

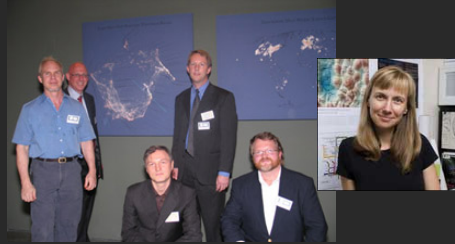
Mapping, Illuminating, and Interacting with Science (sap_0116)

Kevin W. Boyack
Sandia National Laboratories

Richard Klavans
SciTech Strategies, Inc.

W. Bradford Paley
Digital Image Design Incorporated

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



SIGGRAPH2007

Siggraph, San Diego, August 7th, 2007

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/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.



Illuminated Diagram Display

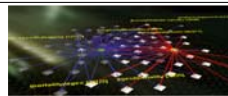
Combines the incredibly high data density of two large prints: a map of the world and a map of science with the flexibility of an interactive program driving a touch panel display and two projectors that illuminate the maps.

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(SuppL1).
- 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.	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) ind. 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
BROADENING By citation By terms					

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.

places & spaces &

Places & Spaces: Mapping Science
An exhibition created to demonstrate the power of maps to understand, navigate, and manage not only physical places, but also abstract information spaces.

Home Browse Maps Compare & Contrast Maps Schedule Connect

Home

Exhibit Purpose and Goals

The Places & Spaces: Mapping Science 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.

Check out the **schedule of physical showings** and 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.

"Places & Spaces: Mapping Science" on display at the New York Hall of Science, Dec. 9, 2006 - Feb. 25, 2007.

Places & Spaces at the **NYPL Science, Industry, and Business Library** (Madison/34th), New York, April 3rd - August 31st, 2006.

ORDER DVD HERE!

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

places & spaces &

Places & Spaces: Mapping Science
An exhibition created to demonstrate the power of maps to understand, navigate, and manage not only physical places, but also abstract information spaces.

Home Browse Maps Compare & Contrast Maps Schedule Connect

Home

Exhibit Purpose and Goals

The Places & Spaces: Mapping Science 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.

Check out the **schedule of physical showings** and 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.

"Places & Spaces: Mapping Science" on display at the New York Hall of Science, Dec. 9, 2006 - Feb. 25, 2007.

Places & Spaces at the **NYPL Science, Industry, and Business Library** (Madison/34th), New York, April 3rd - August 31st, 2006.

ORDER DVD HERE!

Places & Spaces: Mapping Science
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.

Infographic
It was the way the property market map was displayed that drew the most attention. It was a map of the UK with a red line showing the price index. The map was interactive, allowing visitors to click on different regions to see their performance. The map was also a great example of data visualization, showing the relationship between the property market and the economy.

Interactive
The interactive map of the UK was a great example of data visualization. It allowed visitors to explore the property market in different regions and see how it related to the overall economy. The map was also a great example of user experience design, making it easy for visitors to interact with the data.

NEWS FOR NERDS. STUFF THAT MATTERS.

[Login](#) | [Create Account](#) | [Subscribe](#)

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 by **Gene Munk**

A MAP OF SCIENCE
This is a map of relationships among scientific papers published in 2006. The map is a complex network of nodes and edges, where nodes represent individual papers and edges represent citations or relationships between them. The map is visually striking, with a central cluster of papers and many smaller clusters branching out.

How Scientific Paradigms Relate
This map shows the relationships between different scientific paradigms. It is a network map where nodes represent different paradigms and edges represent how they relate to each other. The map shows a complex web of connections, with some paradigms being more central than others.

SEED

SCIENTIFIC METHOD: FROM TRUTH TO SCIENCE

By **John Horgan** • First March 7, 2007 12:14 PM

To see the full map of relationships among scientific papers, click on the link below. Also: The map is a large (3.7 MB) file.

This map was constructed by coding roughly 500,000 published papers into 776 different scientific paradigms (shown as grey circles). Nodes based on lower citation counts were cited together by authors of other papers. Links (green/black lines) were made between the paradigms that shared papers. Nodes that are not published links, including nodes.

<http://1.scimaps.org>

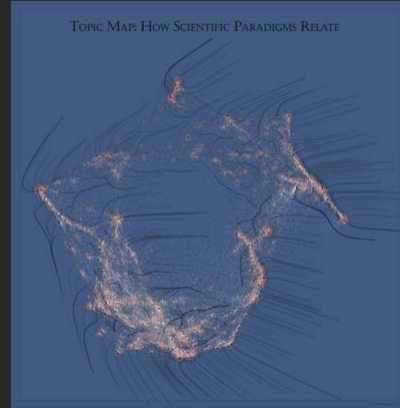
SECURING A PEACEFUL AND FREE WORLD THROUGH SCIENCE

Mapping SCIENCE

(The new paradigm)

Map of Scientific Paradigms(2nd Iteration)

by Kevin W. Boyack and Richard Klavans

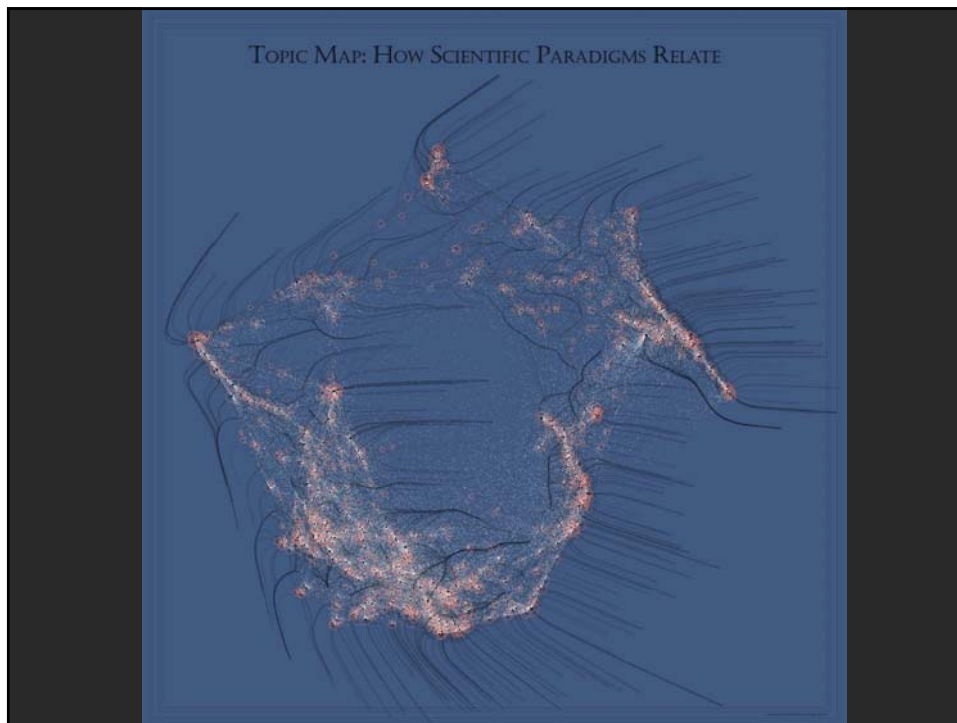


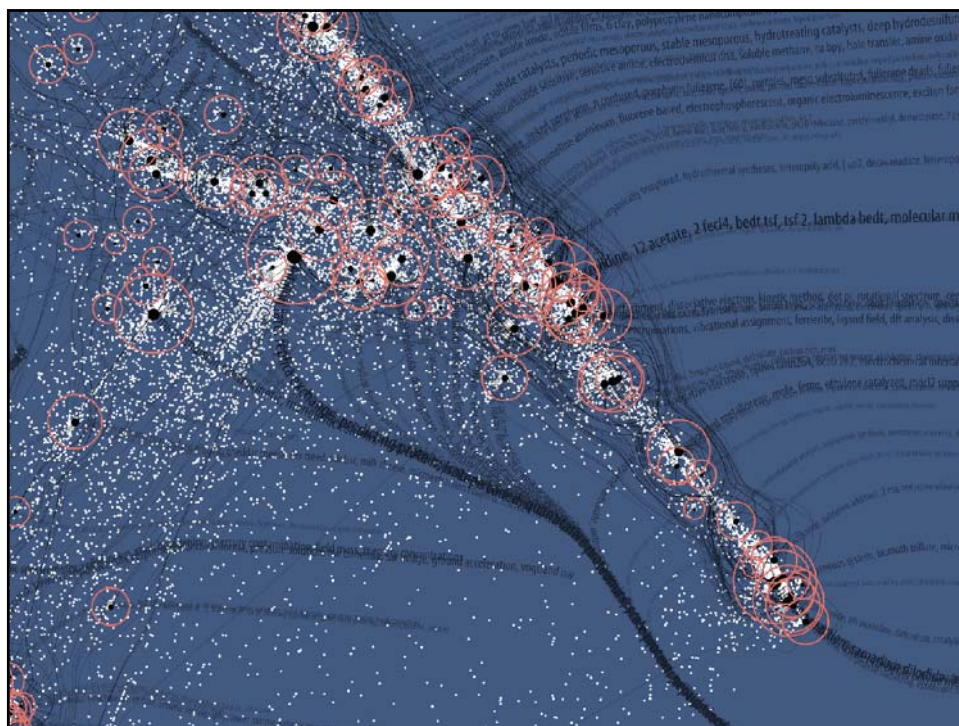
Redesign by W. Bradford Paley

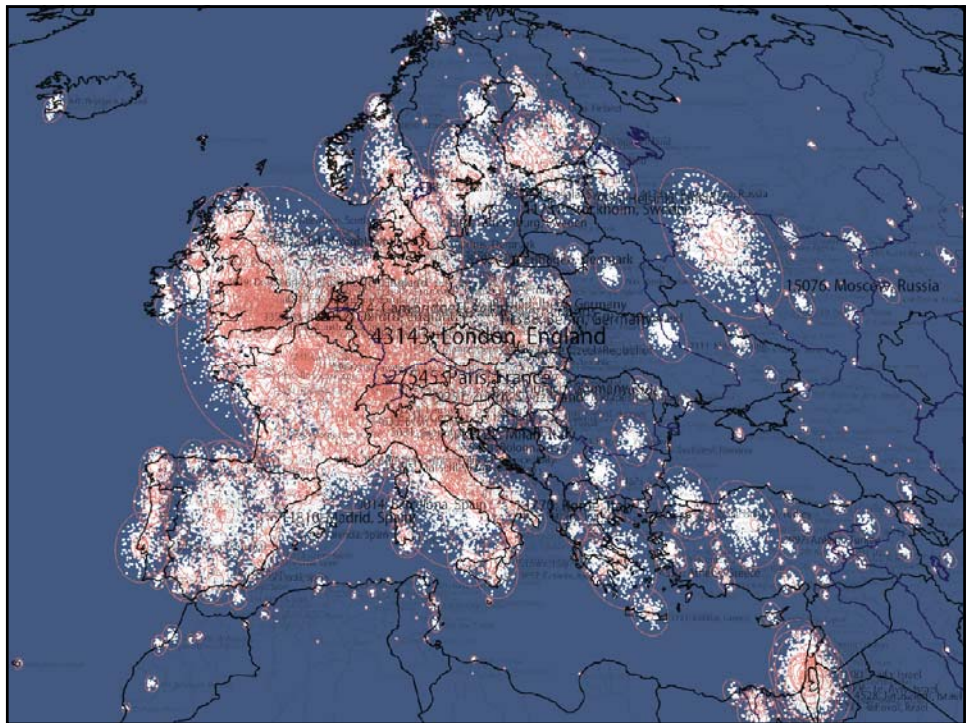
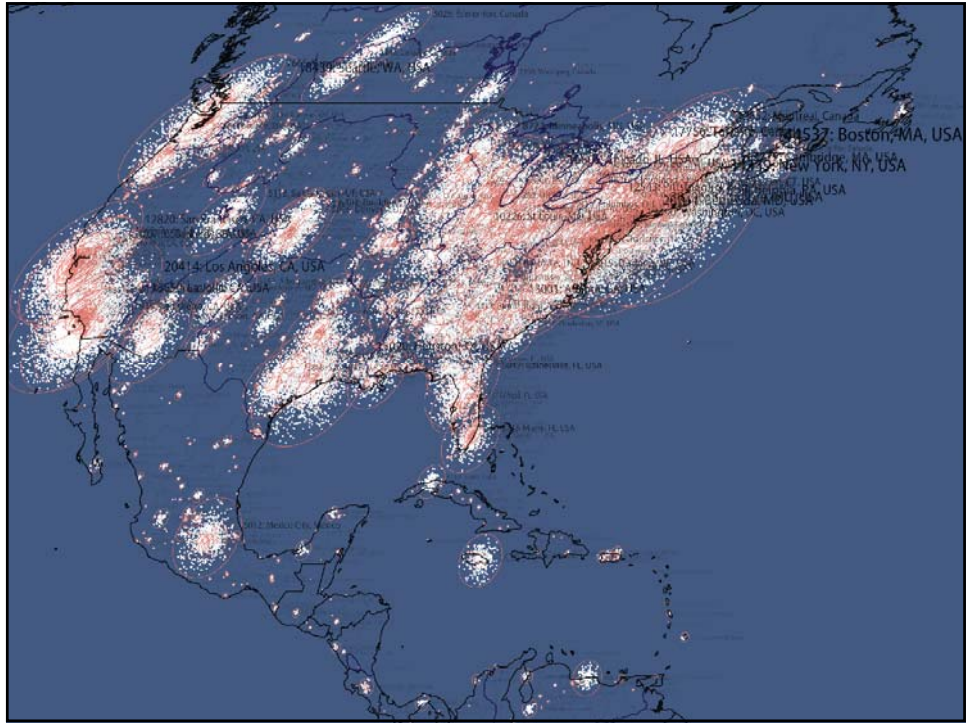
800,000 published papers were grouped into 776 different scientific paradigms (shown as colored circular nodes) based on how often the papers were cited together by authors of other papers.

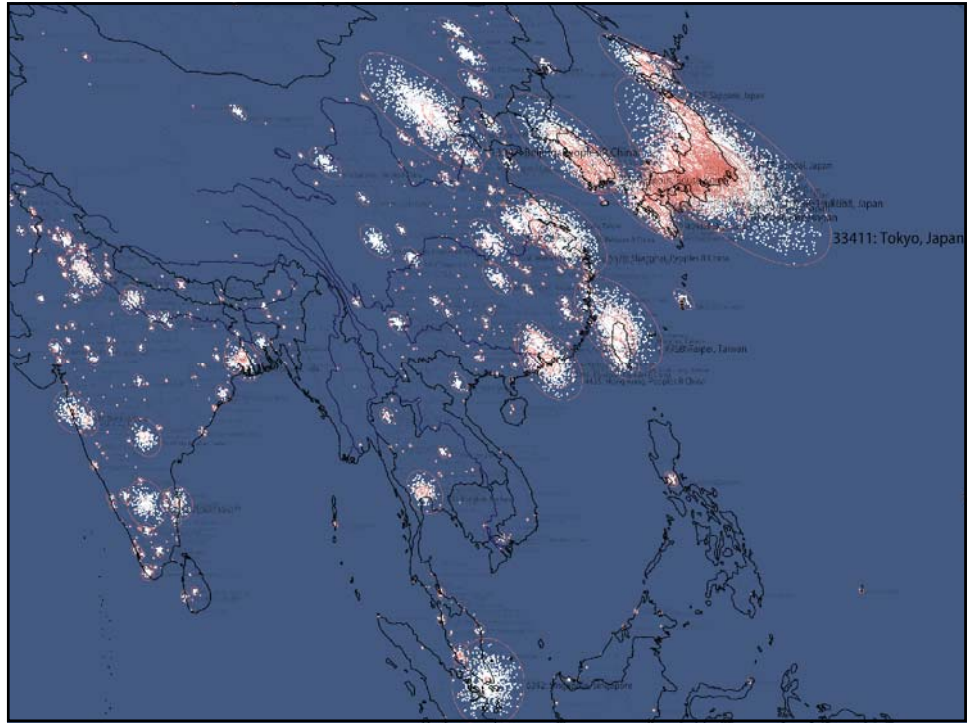
Links (curved black lines) were made between the paradigms that shared papers, then treated as rubber bands, holding paradigms with strong links nearer one another while a general repulsive force was applied; thus the layout derives directly from the data.

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.









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

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

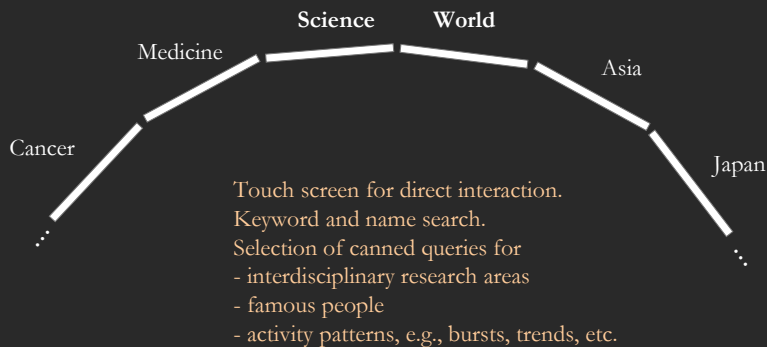


Places & Spaces: Mapping Science exhibit at MCPL in Bloomington, IN, 2007

Re-implementation of Illuminated Diagram Software (in progress)

by Advanced Visualization Lab, Indiana University

Drives unlimited number of ID screens.



Information Visualization CyberInfrastructure

The InfoVis 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, papers, grants and grant opportunities. The database is continuously and automatically updated.

COMPUTING RESOURCES
The InfoVis CyberInfrastructure is hosted at Indiana University's Research Database Complex, consisting of three Sun E10K servers with 12 TB of storage and 16 GB of memory each. A 10 Gbps network card is connected to each server. A Sun X86 server acts as a proxy and FTP server between users and the database server.

SOFTWARE
An open source R2 framework was designed to facilitate the integration of diverse data analysis, modeling and visualization algorithms. The algorithms are implemented in Java and Python. The framework provides a set of tools for the analysis and visualization of diverse data sets.



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. 08. <http://lwwb.slis.indiana.edu>

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](https://arxiv.org/abs/cs/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](https://arxiv.org/abs/cond-mat/0502147).
- Ord, Terry J., Martins, Emilia 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](https://arxiv.org/abs/cond-mat/0402380).
- Börner, Katy, Maru, Jeeagar 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](https://arxiv.org/abs/cond-mat/0311459).

Acknowledgements

We thank John Burgoon for geographic mapmaking and Peter Kennard for system design and programming for the illuminated diagram display. The Advances Visualization Lab at Indiana University designed the screen based ID setup.

The data used to generate the science maps is from Thomson Scientific.

Places & Spaces is supported by SLIS, CI4NetSci Center, UITIS, all three at Indiana University and National Science Foundation awards IIS-0238261 and CHE-0524661.

