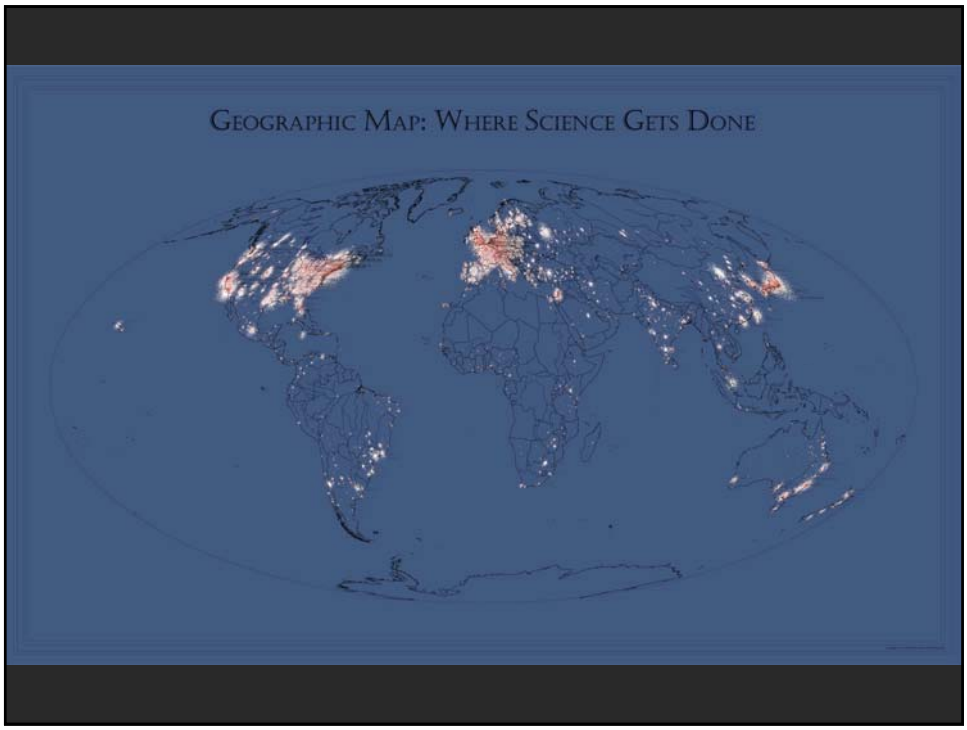
800,000 published papers were grouped into 776 different scientific paradigms (shown as colored circular nodes) based on how often the papers were cited together by authors of other papers.

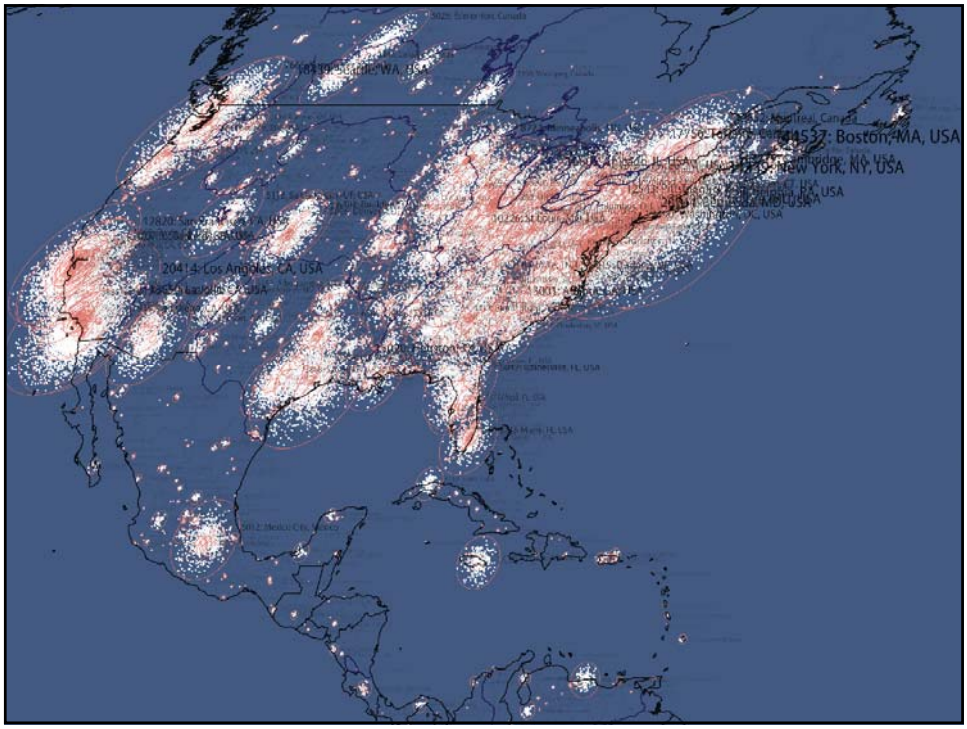
Links (curved black lines) were made between the paradigms that shared papers, then treated as rubber bands, holding paradigms with strong links nearer one another while a general repulsive force was applied; thus the layout derives directly from the data.

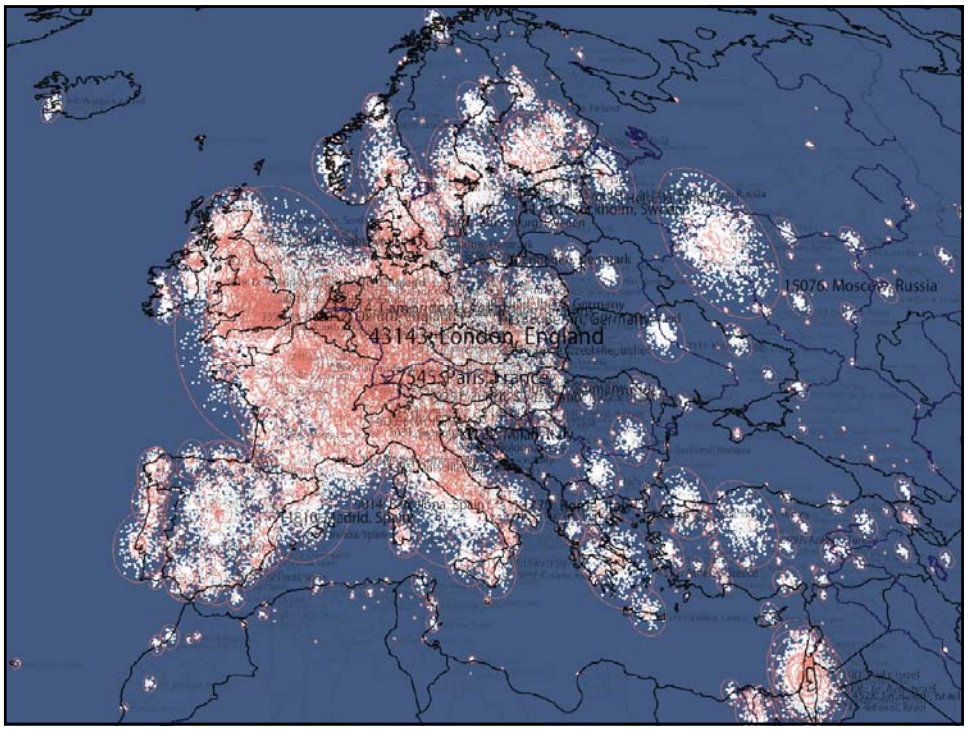
Larger paradigms have more papers; node proximity and darker links indicate how many papers are shared between two paradigms. Flowing labels list common words unique to each paradigm, large labels denote general areas of scientific inquiry.

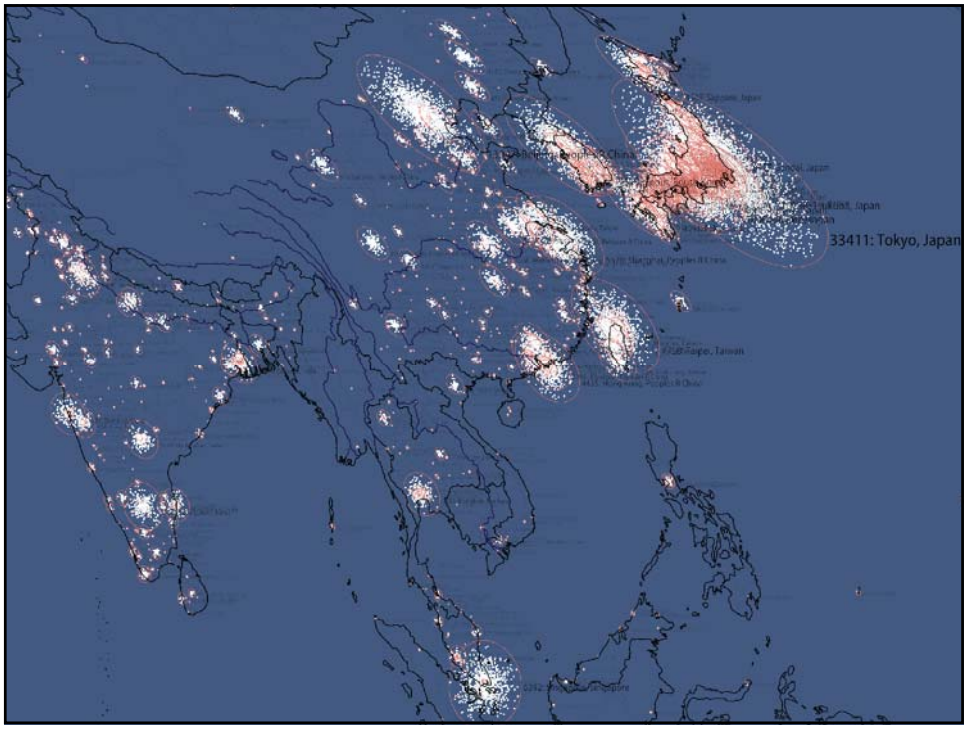
Redesign by W. Bradford Paley

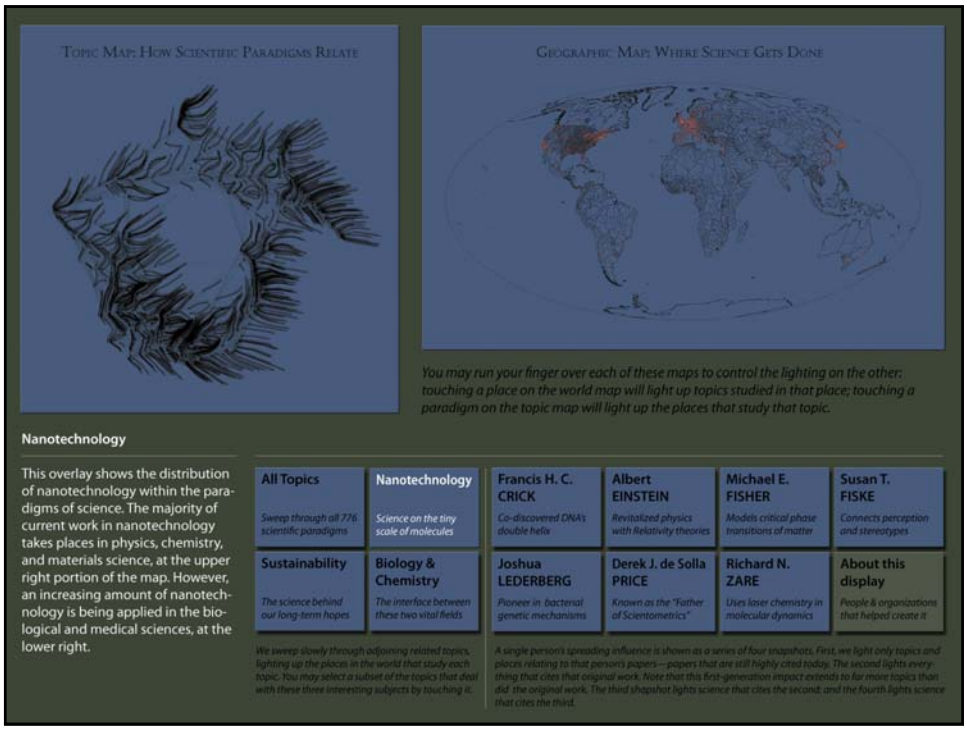



Geographic Map: Where Science Gets Done


20414 Los Angeles, CA, USA
New York, NY, USA


15076 Moscow, Russia
4314 London, England
27543 Paris, France


33411: Tokyo, Japan


Topic Map: How Scientific Paradigms Relate
Geographic Map: Where Science Gets Done
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 places 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.
All Topics
Sweep through all 776 scientific paradigms
Nanotechnology
Science on the tiny scale of molecules
Francis H. C. CRICK
Co-discovered DNA's double helix
Albert EINSTEIN
Revitalized physics with Relativity theories
Michael E. FISHER
Models critical phase transitions of matter
Susan T. FISKE
Connects perception and stereotypes
Sustainability
The science behind our long-term hopes
Biology & Chemistry
The interface between these two vital fields
Joshua LEDERBERG
Pioneer in bacterial genetic mechanisms
Derek J. de Solla PRICE
Known as the "Father of Scientometrics"
Richard N. ZARE
Uses laser chemistry in molecular dynamics
About this display
People & organizations that helped create it
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 shapshot lights science that cites the second, and the fourth lights science that cites the third.

Illuminated Diagram Display

(VIDEO: 4:10-8:45)

Places & Spaces: Mapping Science *exhibit at NYPL, New York, 2006*

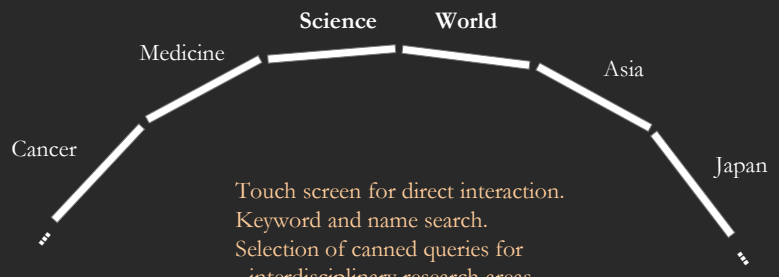
Places & Spaces: Mapping Science *exhibit at ACM in Chicago, 2007*

Places & Spaces: Mapping Science *exhibit at MCPL in Bloomington, IN, 2007*

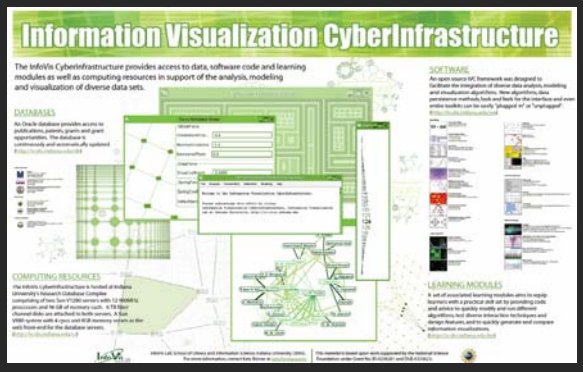
Places & Spaces: Mapping Science *exhibit at MCPL in Bloomington, IN, 2007*

Re-implementation of Illuminated Diagram Software (in progress)
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.



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

CIShell

SDB | SCHOLARLY DATABASE

NetworkWorkbench
A Workbench for Network Scientists

HPNAP
High Performance Network Applications Program

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-Laszlo Barabasi, Santiago Schnell, Alessandro Vespignani & Stanley Wasserman, Eric Wernert (Senior Personnel), $1,120,926) Sept. 05 - Aug. 08. https://nwb.slis.indiana.edu

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References

- Bruce Herr, Weixia Huang, Shashikant Penumarthy, Katy Börner. Designing Highly Flexible and Usable Cyberinfrastructures for Convergence. Submitted to William S. Bainbridge (Ed.) Progress in Convergence. Annals of the New York Academy of Sciences.
- Börner, Katy. Mapping All of Science: How to Collect, Organize and Make Sense of Mankind's Scholarly Knowledge and Expertise. Accepted for *Environment and Planning B*, Special Issue on *Mapping Humanity's Knowledge and Expertise in the Digital Domain*.
- 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.
- Holloway, Todd, Božicevic, Miran and Börner, Katy. Analyzing and Visualizing the Semantic Coverage of Wikipedia and Its Authors. Accepted for *Complexity*. Also available as cs.IR/0512085.
- Katy Börner. (2006) Semantic Association Networks: Using Semantic Web Technology to Improve Scholarly Knowledge and Expertise Management. In Vladimir Geroimenko & Chaomei Chen (eds.) *Visualizing the Semantic Web*, Springer Verlag, 2nd Edition, chapter 11, pp. 183-198.
- Boyack, Kevin W., Klavans, R. and Börner, Katy. (2005). Mapping the Backbone of Science. *Scientometrics,* 64(3), 351-374.
- Hook, Peter A. and Börner, Katy. (2005) Educational Knowledge Domain Visualizations: Tools to Navigate, Understand, and Internalize the Structure of Scholarly Knowledge and Expertise. In Amanda Spink and Charles Cole (eds.) *New Directions in Cognitive Information Retrieval*. Springer-Verlag, Netherlands, chapter 5, pp. 187-208.
- Börner, Katy, Dall'Asta, Luca, Ke, Weimao and Vespignani, Alessandro. (April 2005) Studying the Emerging Global Brain: Analyzing and Visualizing the Impact of Co-Authorship Teams. *Complexity*, special issue on *Understanding Complex Systems*, 10(4): pp. 58 - 67. Also available as cond-mat/0502147.
- Ord, Terry J., Martins, Emília P., Thakur, Sidharth, Mane, Ketan K., and Börner, Katy. (2005) Trends in animal behaviour research (1968-2002): Ethoinformatics and mining library databases. *Animal Behaviour*, 69, 1399-1413. Supplementary Material.
- Mane, Ketan K. and Börner, Katy. (2004). Mapping Topics and Topic Bursts in PNAS. *Proceedings of the National Academy of Sciences of the United States of America*, 101(Suppl. 1):5287-5290. Also available as cond-mat/0402380.
- Börner, Katy, Maru, Jeegar and Goldstone, Robert. (2004). The Simultaneous Evolution of Author and Paper Networks. *Proceedings of the National Academy of Sciences of the United States of America*, 101(Suppl_1):5266-5273. Also available as cond-mat/0311459.

Acknowledgements

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