

Cybertools that Support the Study of Science

Dr. Katy Börner

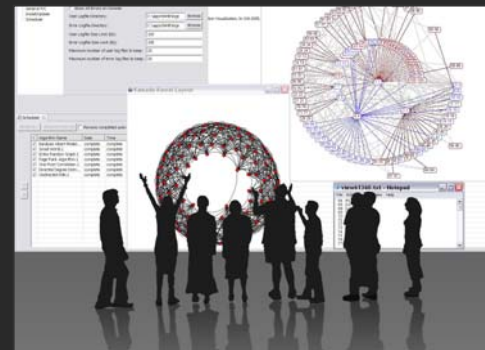
Cyberinfrastructure for Network Science Center, Director
 Information Visualization Laboratory, Director
 School of Library and Information Science
 Indiana University, Bloomington, IN

katy@indiana.edu

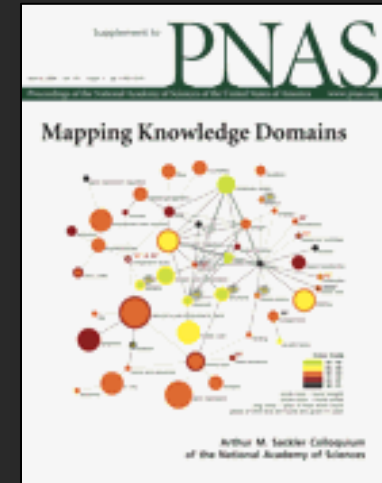
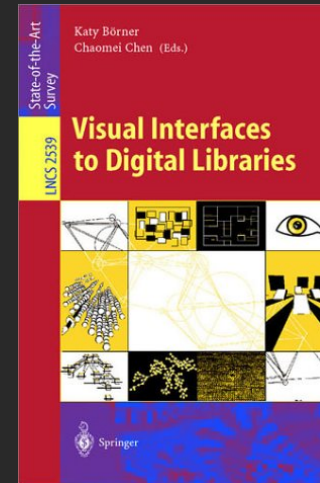
*Institute of Computing Technology, Chinese Academy of Sciences, Beijing, China
 March 27th, 2008*



DATA EXTRACTION	UNIT OF ANALYSIS	MEASURES	LAYOUT (often one code does both semantics and animation steps)		DISPLAY
			SEMANTICS	SYNTAX/VIEW	
SEARCHES	DOMAIN	COUNTS/FREQUENCIES	SCALAR (and by unit/math)	DIMENSIONALITY REDUCTION	INTERACTION
ID	CHOICES	Attributes (e.g. terms)	Directed relation	Eigenvector/Eigenvalue solutions	Browser
INPEC	Journal	Author clusters	Co-clustering	Factor Analysis (FA) and	Plot
Key Words	Document	Co-occurrences	Combined linkage	Principal Component Analysis (PCA)	Zoom
Malware	Author	By year	Co-word / co-term	Multi-dimensional scaling (MDS)	Filter
Researcher/idea	Term		Co-identification	LDA	Query
etc.	THRESHOLDS	By counts	VECTOR (and by attribute/math)	High-order networks (PFM)	Detail-on-demand
			Vector space model (word/terms)	Self-organizing maps (SOM)	Detail-on-demand
BROADENING	By relation		Latent Semantic Analysis (LSA)	Self-organizing maps (SOM)	ANALYSIS
By terms			and Singular Value Decomposition (SVD)	Cluster analysis	
			CORRELATION (if desired)	SCALAR	
			Person's R _i or any of above	Fractalization	
				Force-directed placement (FDP)	



Computational Scientometrics: Studying Science by Scientific Means

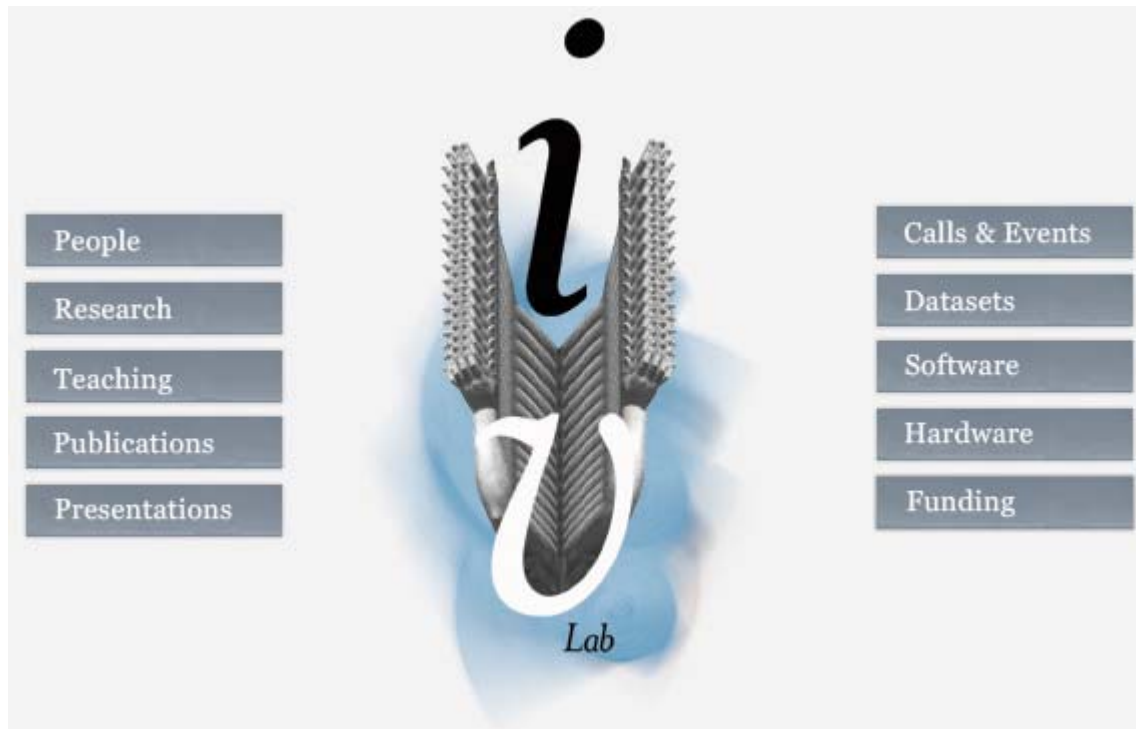


- Börner, Katy, Chen, Chaomei, and Boyack, Kevin. (2003). **Visualizing Knowledge Domains**. In Blaise Cronin (Ed.), *Annual Review of Information Science & Technology*, Medford, NJ: Information Today, Inc./ American Society for Information Science and Technology, Volume 37, Chapter 5, pp. 179-255. <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*, 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>
- **Places & Spaces: Mapping Science** exhibit, see also <http://scimaps.org>.

Data Acquisition for Comprehensive Analysis

Lab/Center Management System vs. **Spacebook and MS Famulus**

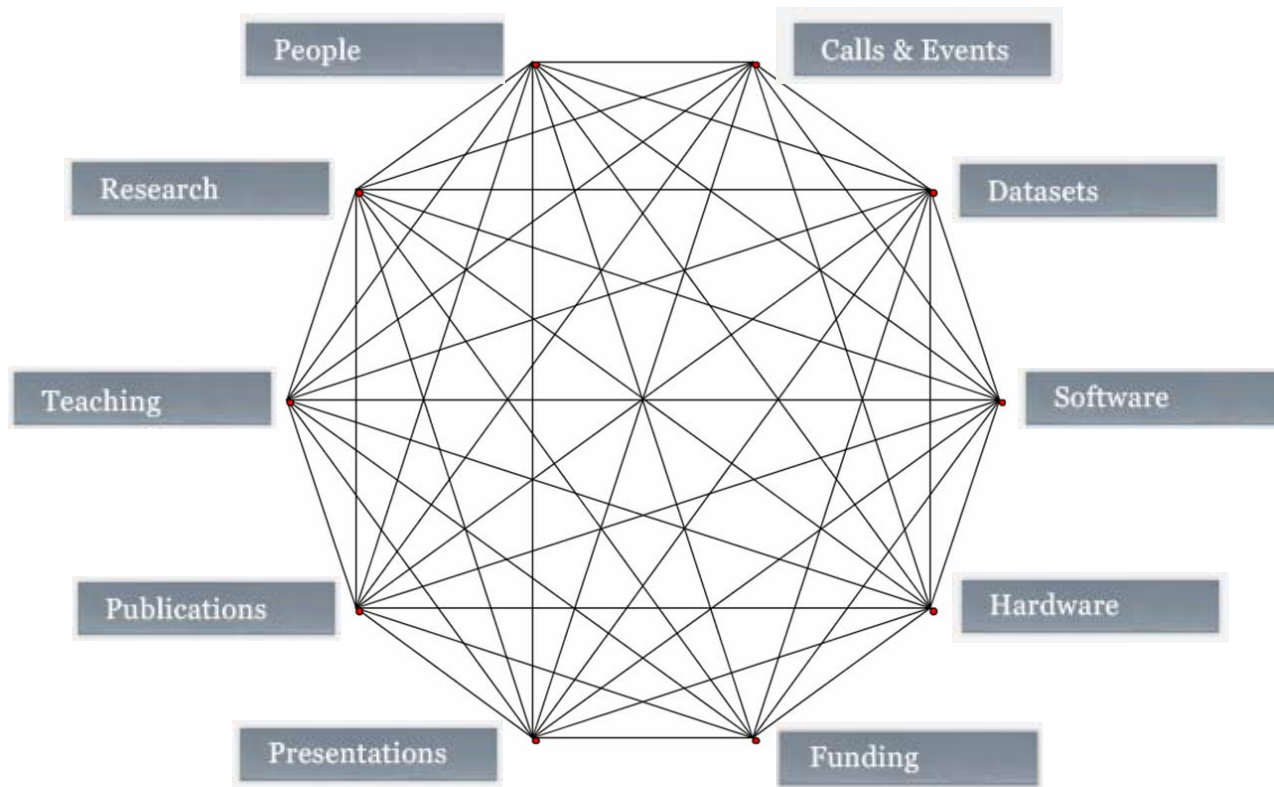
Designed to track, manage, and make use of data relevant for the daily operation of a medium size research team.



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

Data Entities and Interlinkages

Designed for team leads, members, IT admins but also for external scholars and funding agencies.

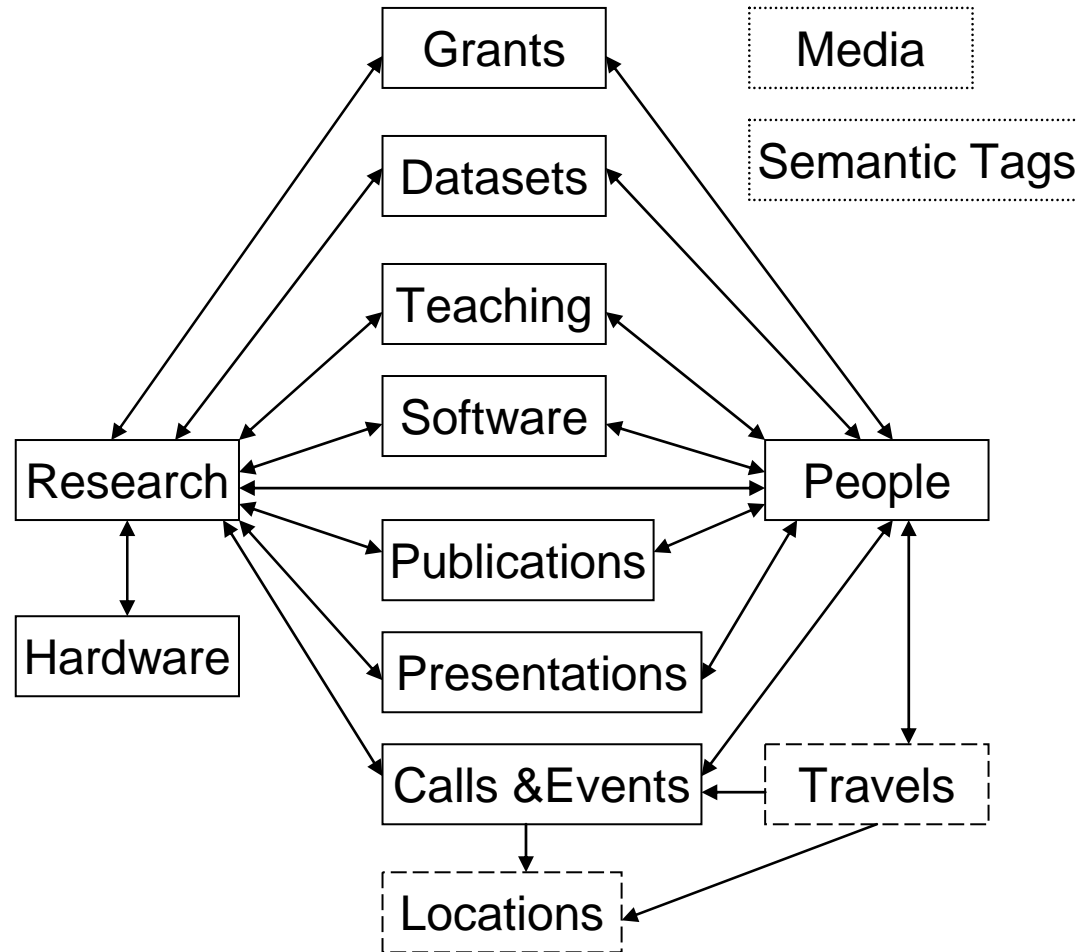


Not covered:

- Queries
- Workflows
- Protocols

- Comments
- Bookmarks
- Ratings

Simplified representation of the IVL database schema



Data Entry

Tutorials - [Back](#)

Title

Link

People

- Aigner, Wolfgang
- Aliman, Ian
- Althoff, K.D.
- Ambre, Sumeet
- Anderson, Christina
- Andersson, Per-Olov
- Andrienko, Gennady
- Ansari, Summaya

Start Date

End Date

Location

Venue

Time (e.g., 1-2PM)

Lab member Dates	Start Date (mm-dd-yyyy)	End Date (mm-dd-yyyy)	
	<input type="text" value="01"/> <input type="text" value="01"/> <input type="text" value="1995"/>	<input type="text" value=""/> <input type="text" value=""/> <input type="text" value=""/>	<input type="button" value="+"/>
	<input type="text" value="4/1/2004"/>	<input type="text" value="Present"/>	<input type="button" value="-"/>

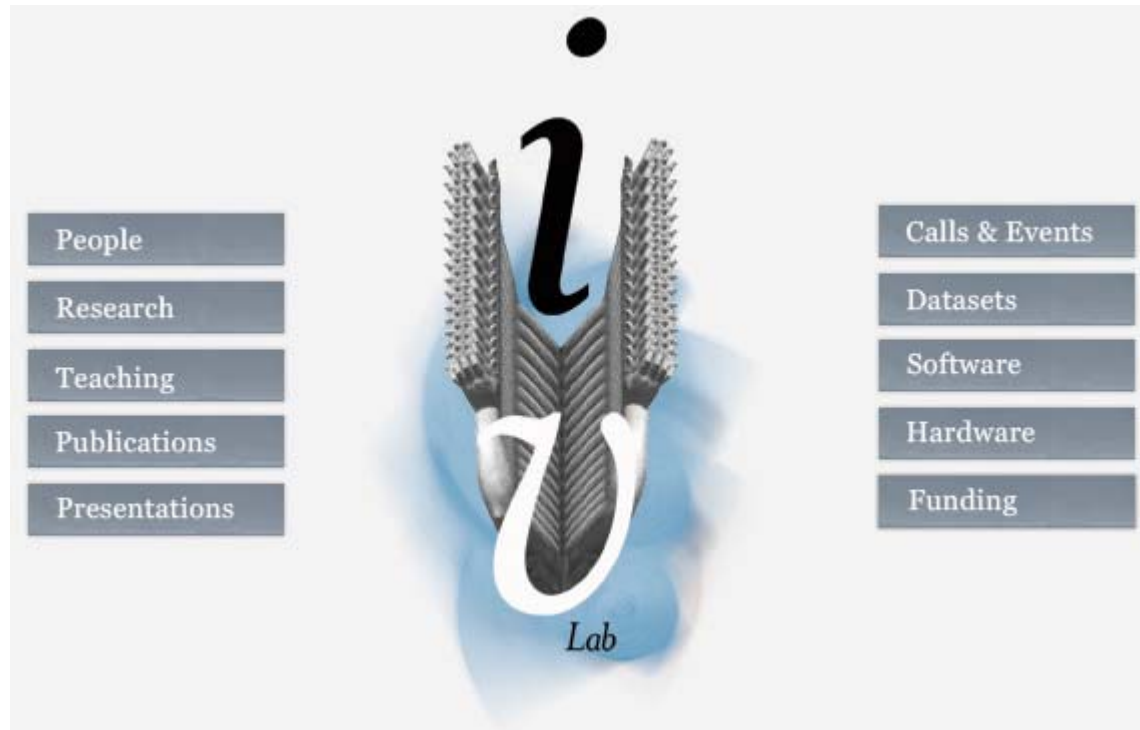
Image

Homepage

Work Log

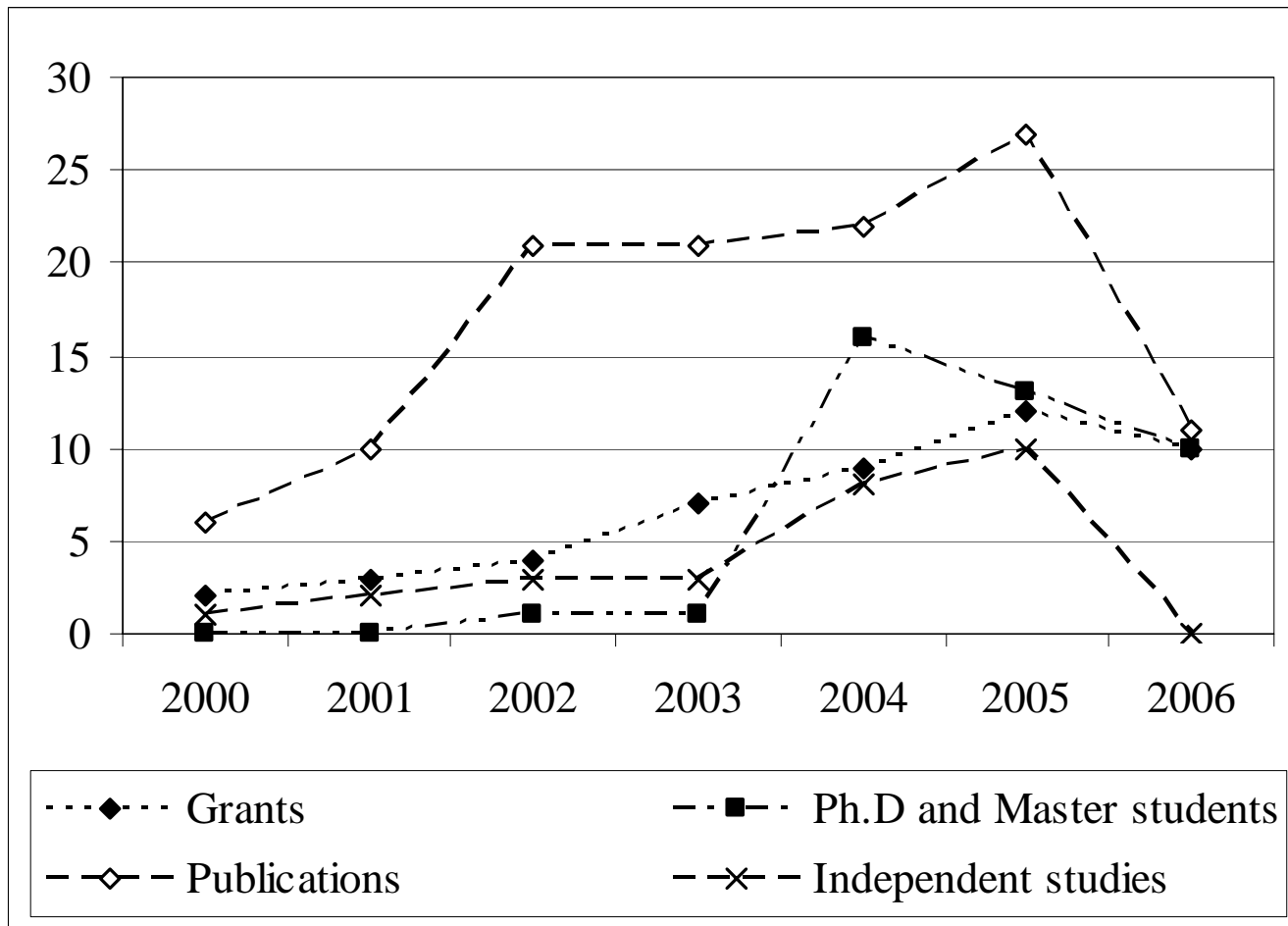


Demo

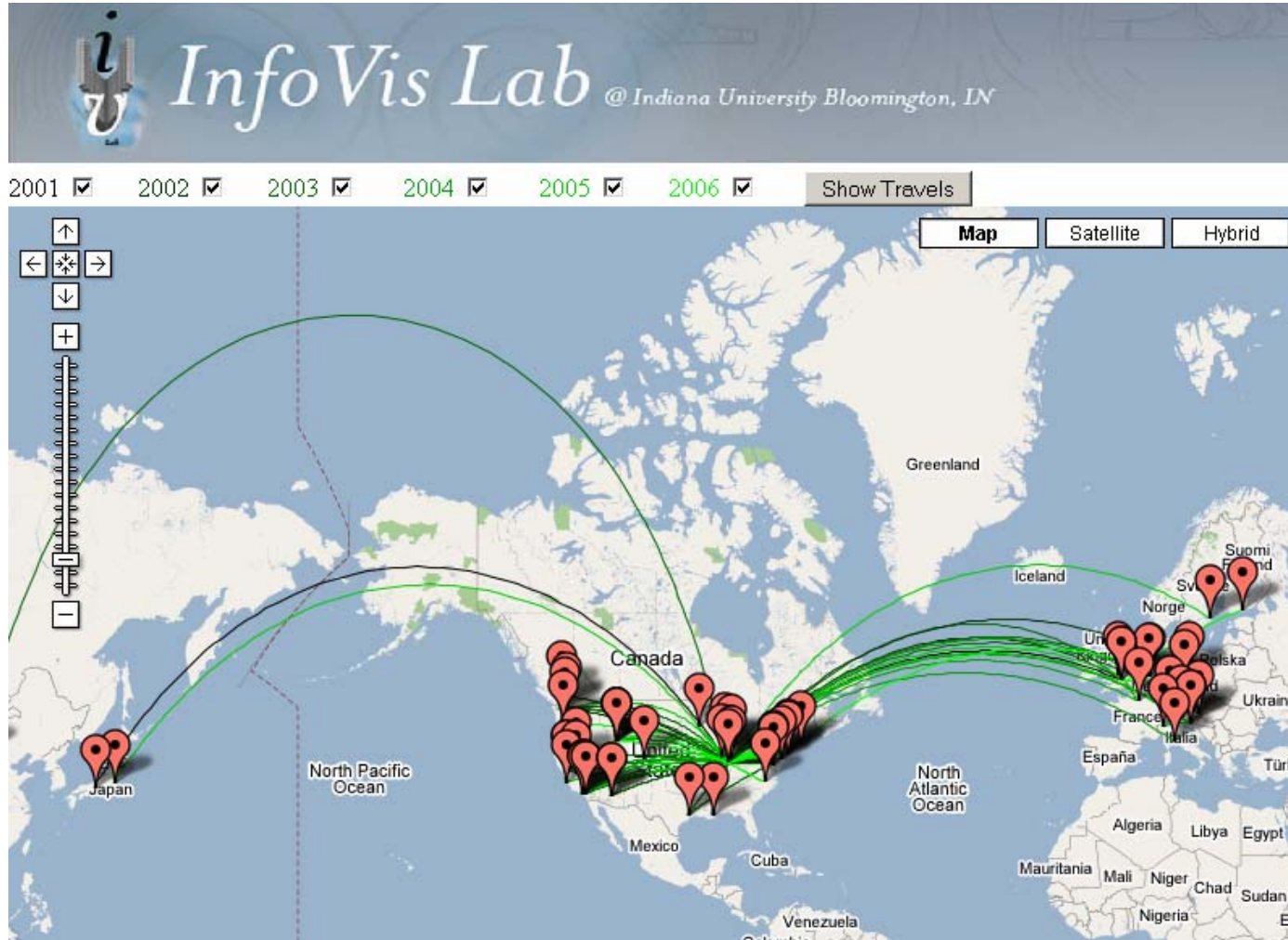


<http://ivl.slis.indiana.edu>

Time series analysis & visualization



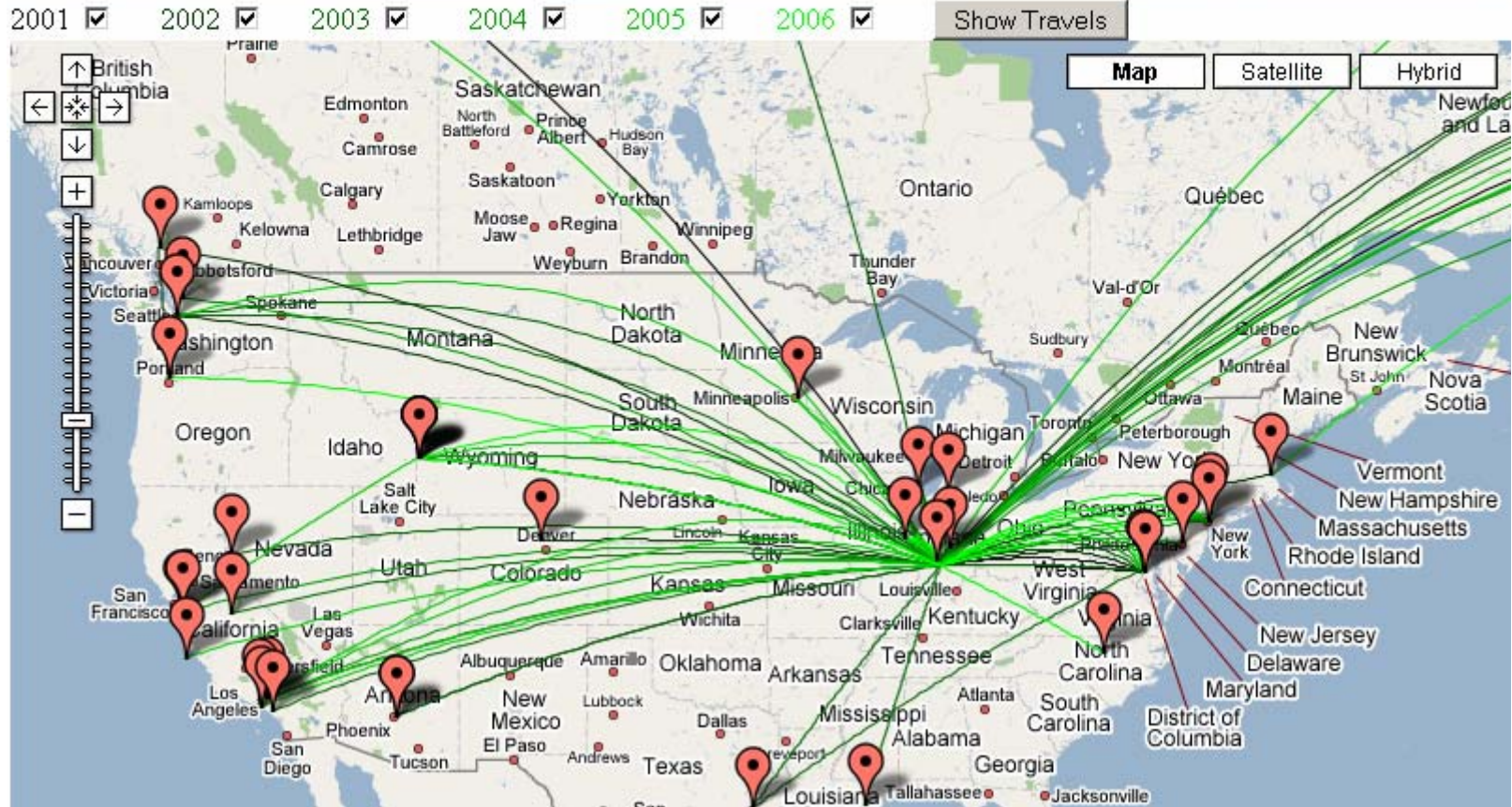
Katy's Travels in 2000-2006





InfoVis Lab @ Indiana University Bloomington, IN

Home	InfoVis Lab	InfoVis Lab
Research		
Education		
Publications		
Presentations		
Projects		
Software		
Staff		
Students		
Partners		
Privacy		
Contact		





InfoVis Lab @ Indiana University Bloomington, IN

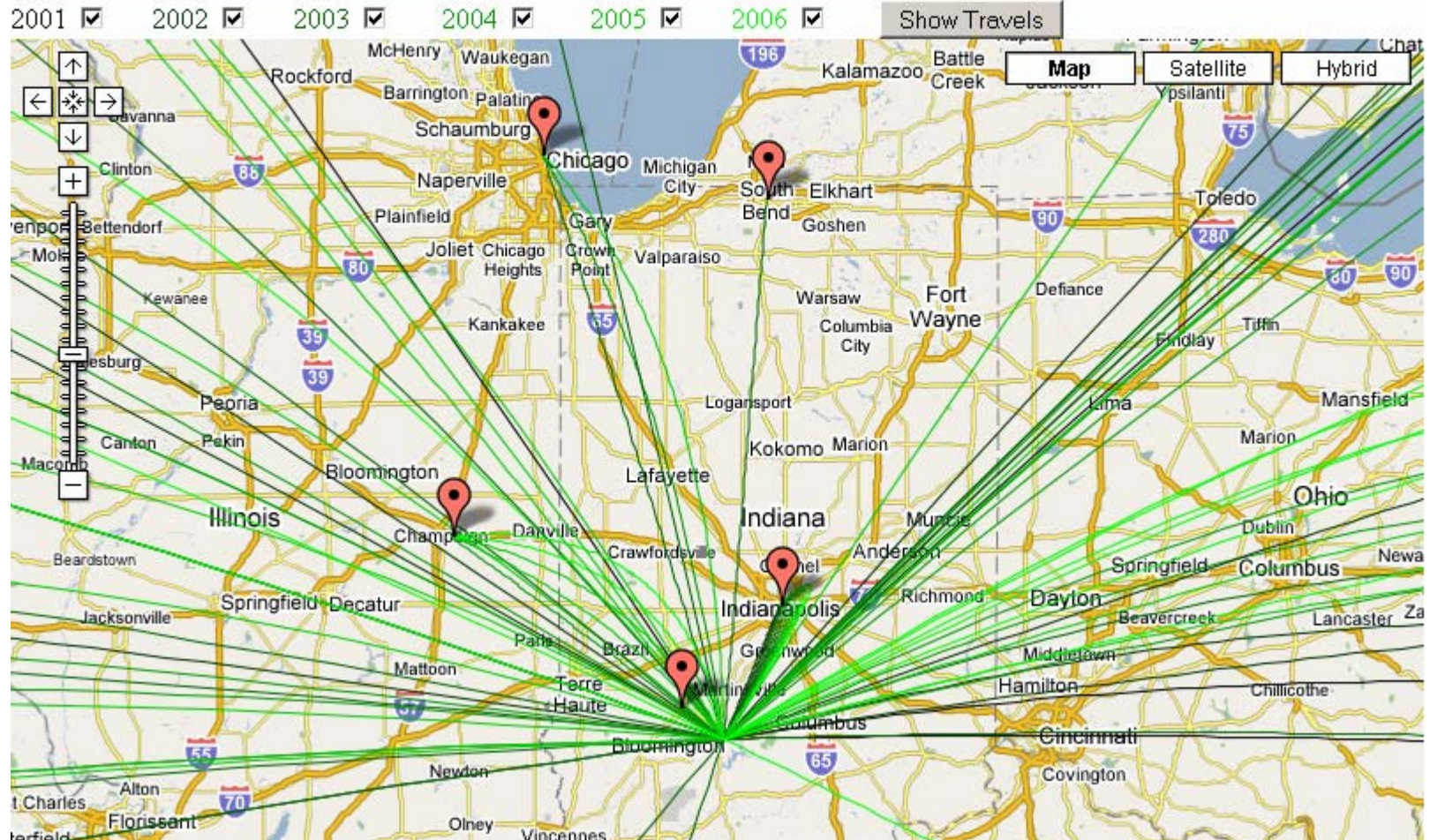
2001
 2002
 2003
 2004
 2005
 2006

Show Travels



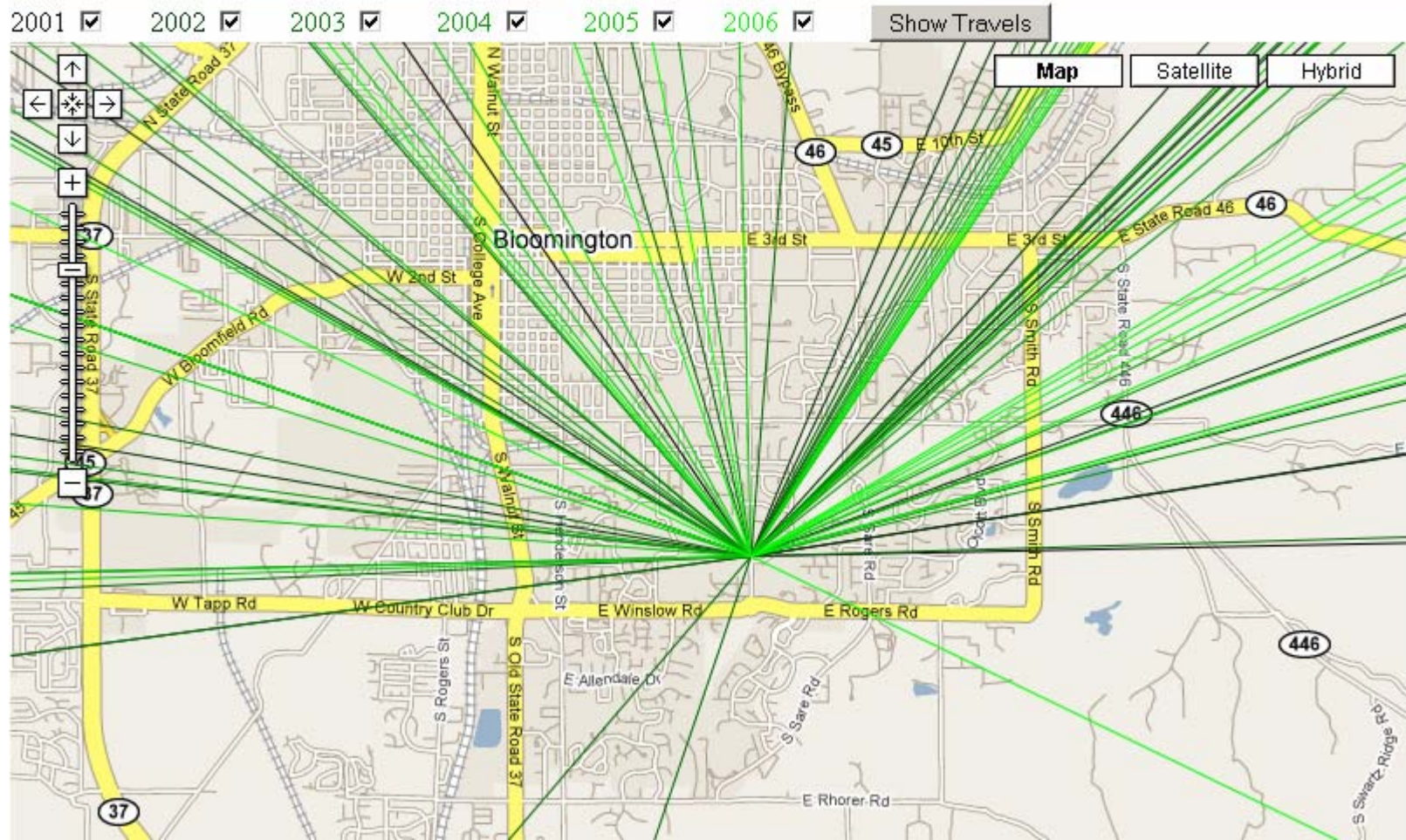


InfoVis Lab @ Indiana University Bloomington, IN

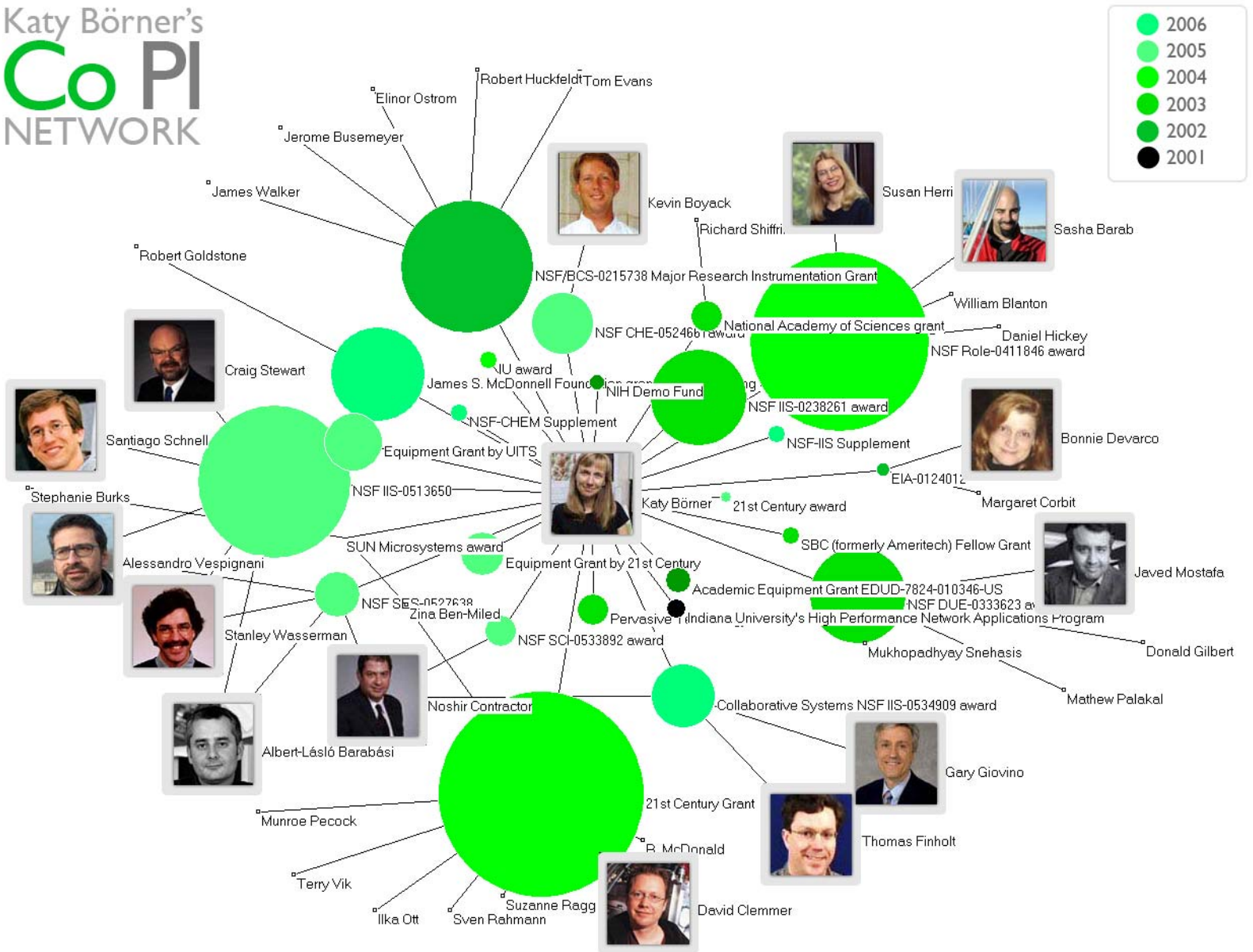




InfoVis Lab @ Indiana University Bloomington, IN

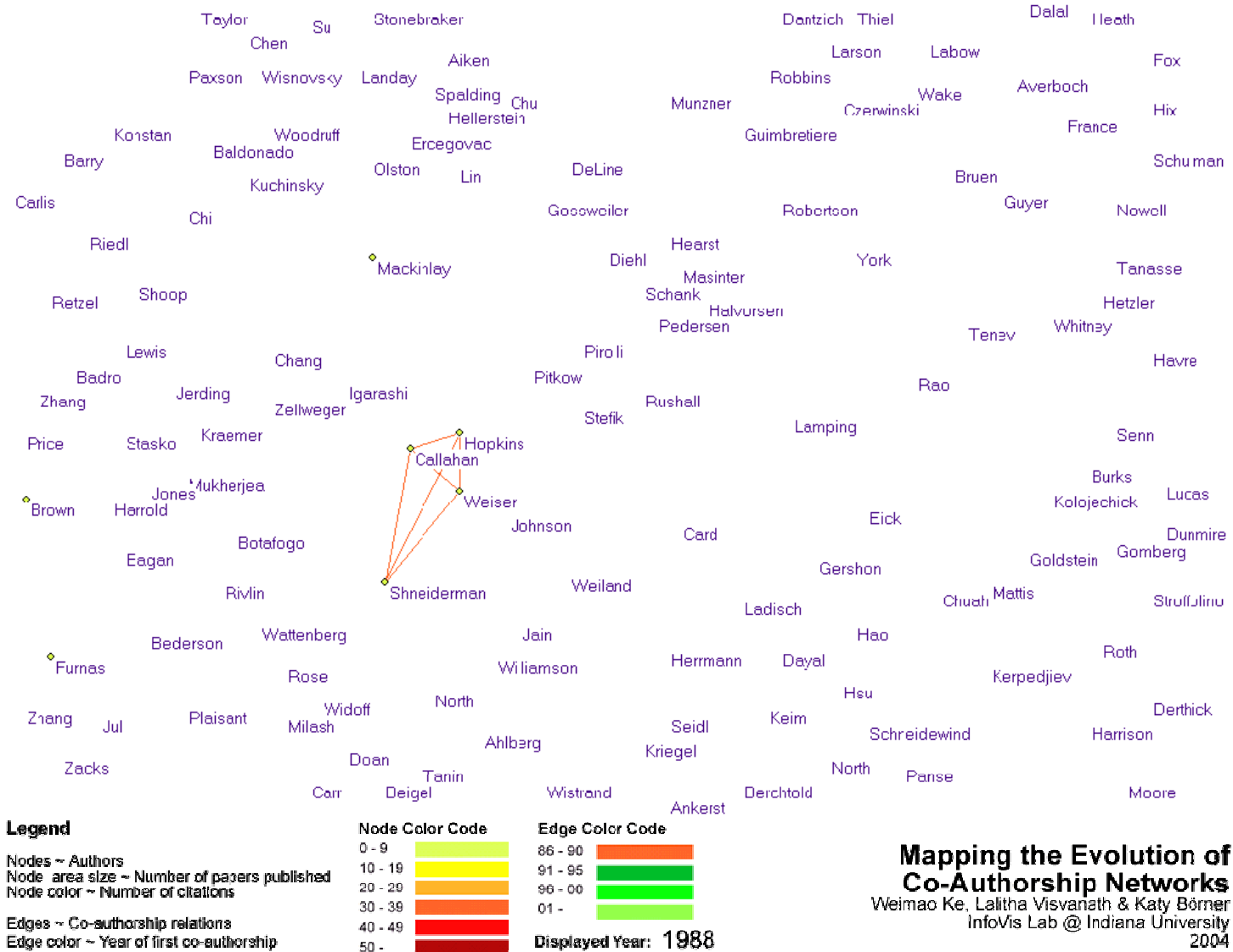


Katy Börner's Co PI NETWORK



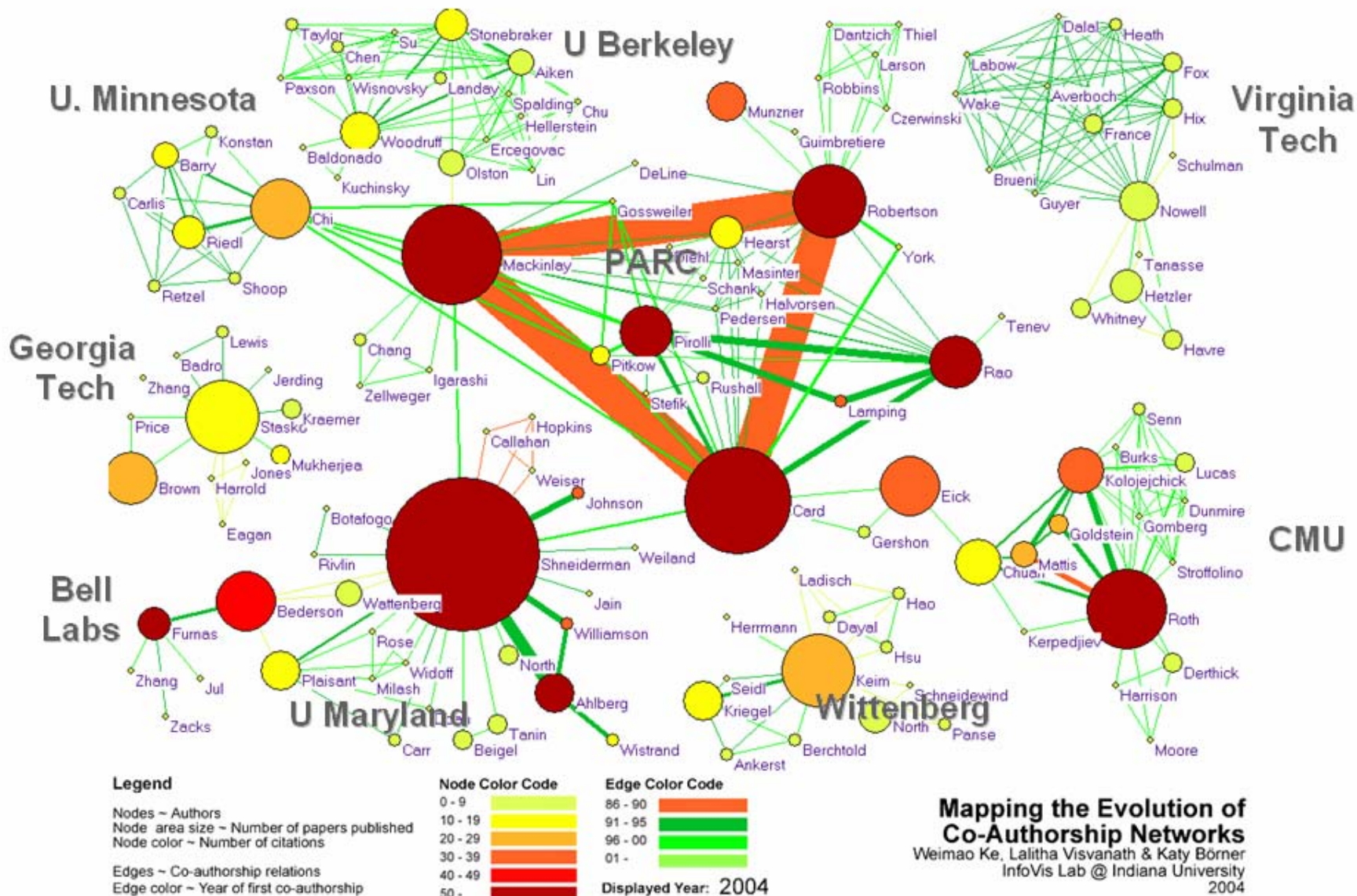
Mapping the Evolution of Co-Authorship Networks

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



Mapping the Evolution of Co-Authorship Networks

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



Information Visualization CyberInfrastructure

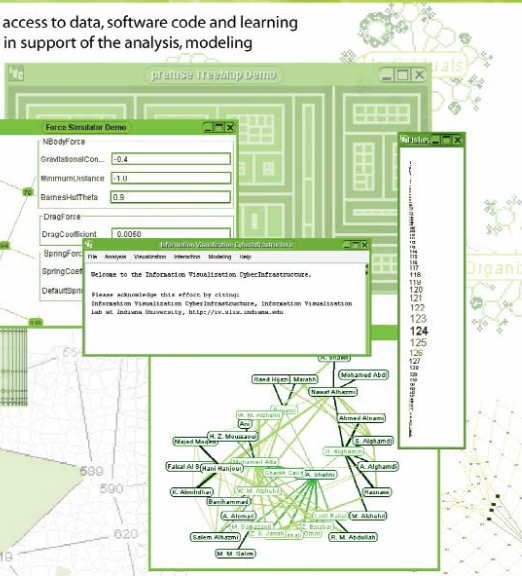
The InfoVis CyberInfrastructure provides access to data, software code and learning modules as well as computing resources in support of the analysis, modeling and visualization of diverse data sets.

DATABASES

An Oracle database provides access to publications, patents, grants and grant opportunities. The database is continuously and automatically updated. (<http://iv.slis.indiana.edu/db>)

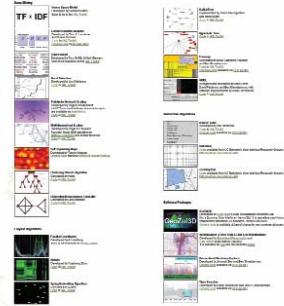
COMPUTING RESOURCES

The InfoVis CyberInfrastructure is hosted at Indiana University's Research Database Complex comprising of two Sun V1280 servers with 12 900MI lz processors and 96 GB of memory each. 6 TB fiber channel disks are attached to both servers. A Sun V880 system with 4 cpus and 8GB memory serves as the web front-end for the database servers. (<http://iv.slis.indiana.edu/cr>)



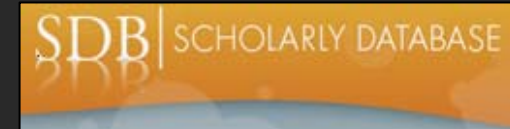
SOFTWARE

An open source IVC framework was designed to facilitate the integration of diverse data analysis, modeling and visualization algorithms. New algorithms, data persistence methods, look and feels for the interface and even entire toolkits can be easily "plugged in" or "unplugged". (<http://iv.slis.indiana.edu/sw>)



LEARNING MODULES

A set of associated learning modules aims to equip learners with a practical skill set by providing code and advice to quickly modify and run different algorithms, test diverse interaction techniques and design features, and to quickly generate and compare information visualizations. (<http://iv.slis.indiana.edu/lm>)



Scholarly Database

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

CAREER: Visualizing Knowledge Domains. NSF IIS-0238261 award

(Katy Börner, \$451,000) Sept. 03-Aug. 08.

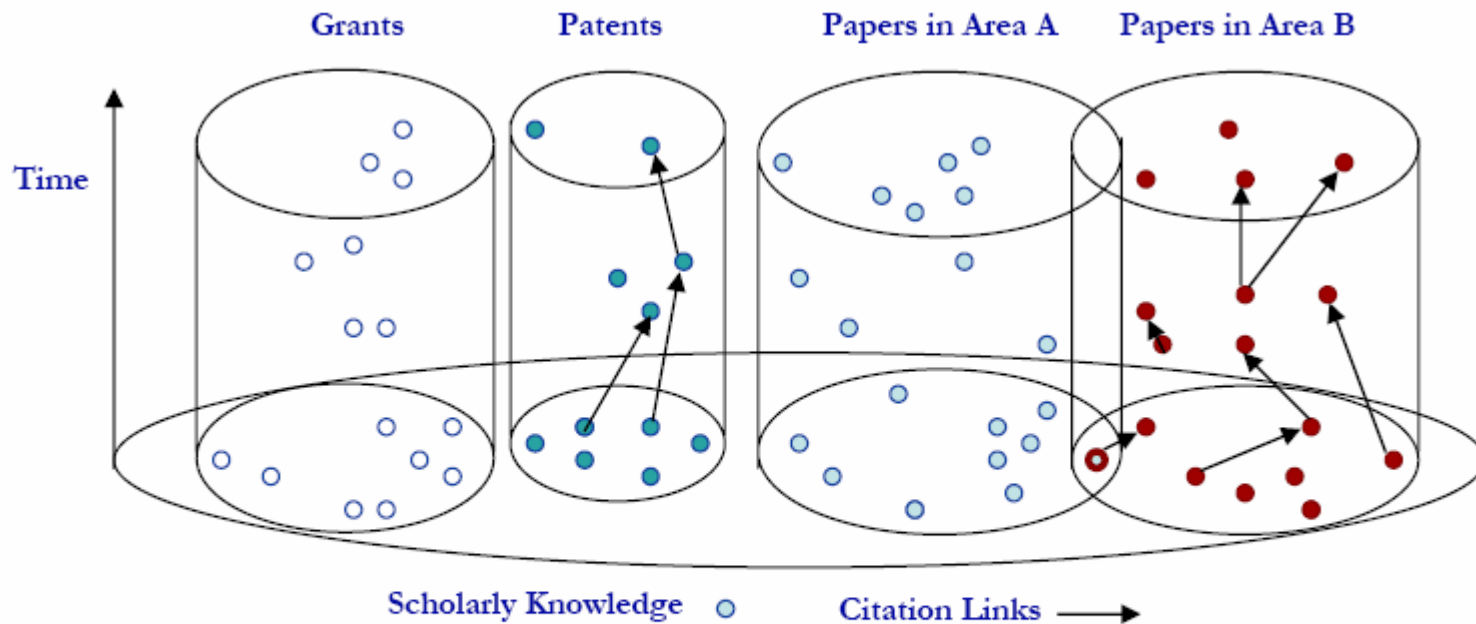
<http://iv.slis.indiana.edu/>



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



Challenges - Interlink \$ Input & Output Publication/Patent Citation Output



Need to interlink

- Grants and papers/patents.
- Grants/papers/patents and their PIs/authors/inventors, etc.

Use resulting networks to

- Count #papers, #citations, etc.
- Determine strength of co-PI/author/inventor relations, etc.

SCHOLARLY DATABASE

PAPERS



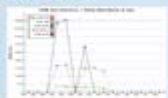
SDB MEDLINE



SDB PHYSREV



SDB PNAS



SDB JCR



PATENTS



SDB USPATENTS



SEARCH INTERFACE: <https://iv.slis.indiana.edu/db/>
 DOCUMENTATION: <http://iv.slis.indiana.edu/db/>

DB PROJECT LEAD

Gavin LaRowe
glarowe@indiana.edu

DB DEVELOPER

Sumeet Ambre
sambre@indiana.edu

PROJECT MANAGER

Katy Börner

STATUS

as of 06.08.28

Information Visualization Laboratory
 Cyberinfrastructure for Network Science Center
 School of Library and Information Science
 Indiana University
 Bloomington, IN 47405, USA

DOCUMENT TABLE



cyberinfrastructure for network science center

KNOWLEDGE WEBS



SDB WIKI

GRANT AWARDS



SDB NSF



SDB NIH



FUNDING OPPORTUNITIES



SDB COS





Scholarly Database: Web Interface

Search across publications, patents, grants.

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

SDB | SCHOLARLY DATABASE

Home Search Admin Logout

Select Database

COS NIH NSF USPAT MEDLINE PHYSREV

PNAS

Author(s) Last Name Middle Name First Name
james

Title: _____ e.g. Classifying DNA

Journal: _____ e.g. Journal of Biological Sciences

Publication Range

From 1995 to 2005 (default Year range is 1945-2005)

Submit · Reset

SDB | SCHOLARLY DATABASE

Home Search Admin Logout

NIH (336 Matching Records)

1. JAMES, ERIC (2001) GLUCOCORTICOID RECEPTOR-MEDIATED CATARACT.
DESCRIPTION (Applicant's Abstract) Cataracts are a serious risk to those undergoing steroid therapy, restricting the efficacy of these compounds. Steroid-induced cataracts are posterior subcapsular, frequently occlude the central visual axis and often ...

2. JAMES, GARTH (2001) THE USE OF BIOFILMS TO COUNTER BIOTERRORISM.
DESCRIPTION (Verbatim from Applicant's Abstract) The possibility that terrorists will contaminate public drinking water supplies with biological agents, such as bacteria, viruses, or toxins, becomes greater every day. Recent cases of intentional food c...

3. JAMES, JUDITH (2001) Fine specificity of scleroderma autoantibodies.
DESCRIPTION (provided by applicant) Systemic sclerosis (scleroderma) is a disfiguring, multi-system disease of unknown etiology, which is characterized by a broad spectrum of disease manifestations with varying organ involvement. Raynaud's phenomenon, ...

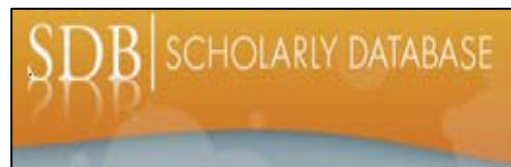
4. JAMES, LAURA (2001) NOVEL THERAPIES FOR ACETAMINOPHEN TOXICITY.
DESCRIPTION (adapted from the application) The long term goal of this award is to develop therapies, based on new mechanistic data, that can be utilized in the treatment of the acetaminophen (APAP) overdose patient. At therapeutic doses, APAP is metab...

5. JAMES, LAURA (2001) NOVEL THERAPIES FOR ACETAMINOPHEN TOXICITY.
DESCRIPTION (adapted from the application) The long term goal of this award is to develop therapies,

<< Prev 1 2 3 4 5 6 7 8 9 10 Next >>

New Search Refine Search Download Records

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

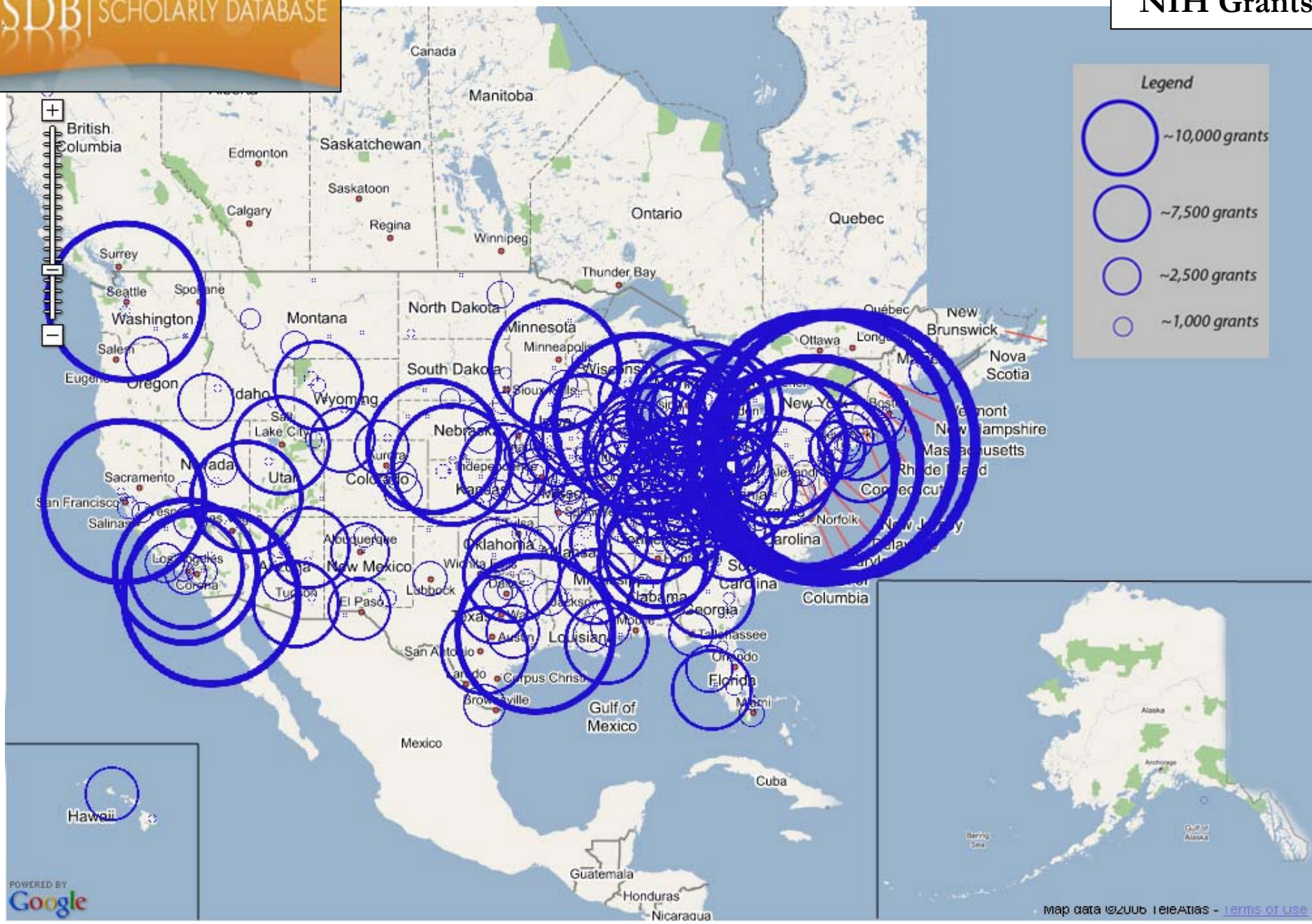


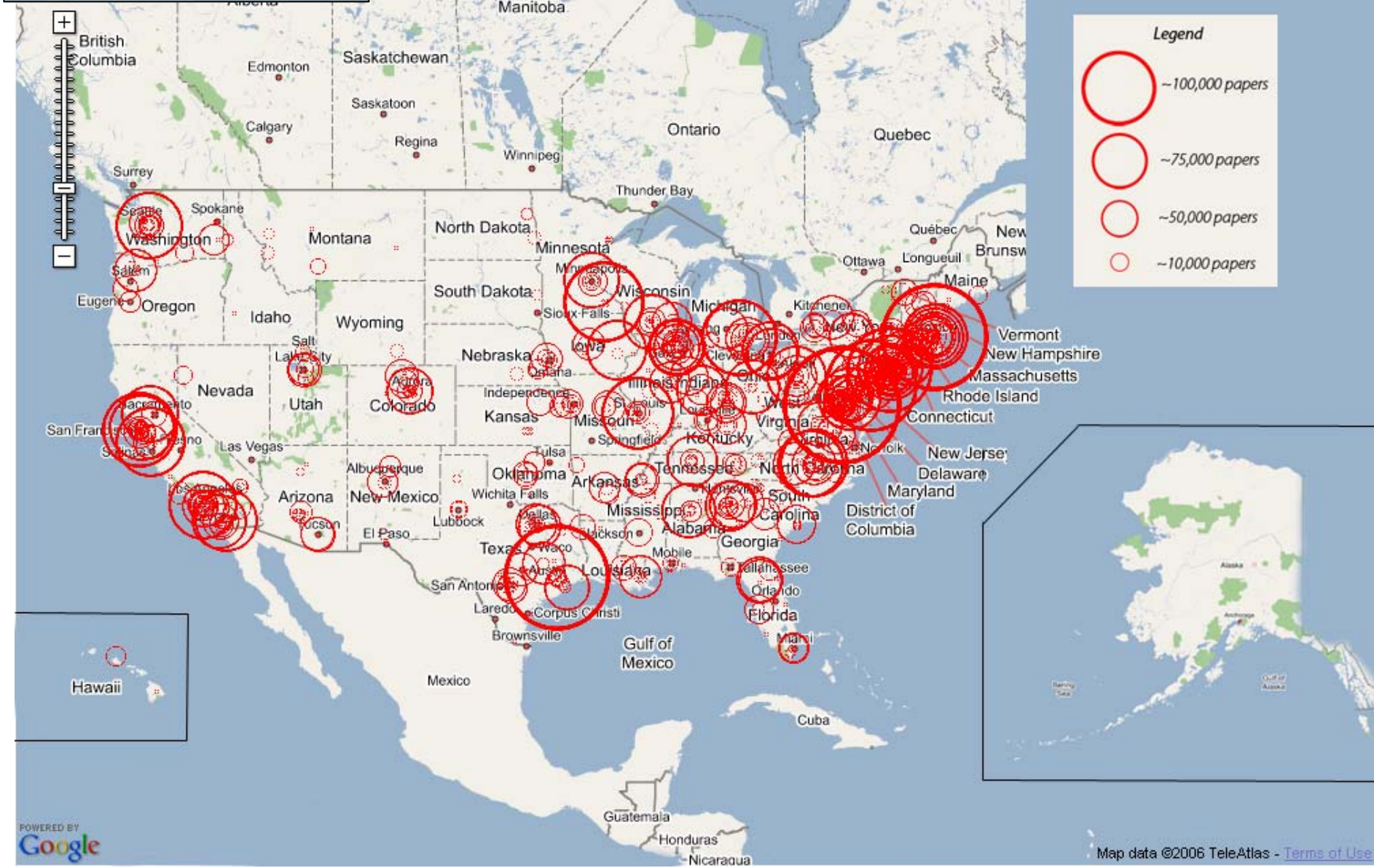
Scholarly Database: # Records & Years Covered

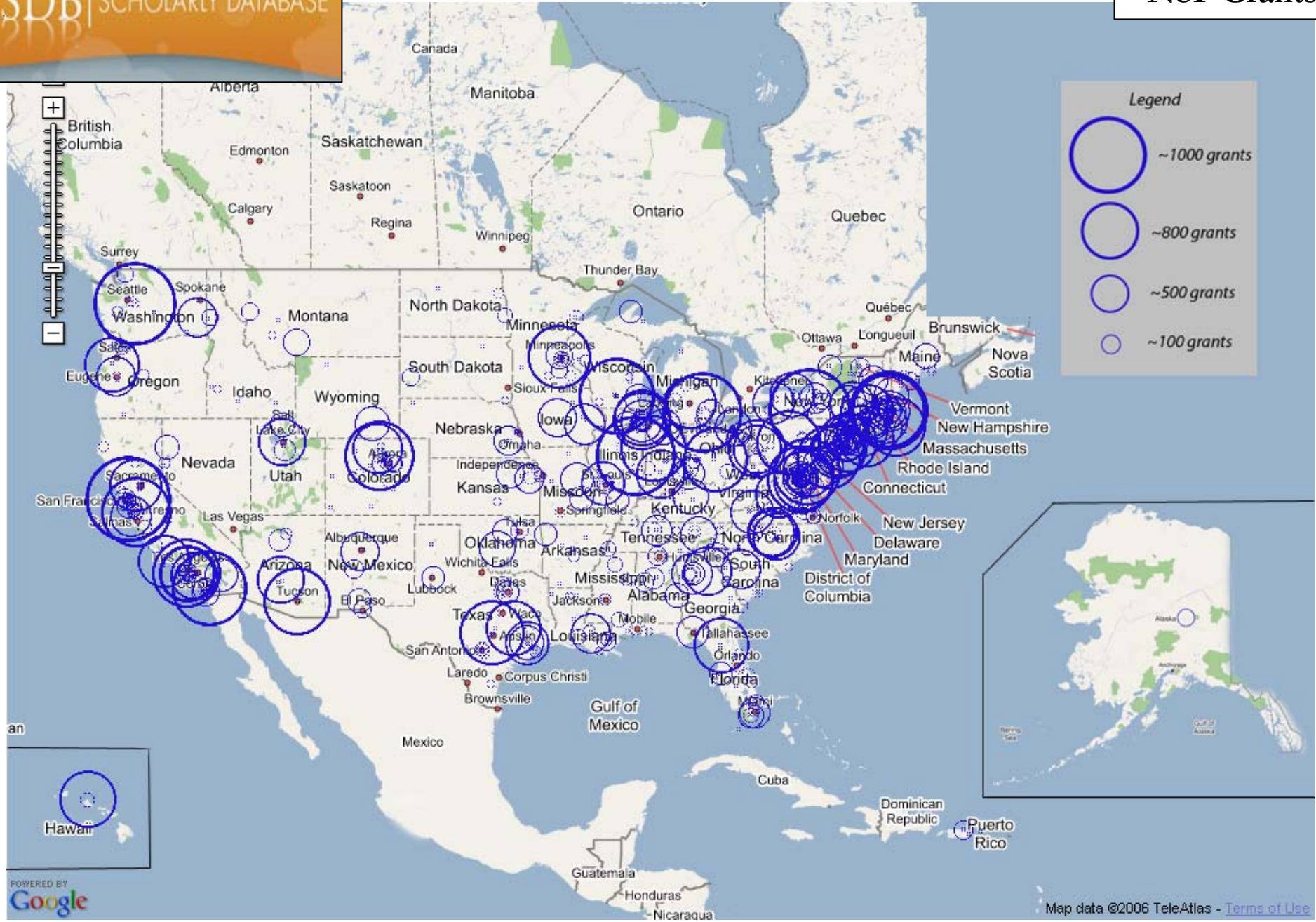
Datasets available via the Scholarly Database (* future feature)

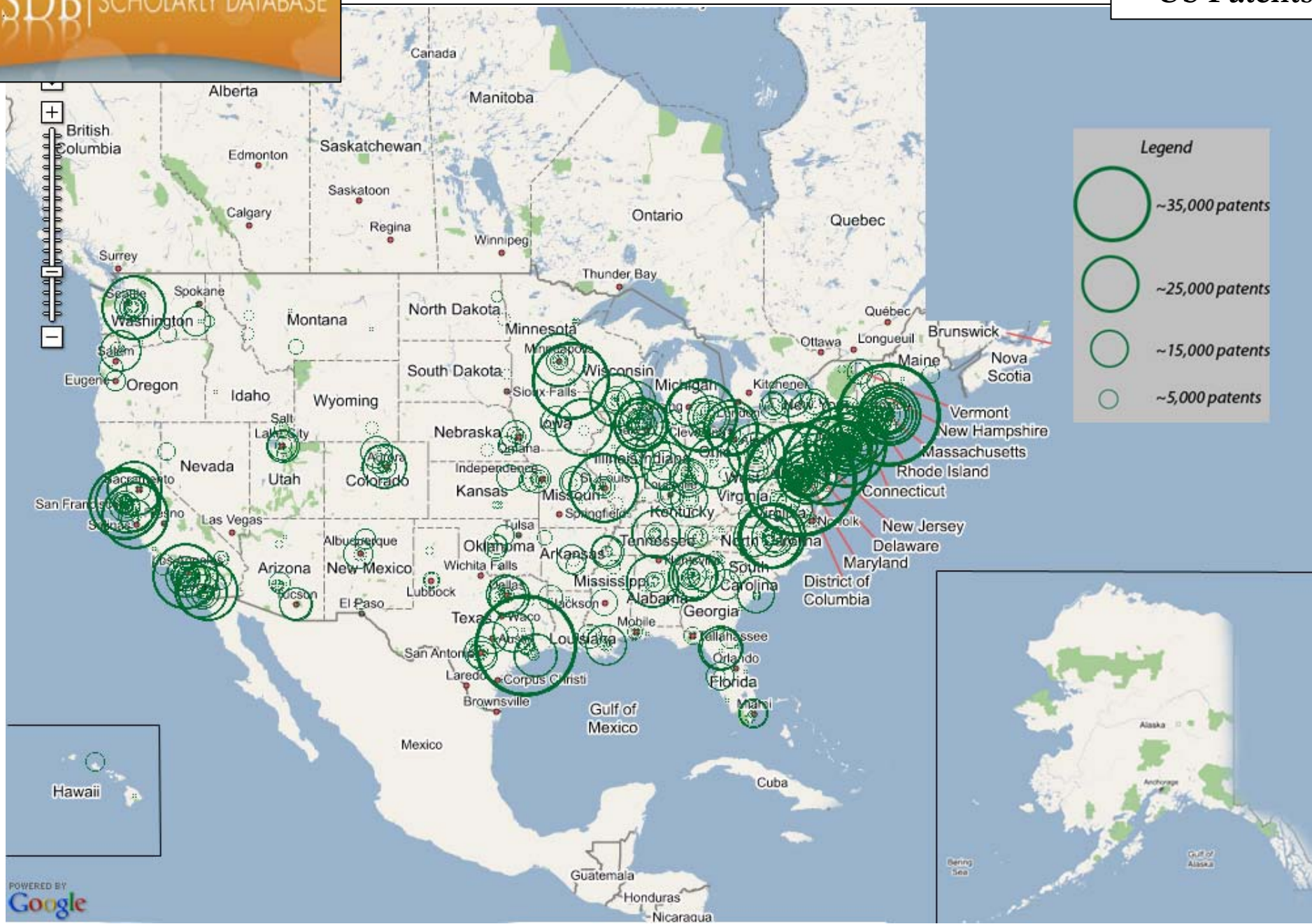
Dataset	# Records	Years Covered	Updated	Restricted Access
Medline	13,149,741	1965-2005	Yes	
PhysRev	398,005	1893-2006		Yes
PNAS	16,167	1997-2002		Yes
JCR	59,078	1974, 1979, 1984, 1989 1994-2004		Yes
USPTO	3,179,930	1976-2004	Yes*	
NSF	174,835	1985-2003	Yes*	
NIH	1,043,804	1972-2002	Yes*	
Total	18,021,560	1893-2006	4	3

Aim for comprehensive time, geospatial, and topic coverage.





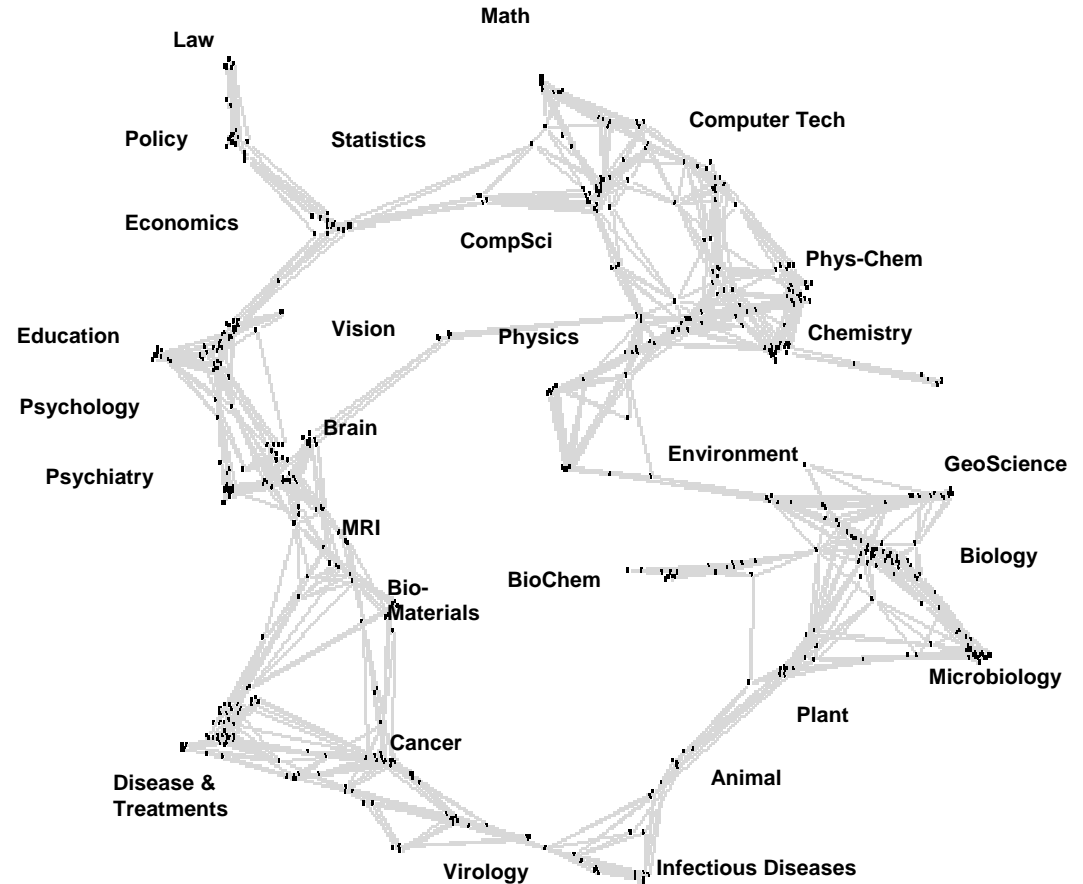




Latest 'Base Map' of Science

Kevin W. Boyack & Richard Klavans, unpublished work.

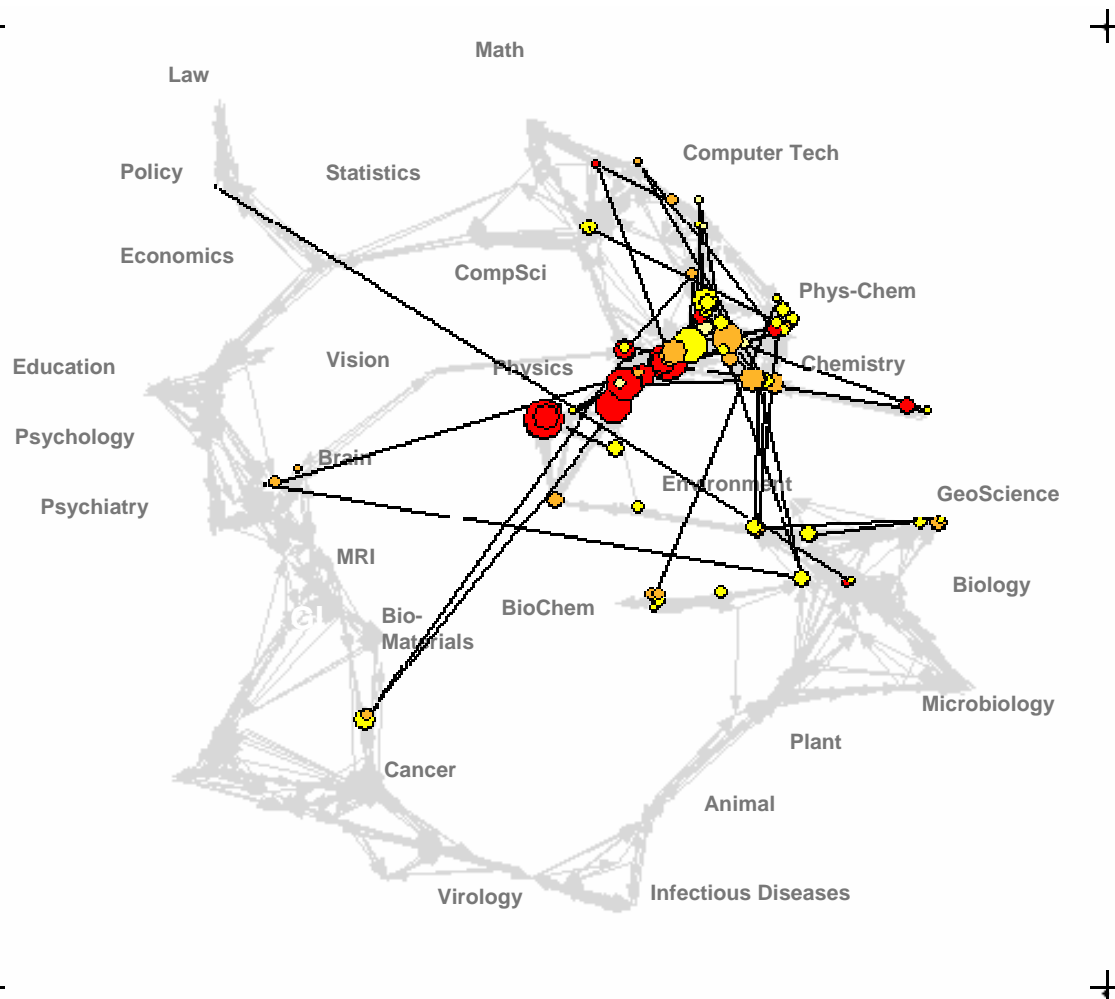
- Uses combined SCI/SSCI from 2002
 - 1.07M papers, 24.5M references, 7,300 journals
 - Bibliographic coupling of papers, aggregated to journals
- Initial ordination and clustering of journals gave 671 clusters
- Coupling counts were reaggregated at the journal cluster level to calculate the
 - (x,y)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



Science map applications: Identifying core competency

Kevin W. Boyack & Richard Klavans, unpublished work.

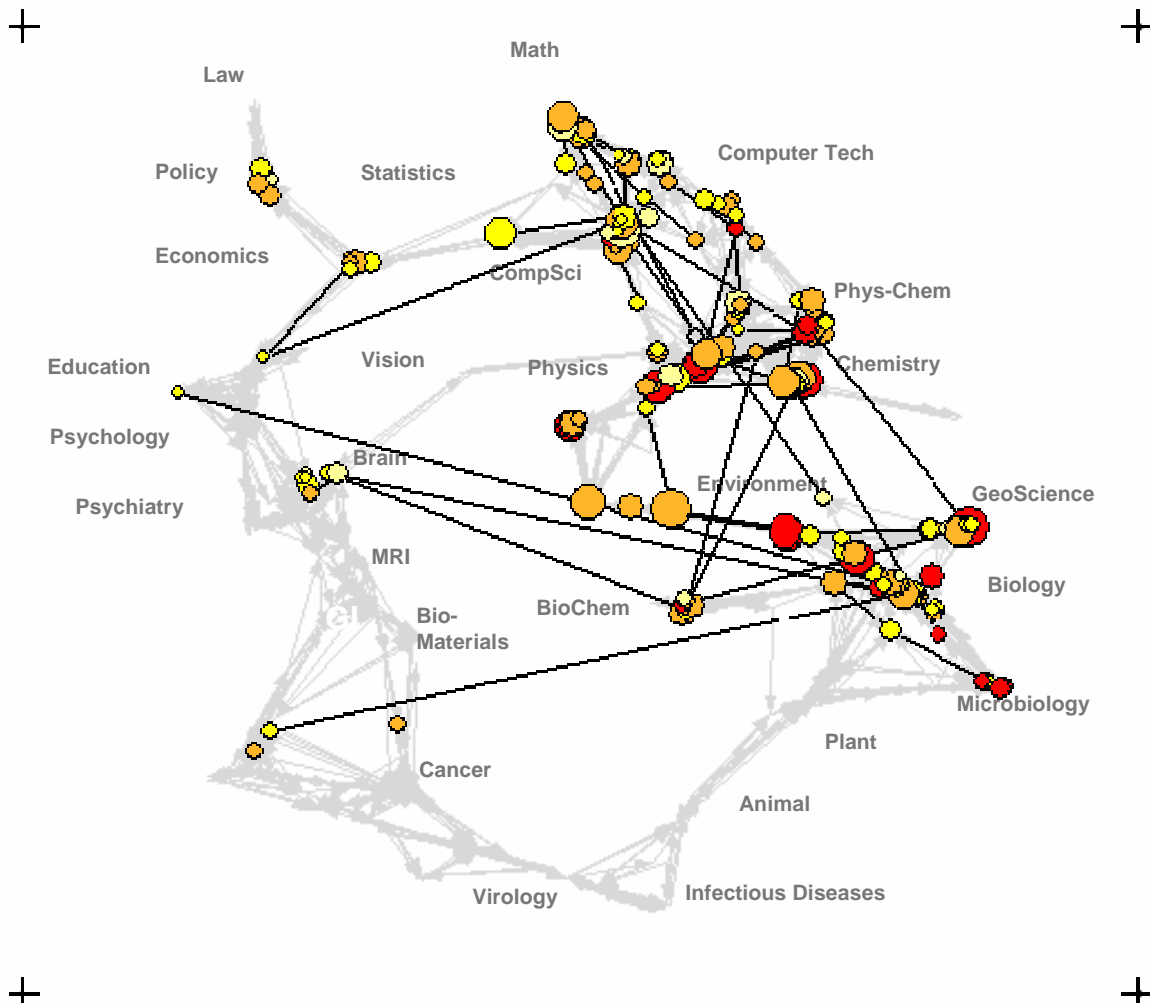
Funding patterns of the US Department of Energy (DOE)



Science map applications: Identifying core competency

Kevin W. Boyack & Richard Klavans, unpublished work.

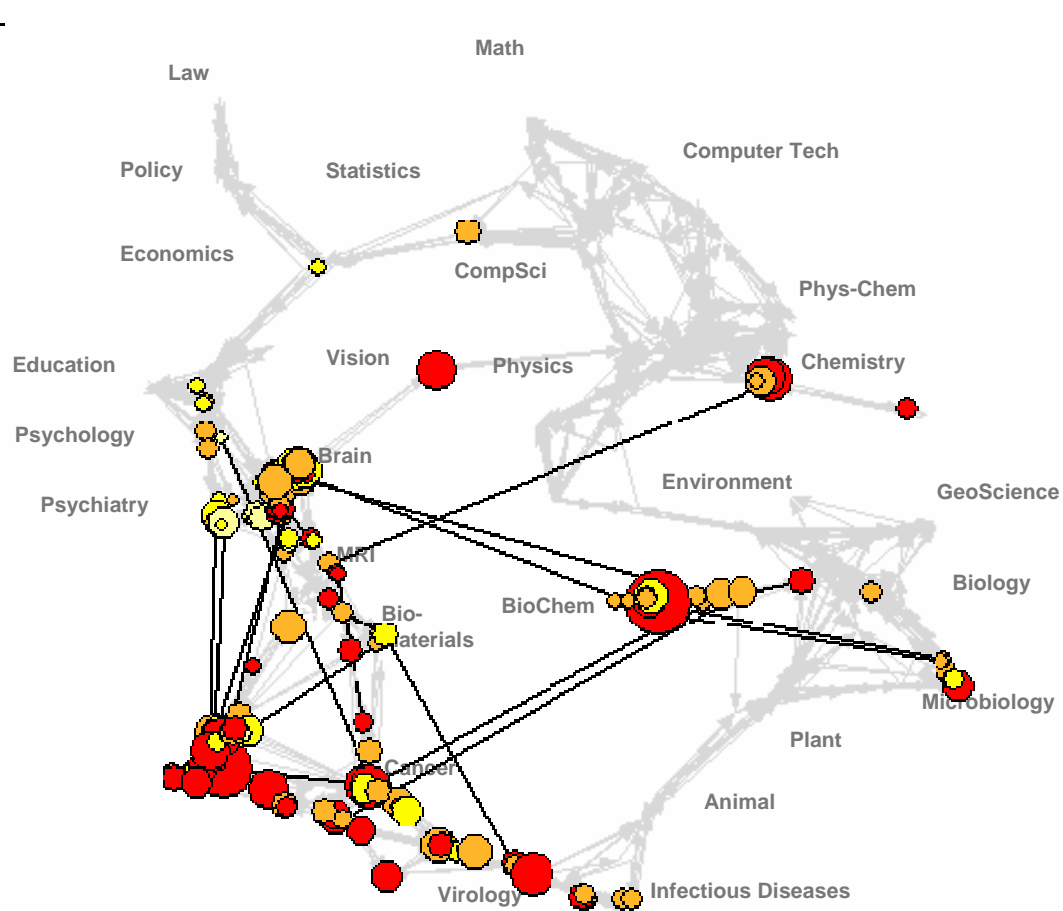
Funding Patterns of the National Science Foundation (NSF)



Science map applications: Identifying core competency

Kevin W. Boyack & Richard Klavans, unpublished work.

Funding Patterns of the National Institutes of Health (NIH)



Building Market Places not Cathedrals



- ‘Software glue’ has to interlink datasets and algorithms written in different languages using different data formats.
- The smaller the glue or ‘CI Shell’, the more likely it can be maintained.





CIShell – Serving Non-CS Algorithm Developers & Users

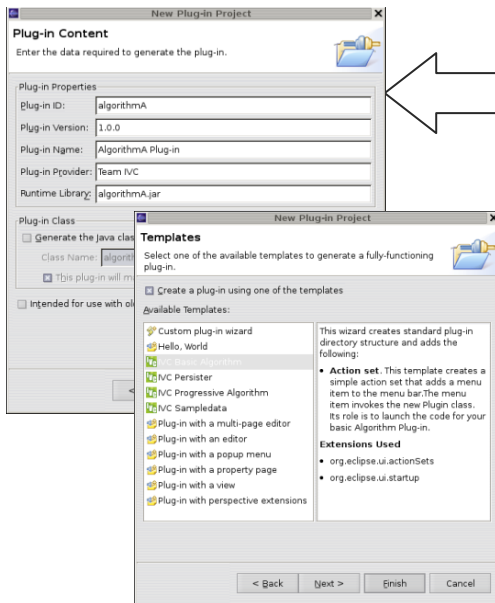
Developers



Users



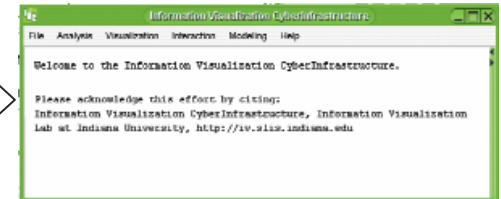
CIShell Wizards



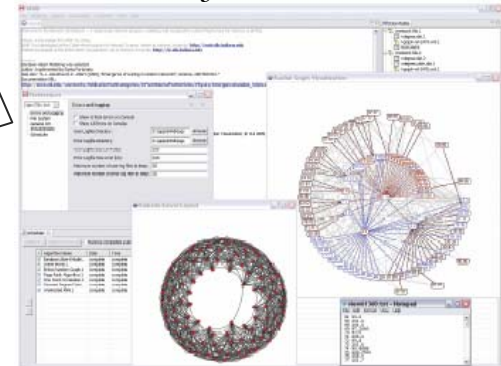
CIShell



IVC Interface



NWB Interface





CIShell – Build on OSGi Industry Standard

CIShell is built upon the Open Services Gateway Initiative (OSGi) Framework.

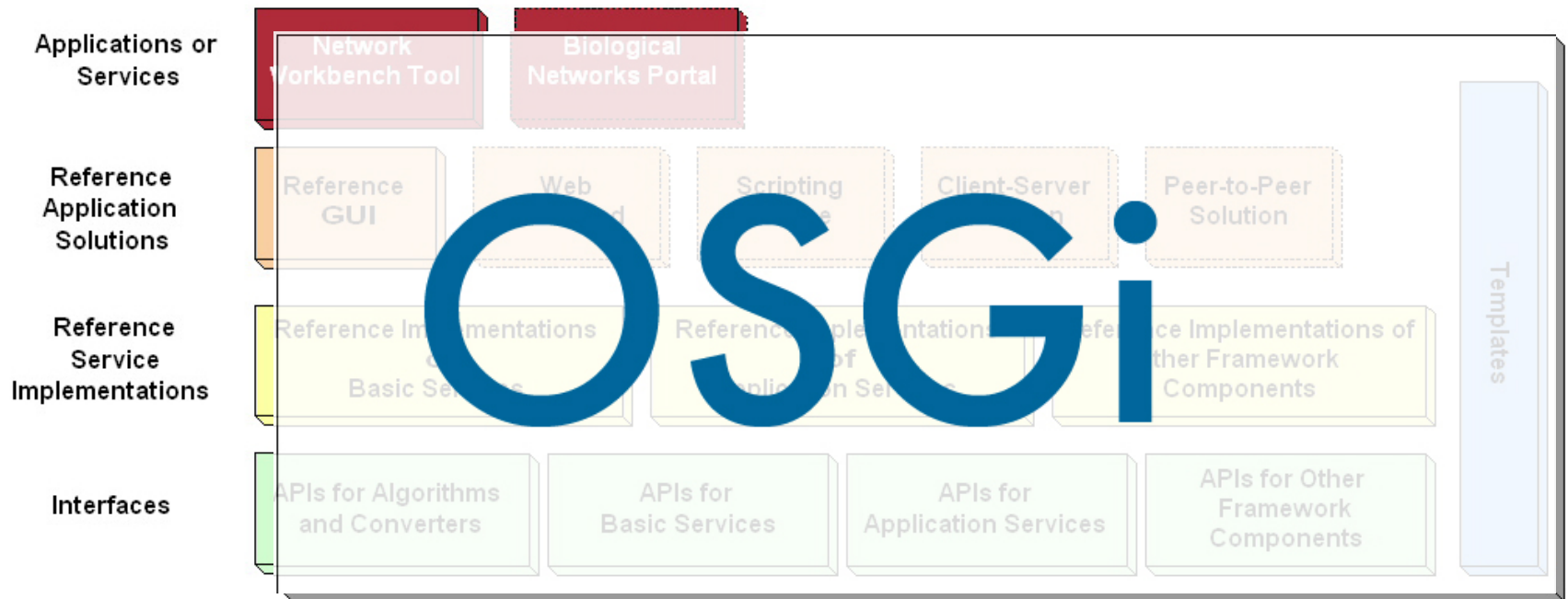
OSGi (<http://www.osgi.org>) is

- A standardized, component oriented, computing environment for networked services.
- Successfully used in the industry from high-end servers to embedded mobile devices since 7 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.

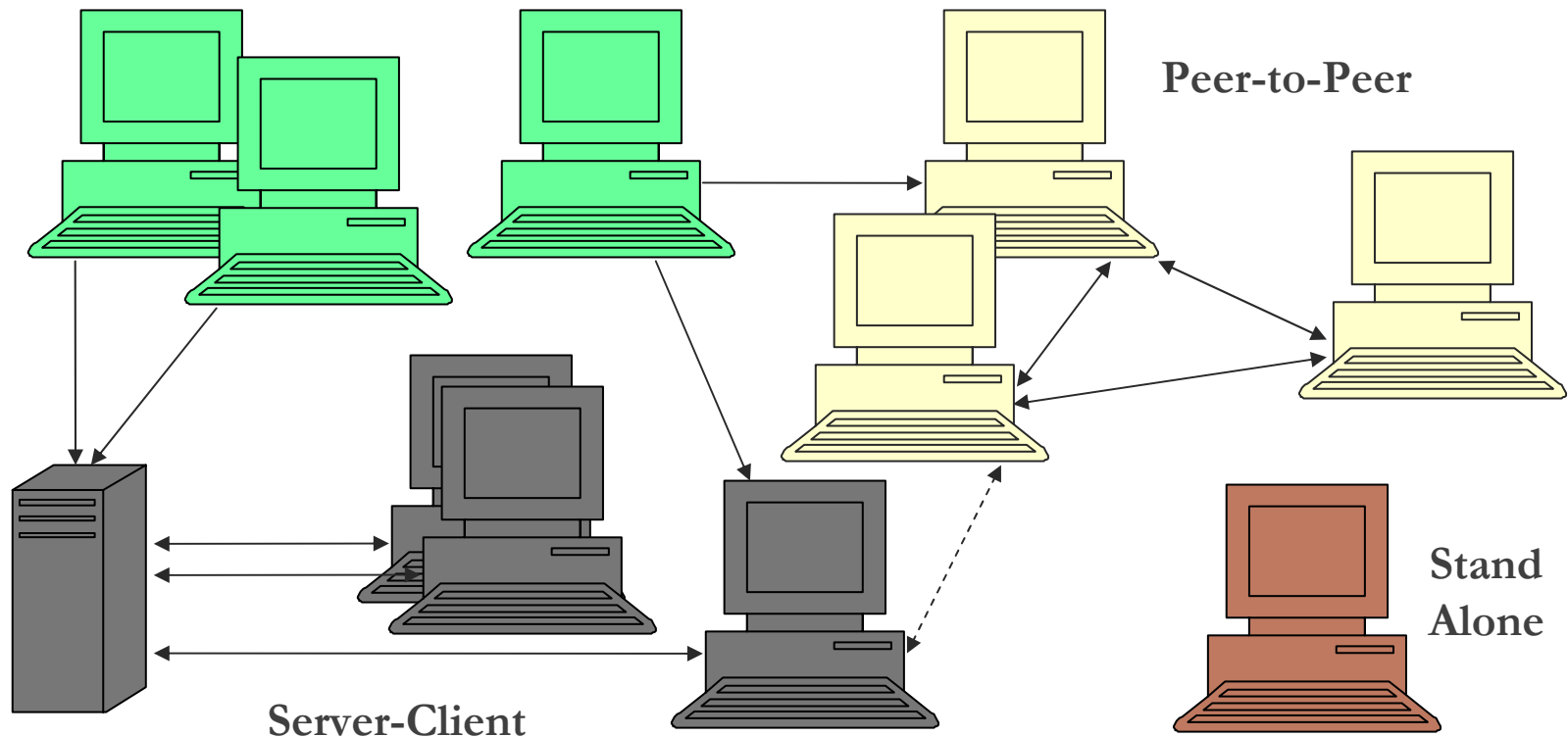
Advantages of Using OSGi

- 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.



Data-Algorithm Repositories



CIShell applications can be deployed as distributed data and algorithm repositories, stand alone applications, peer-to-peer architectures, and server-client architectures.

NWB Tool: Interface Elements

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

Load Data

Select Preferences

List of Data Models

Console

Visualize Data

Scheduler

Open Text Files

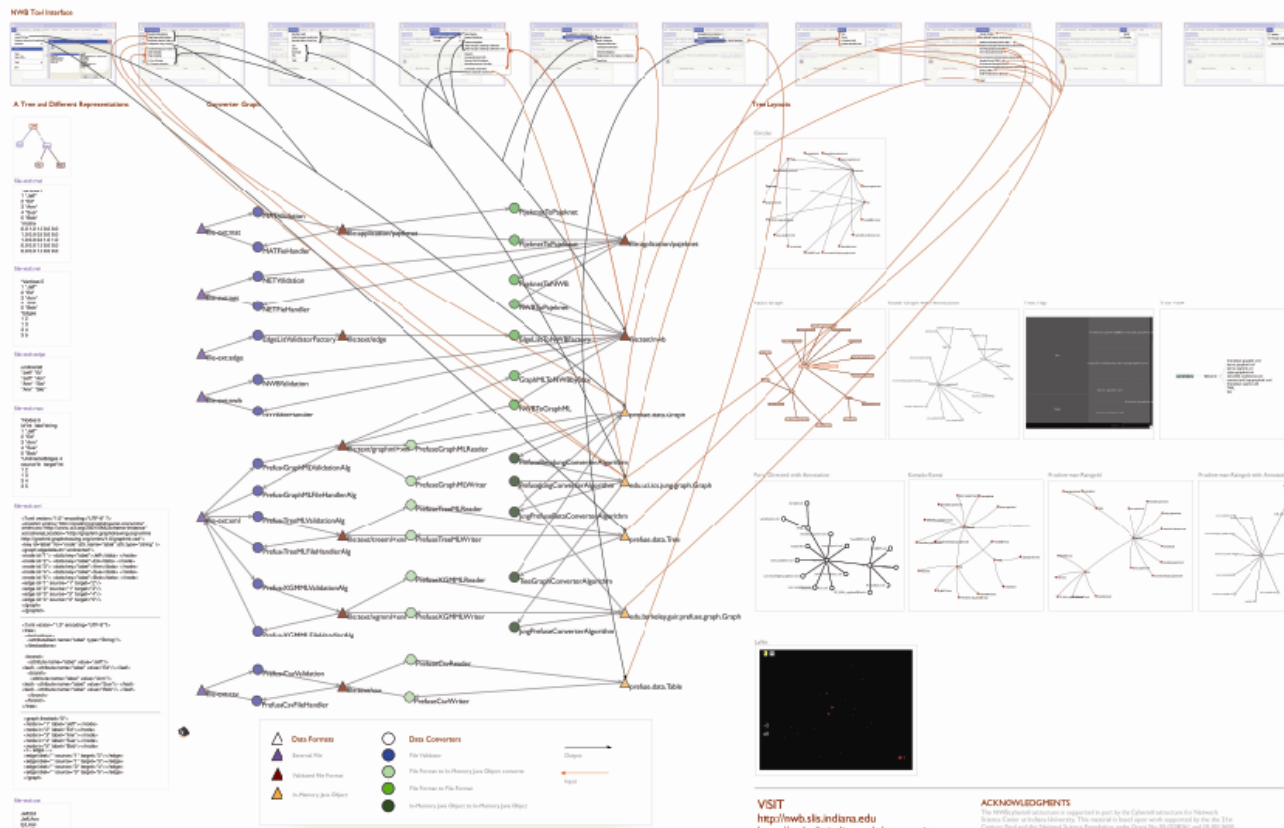
The screenshot shows the NWB Tool interface with several windows and panels:

- Console:** Displays a welcome message and instructions for citing the software.
- Preferences:** A dialog box for configuring the application, including options for errors and logging.
- Scheduler:** A table showing the status of various algorithms.

Algorithm Name	Date	Time
Barabasi-Albert Model...	complete	complete
Small World 1	complete	complete
Erdos Random Graph.1	complete	complete
Page Rank Algorithm.1	complete	complete
One Point Correlation.1	complete	complete
Directed Degree Distr...	complete	complete
Undirected W/N.1	complete	complete
- Data Models:** A list of loaded data files, including network files and degree distributions.
- Radial Graph Visualization:** A large network graph with nodes and edges, showing a radial layout.
- Kamada-Kawai Layout:** A smaller network graph visualization showing a circular layout.
- view61360.txt - Notepad:** A text editor window displaying a list of numbers.



Network Workbench Marketplace: An Ecology of Data Formats, Converters, and Algorithms



INVESTIGATORS
 Dr. Katy Borner
 Dr. Adam L. Galvani
 Dr. Santiago Solari
 Dr. Alexander Hoffmann
 Dr. Steven Wasserman
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Clear A. H. Rangel
 University of Illinois

Network Workbench: A Large-Scale Network Analysis, Modeling and Visualization System for Biological, Social Science and Physics Research.

The project will design, embed, and operate a unique distributed, shared resources environment for large-scale network analysis, modeling, and visualization, named Network Workbench (NWB). The envisioned data-cock-picking resources environment will provide a one-stop online portal for researchers, educators, and practitioners interested in the study of biological, social and behavioral science, physics, and other networks.

The NWB will support network science research across scientific boundaries. Users of the NWB will have online access to major network datasets or can upload their own networks. They will be able to perform network analysis with the most effective algorithms available. In addition, they will be able to generate, run, and visualize network models to advance their understanding of the structure and dynamics of particular networks. NWB will provide advanced visualization tools to interactively explore and understand specific networks, as well as their interaction with other types of networks.

A major computer science challenge is the development of an algorithm integration framework that supports the easy integration and dissemination of existing and new algorithms and can deal with multiple of network data formats in existence today. Another challenge is the design and implementation of an easy-to-use menu-based, online portal interface for interactive algorithm selection, data manipulation, user and session management. The NWB will be industrial in design, research projects and educational settings in biology, social and behavioral science, and physics research. It will be well documented and available in open source for easy duplication and usage at other sites. An annual seminar school and a series of workshops and tutorials are planned to introduce the tool to diverse research communities.

The NWB will provide members of the scientific research community (college professors, physicists, engineers, scientists, social and behavioral scientists, engineers, etc.) with the means to carry out network analysis, modeling, and visualization projects in their own fields. This will result in a direct transfer of knowledge and results from the fields of applied network research to a wider scientific community. Researchers will have access to validated algorithms that in the past have been obtained through time-consuming personal developments of ad hoc computer programs. The NWB is designed to promote and encourage the empirical analysis and model validation of networks, granting an essential acceleration in the development of network science research. Online instructional material will support the use of the NWB in educational settings.

The NWB will provide a unique tool for network science researchers in many disciplines. In effect, NWB can display the knowledge accumulated in network theory and practice across scientific fields and use web-based or any interested researcher, practitioner, or student. The NWB shared resources environment will support and ease network science applications and education in biology, social and behavioral science, and large infrastructure analysis, thereby accelerating the rate of scientific discovery.

NWB Community Wiki

Home | About | Contact | Search

Recent changes: [List of recent edits]

Categories: [List of categories]

Pages: [List of pages]

Users: [List of users]

Discussion: [List of discussion threads]

VISIT
<http://nwb.sls.indiana.edu>
<https://nwb.sls.indiana.edu/community>
<http://www.cishell.org>

DOWNLOAD: NWB Tool
<http://nwb.sls.indiana.edu/software.html>

ACKNOWLEDGMENTS

The NWB development is supported in part by the Cyberinfrastructure for Network Science Center at Indiana University. The network is built upon work supported by the The Center for Policy and the National Science Foundation under Grant No. SES-0206247 and IRI-00-8450. Any opinions, findings, and conclusions or recommendations expressed here are those of the authors and do not necessarily reflect the views of the National Science Foundation.





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

Home



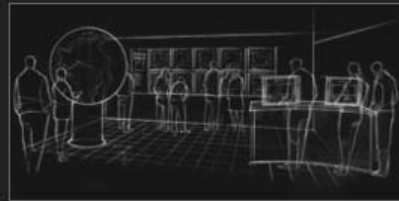
Exhibit Purpose and Goals

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.



Places & Spaces: Mapping Science

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

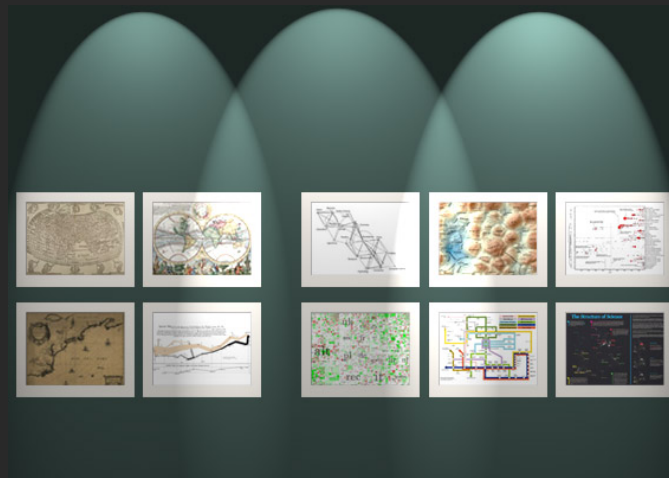
<http://scimaps.org>

Exhibit Curators: Dr. Katy Börner & Elisha Hardy



The Power of Maps

Four Early Maps of Our World VERSUS Six Early Maps of Science



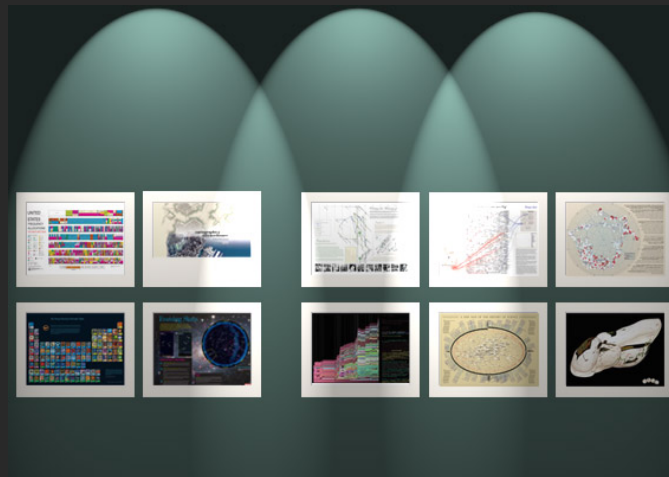
(1st Iteration of Places & Spaces Exhibit - 2005)

The Power of Reference Systems

Four Existing Reference Systems

VERSUS

Six Potential Reference Systems of Science



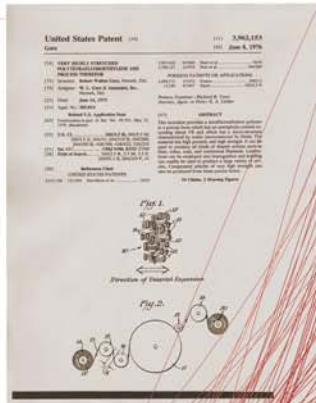
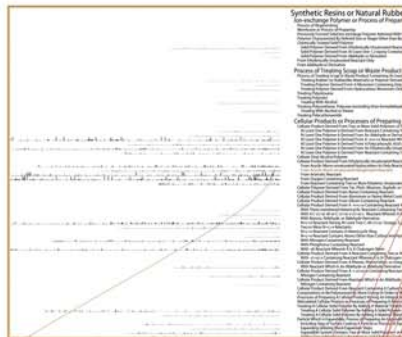
(2nd Iteration of Places & Spaces Exhibit - 2006)

Impact

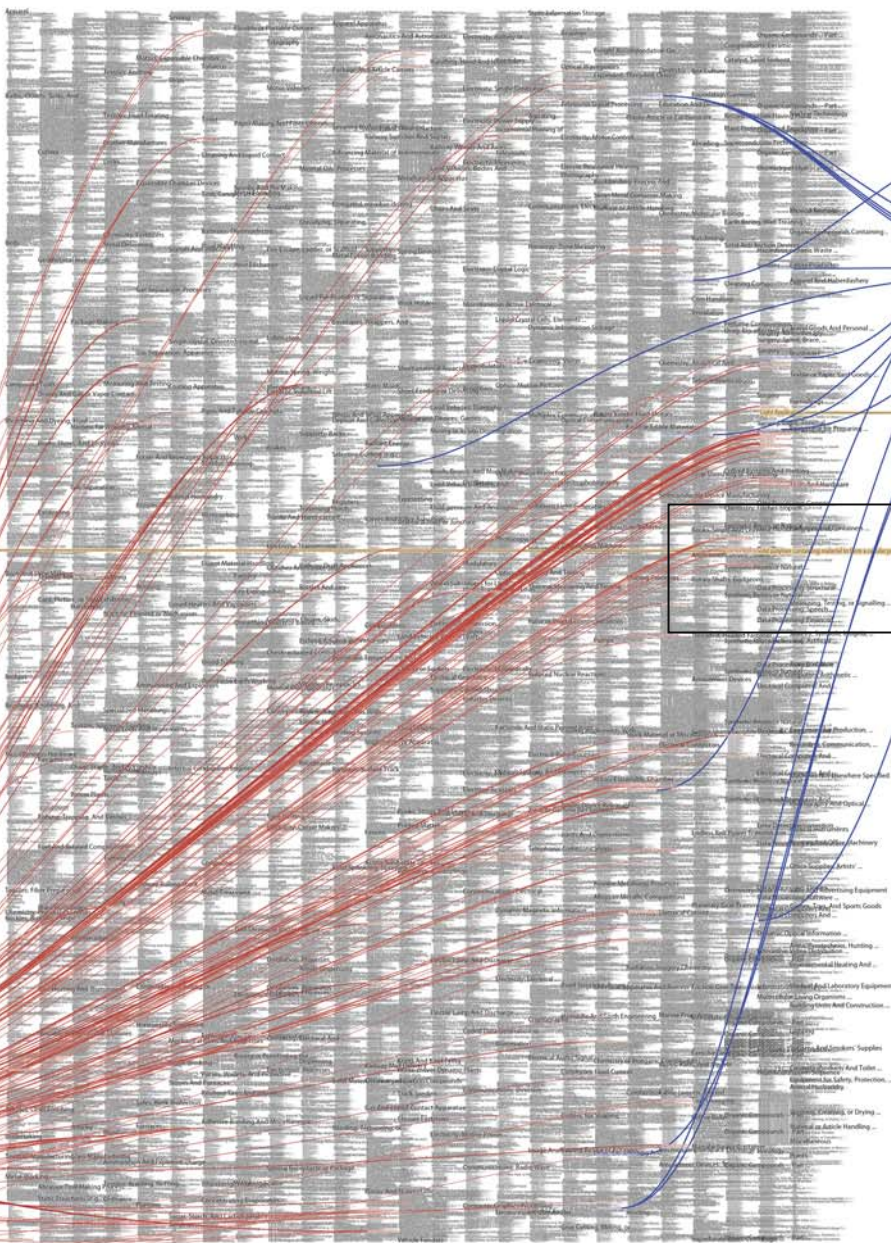
The United States Patent and Trademark Office does scientists and industry a great service by granting patents to protect inventions. Inventions are categorized in a taxonomy that groups patents by industry or use, proximate function, effect or product, and structure. At the time of this writing there are 160,523 categories in a hierarchy that can get as deep as 15 levels. We display the first three levels (13,529 categories) at right in what might be considered a textual map of inventions.

Patent applications are required to be unique and non-obvious, partially by revealing any previous patents that might be similar in nature or provide a foundation for the current invention. In this way we can trace the impact of a single patent, seeing how many patents and categories it affects.

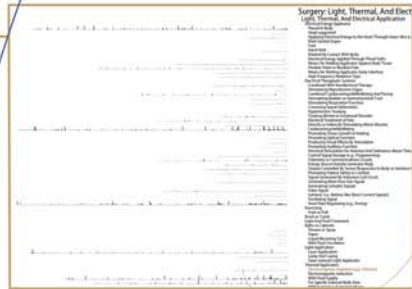
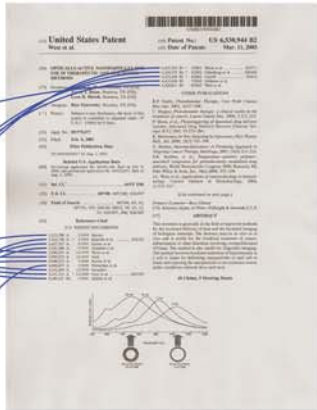
The patent on Goretex—a lightweight, durable synthetic fiber—is an example of one that has had significant impact. The box below enlarges the section of the hierarchy where it is filed, and the red lines (arranged to start along a time line from 1981 to 2006) point to the 130 categories that contain 182 patents, from waterproof clothing to surgical cosmetic implants, that mention Goretex as prior art.



US Patent Hierarchy



Prior Art

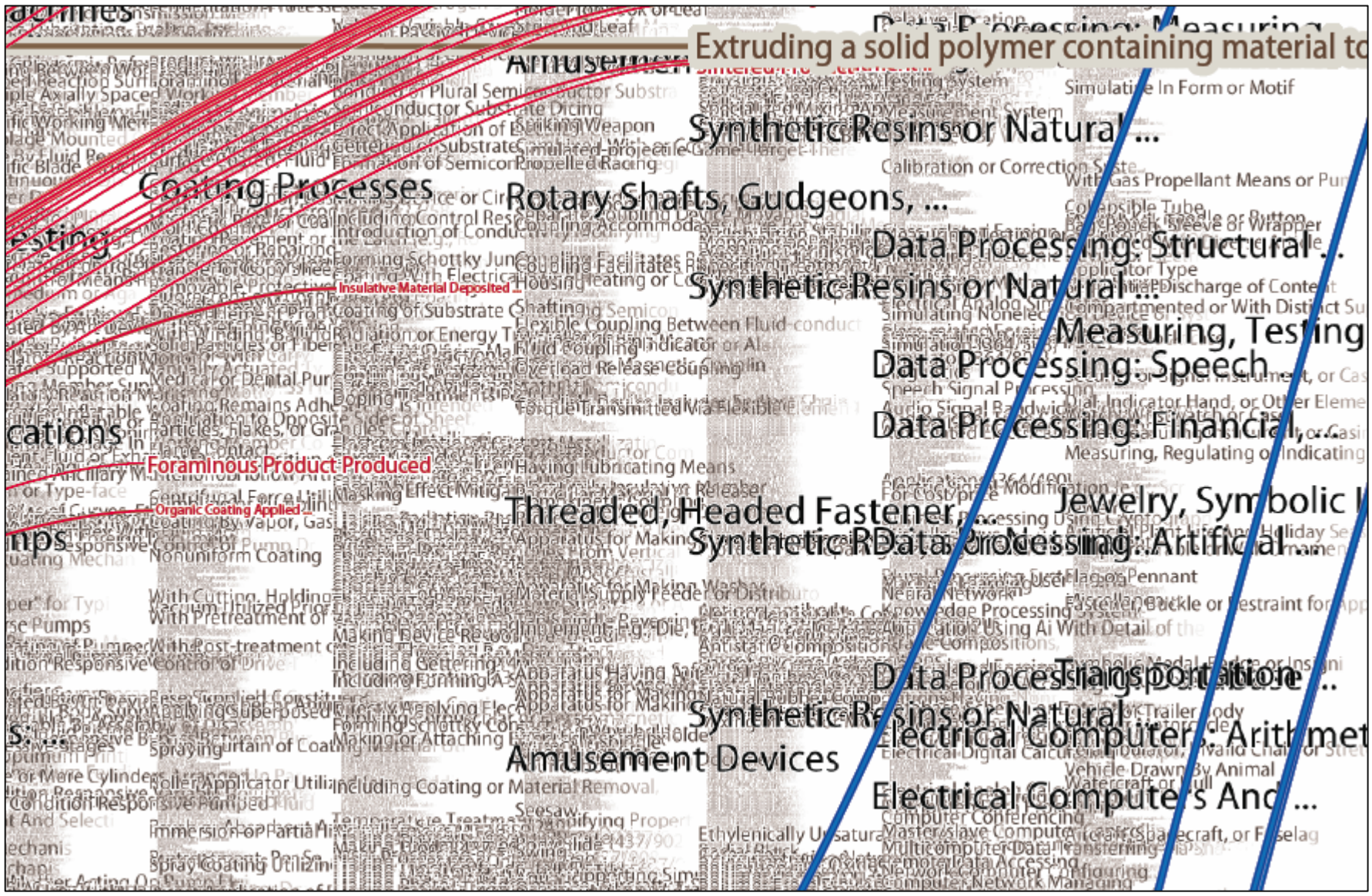


New patents often build on older ideas from many categories. Here, blue lines originate in sixteen different categories that contain the patents cited as prior art for a patent on 'gold nanoshells.' Gold nanoshells are a new invention: tiny spheres (with a diameter ten million times smaller than a human hair) that can be used to make tumors more visible in infrared scans, and have even helped cause complete remission of tumors in tests with laboratory mice. The blue lines show that widely separated categories provided background for this invention.

Keeping categories understandable is an important part of maintaining any taxonomy, including the patent hierarchy. Categories are easier to understand, search, and maintain if they contain elements (patents in this case) that fit well within the definition of the category. The box above shows a tiny bar chart, part of a "Taxonomy Validator" that helps people decide whether categories are good ones.

Categories can be redefined or combined, and sometimes need to be split when they become too large; a constant problem shared by many classifications systems in this information-rich century. But how can we determine exactly where to split a category in two, for example—if there are hundreds or thousands of elements in it?

The Taxonomy Validator measures a "distance to prototype," how far each element is from an idealized "prototype" element for each bucket. This can be based on statistics, computational comparisons of words, or even human judgement. A simple bar chart can then show how good a category is. A good category has lots of small bars; a generally ragged category is one that might need scrutiny or reorganization; while one that has only one or two tall bars may just mean that one or two elements don't belong. Even simple visualizations like this can ease knowledge work by showing the eye much more than can fit into memory as words; focusing people on just the right issues, and providing a vastly broader background to support more informed judgements.



Coating Processes

Extruding a solid polymer containing material to

Synthetic Resins or Natural ...

Rotary Shafts, Gudgeons, ...

Data Processing: Structural ..

Synthetic Resins or Natural ...

Measuring, Testing

Data Processing: Speech

Data Processing: Financial

Foraminous Product Produced

Threaded, Headed Fastener

Jewelry, Symbolic I

Data Processing: Artificial

ps

Organic Coating Applied ...

Amusement Devices

Synthetic Resins or Natural

Data Processing: Transportation ..

Electrical Computer, Arithmet

Electrical Computer's And ...

Impact

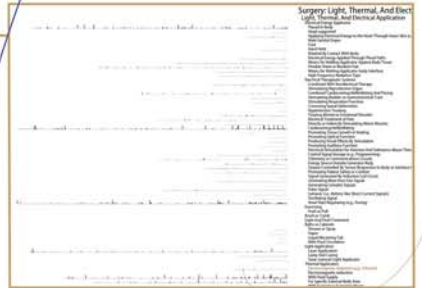
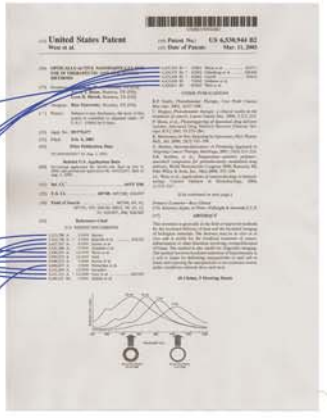
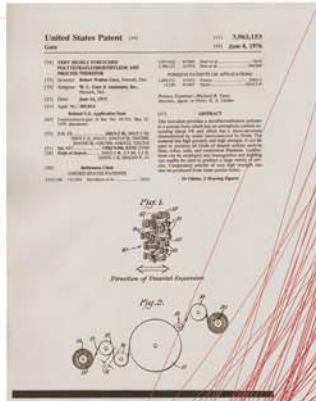
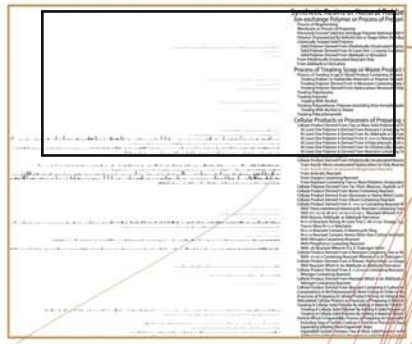
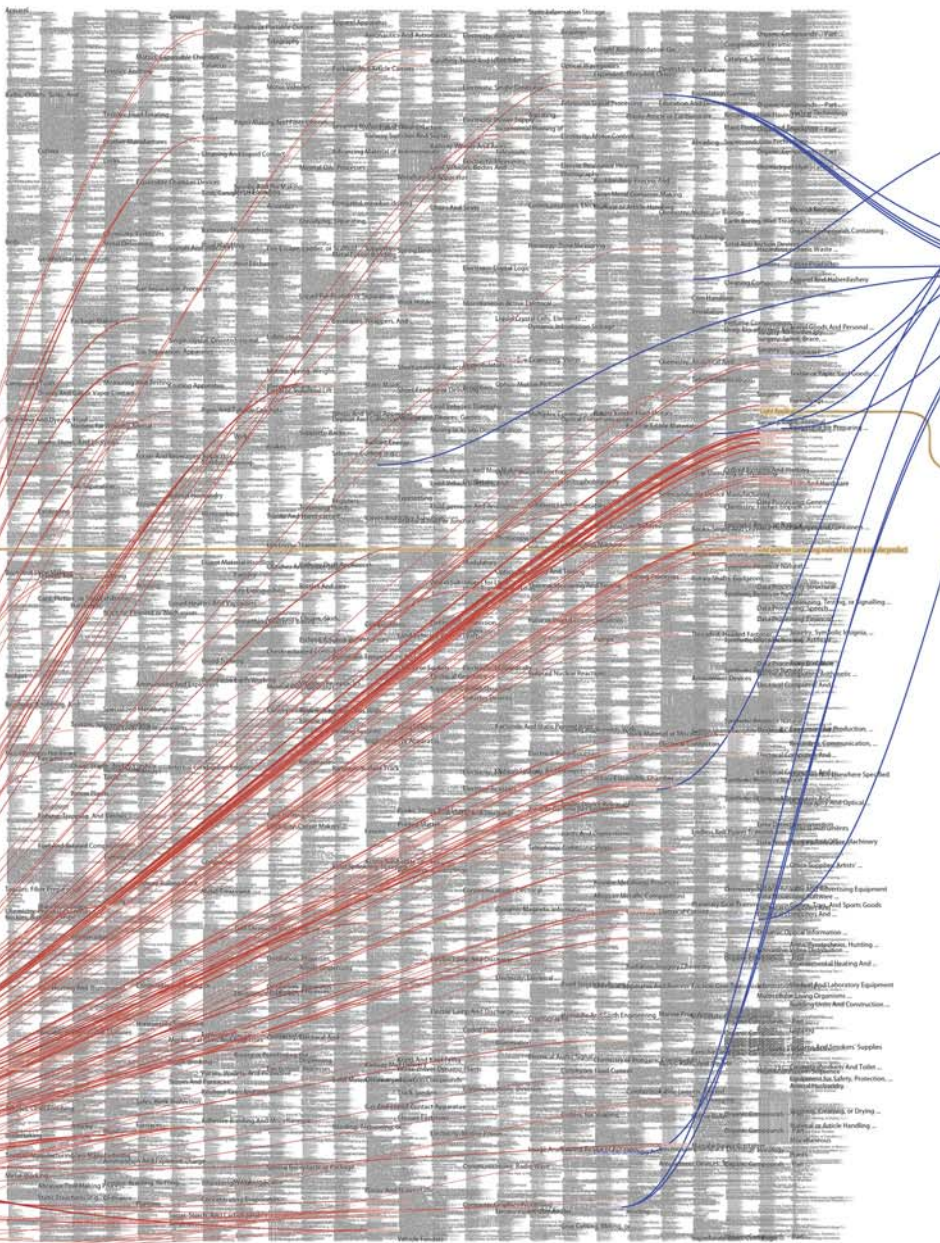
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Synthetic Resins or Natural Rubbers

Ion-exchange Polymer or Process of Preparation

Process of Regenerating

Membrane or Process of Preparing

Previously Formed Solid Ion-exchange Polymer Admixed With Nonpolymer Characterized By Defined Size or Shape Other than Beads

Chemically Treated Solid Polymer

Solid Polymer Derived From Ethylenically Unsaturated Reactant

Solid Polymer Derived From At Least One 1,2-epoxy Containing

Solid Polymer Derived From Aldehyde or Derivative

From Ethylenically Unsaturated Reactant Only

From Aldehyde or Derivative

Process of Treating Scrap or Waste Product Containing

Process of Treating Scrap or Waste Product Containing At Least

Treating Rubber (or Rubberlike Materials) or Polymer Derived

Treating Polymer Derived From A Monomer Containing Only One

Treating Polymer Derived From Hydrocarbon Monomers Only

Treating Polysiloxane

Treating Polyester

Treating With Alcohol

Treating Polyurethane, Polyurea (excluding Urea-formaldehyde)

Treating With Alcohol or Amine

Treating Polycarbonamide

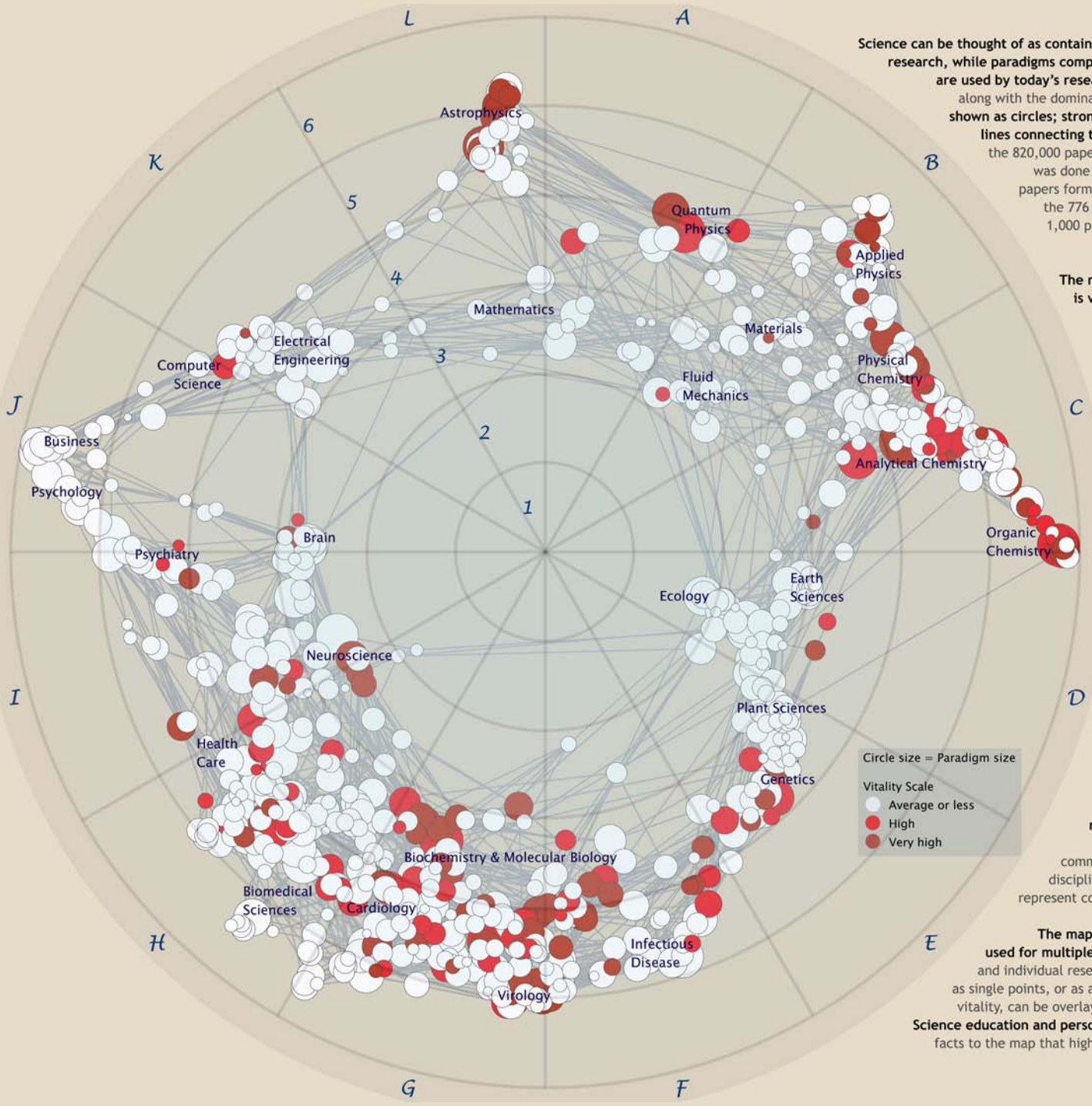
Cellular Products or Processes of Preparing

Cellular Product Derived From Two or More Solid Polymers or From

At Least One Polymer Is Derived From Reactant Containing Two

At Least One Polymer Is Derived From An Aldehyde or Derivative

At Least One Polymer Is Derived From A $-n=c=x$ Reactant Where



Science can be thought of as containing themes and paradigms. Themes are areas of current research, while paradigms comprise the dominant tool sets and existing knowledge that are used by today's researchers. This map shows 776 major paradigms in science along with the dominant relationships between these paradigms. Paradigms are shown as circles; strong relationships between paradigms are indicated by the lines connecting the circles. The map was created by recursively clustering the 820,000 papers referenced most often in 2003. Clustering at each level was done using VxOrd, a force-directed graph layout routine. These papers formed 53,000 clusters, 6,100 higher-level clusters, and finally the 776 paradigms. Although each paradigm contains, on average, 1,000 papers, some are larger and some are smaller, as shown by different sized circles on the map.

The ring-like structure that is formed by scientific paradigms is very robust. We find similar structures for different years, and for maps generated from scientific journals. "The Structure of Science", a galaxy map shown in the first iteration of Places & Spaces, is a map based on clustering of scientific journals, with superimposition of papers on the journal structure, whereas this map was generated directly from highly-cited papers. "The Structure of Science" shows current science in a disciplinary context, while this map can show the breadth of disciplines that contribute to single paradigms.

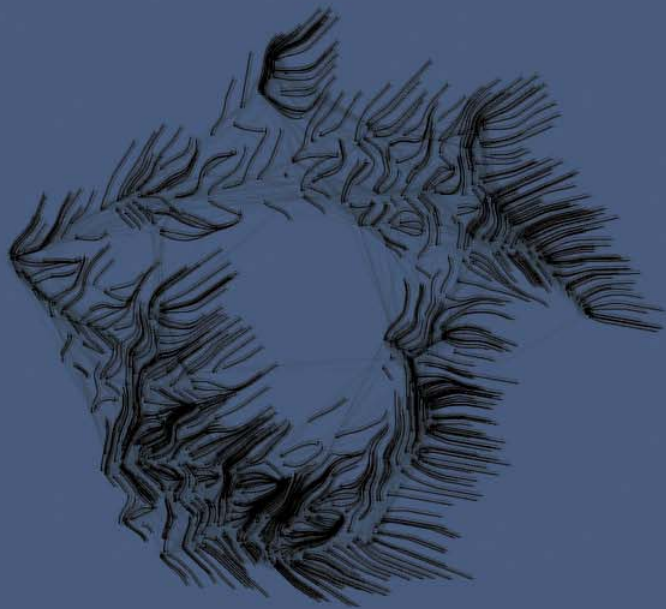
Because of the robust nature of the structure of science and its paradigms, we have placed our 776 scientific paradigms within a reference system containing 12 radial slices and 6 rings. This allows the position of each paradigm to be codified and available for lookup; for instance *Fluid Mechanics* paradigms are in grid B3.

We have also calculated and displayed the vitality of each paradigm. **Vitality is a measure of the speed at which a group of researchers reaches consensus about major improvements.** Paradigms are constantly being improved, but it usually takes years to reach consensus about which improvements are major. The white circles represent communities where consensus is reached relatively slowly. This is a common phenomenon in the social sciences, ecological sciences, computer sciences, and mathematics disciplines. **The red circles represent communities of researchers where consensus is reached relatively rapidly.** This is more common in physics, chemistry, biochemistry, and many medical disciplines. Very dark circles (such as those in *Astrophysics*, L5-6) represent communities where consensus is reached extremely quickly.

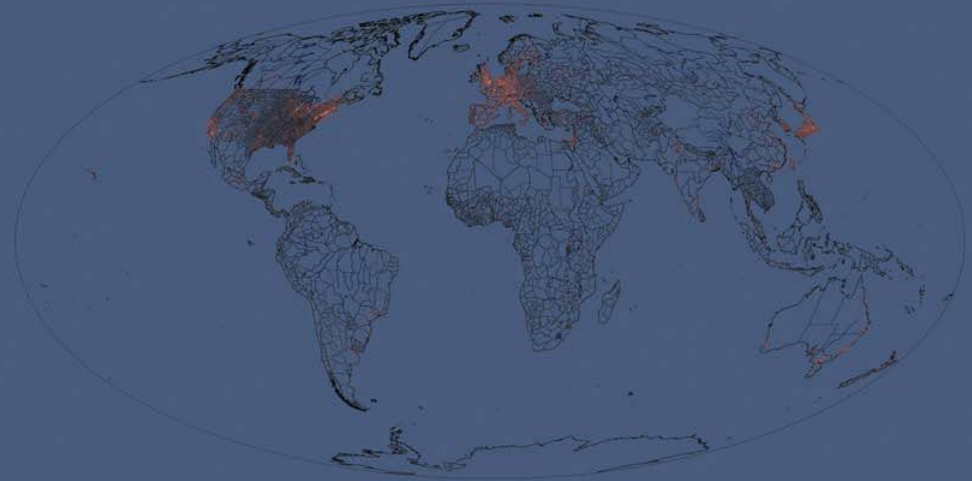
Circle size = Paradigm size
 Vitality Scale
 ● Average or less
 ● High
 ● Very high

The map of scientific paradigms and its reference system can be used for multiple purposes. Countries, industries, companies, universities, and individual researchers can all locate themselves within the map, either as single points, or as a specific collection of paradigms. Various metrics, such as vitality, can be overlaid on this reference system to highlight specific impacts. **Science education and personal discovery** can also be enhanced by linking stories and facts to the map that highlight scientific history, current advances and relationships between scientific paradigms.

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 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.

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

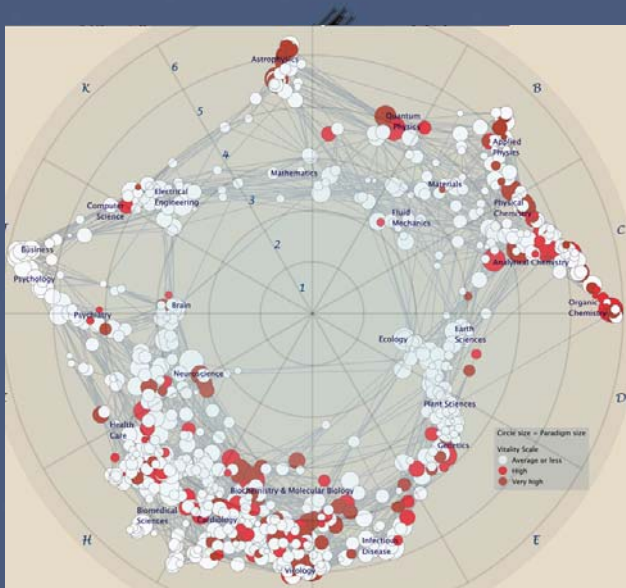
About this display

People & organizations that helped create it

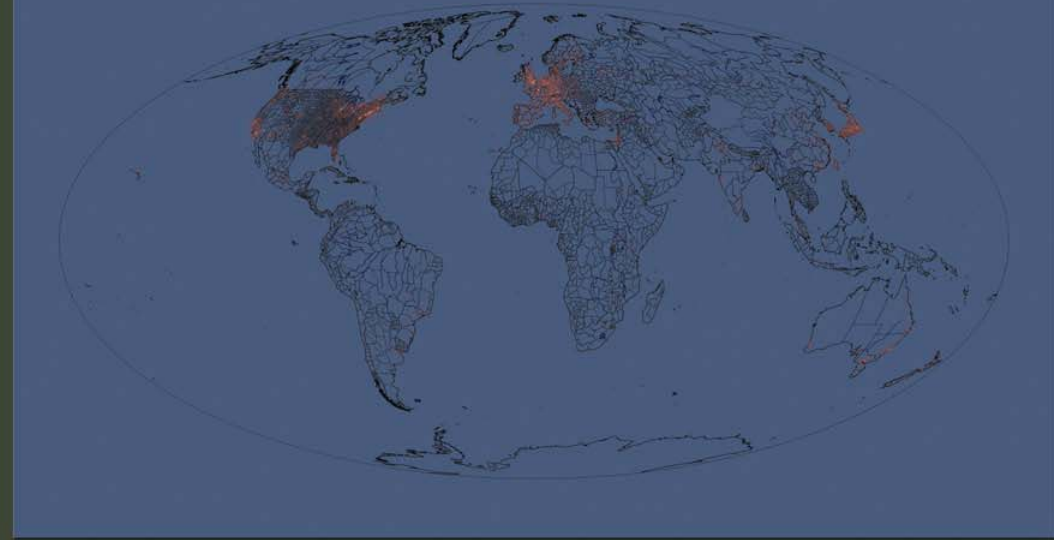
We sweep slowly through adjoining related topics, lighting up the places in the world that study each topic. You may select a subset of the topics that deal with these three interesting subjects by touching it.

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 snapshot lights science that cites the second; and the fourth lights science that cites the third.

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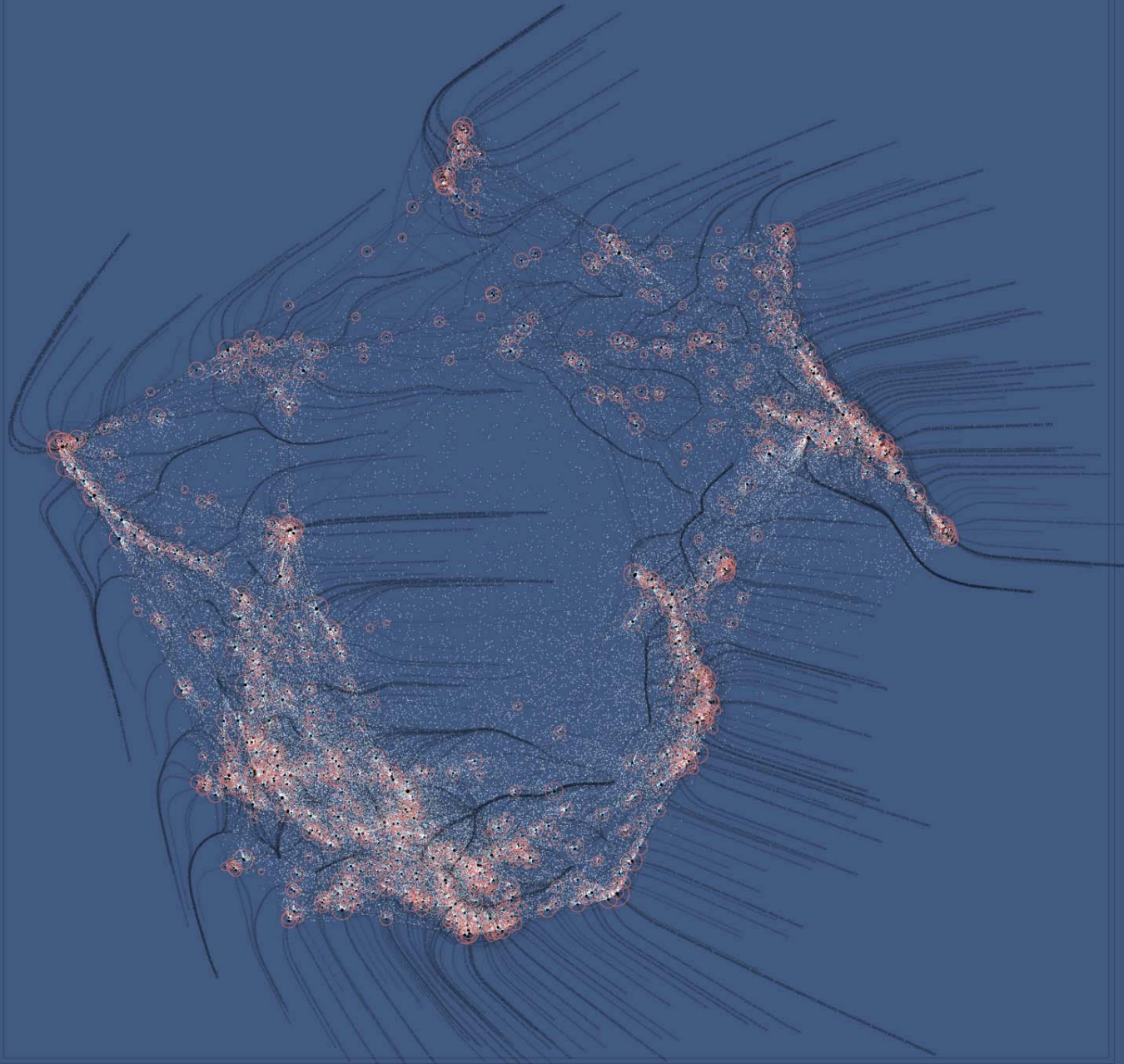
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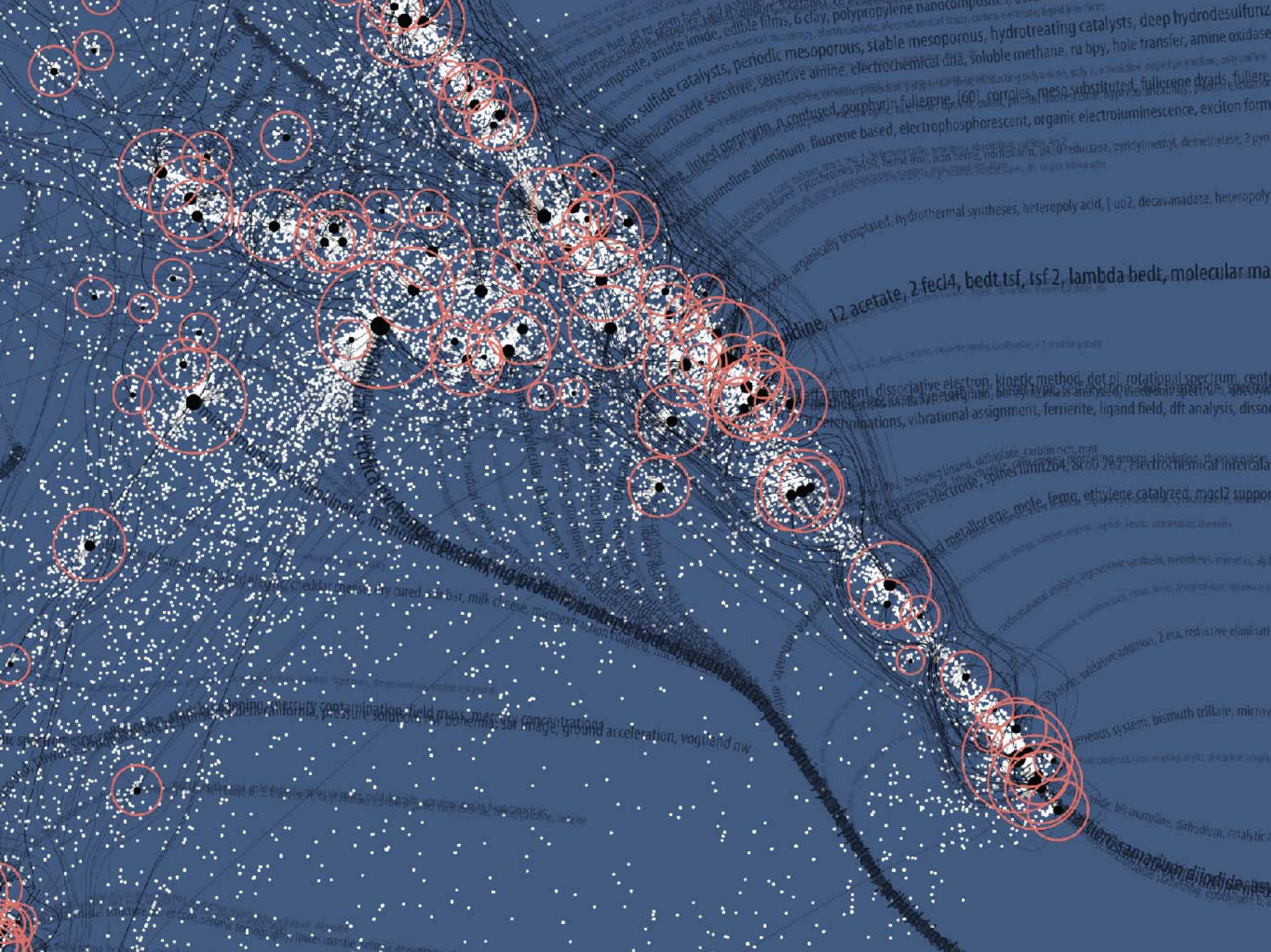
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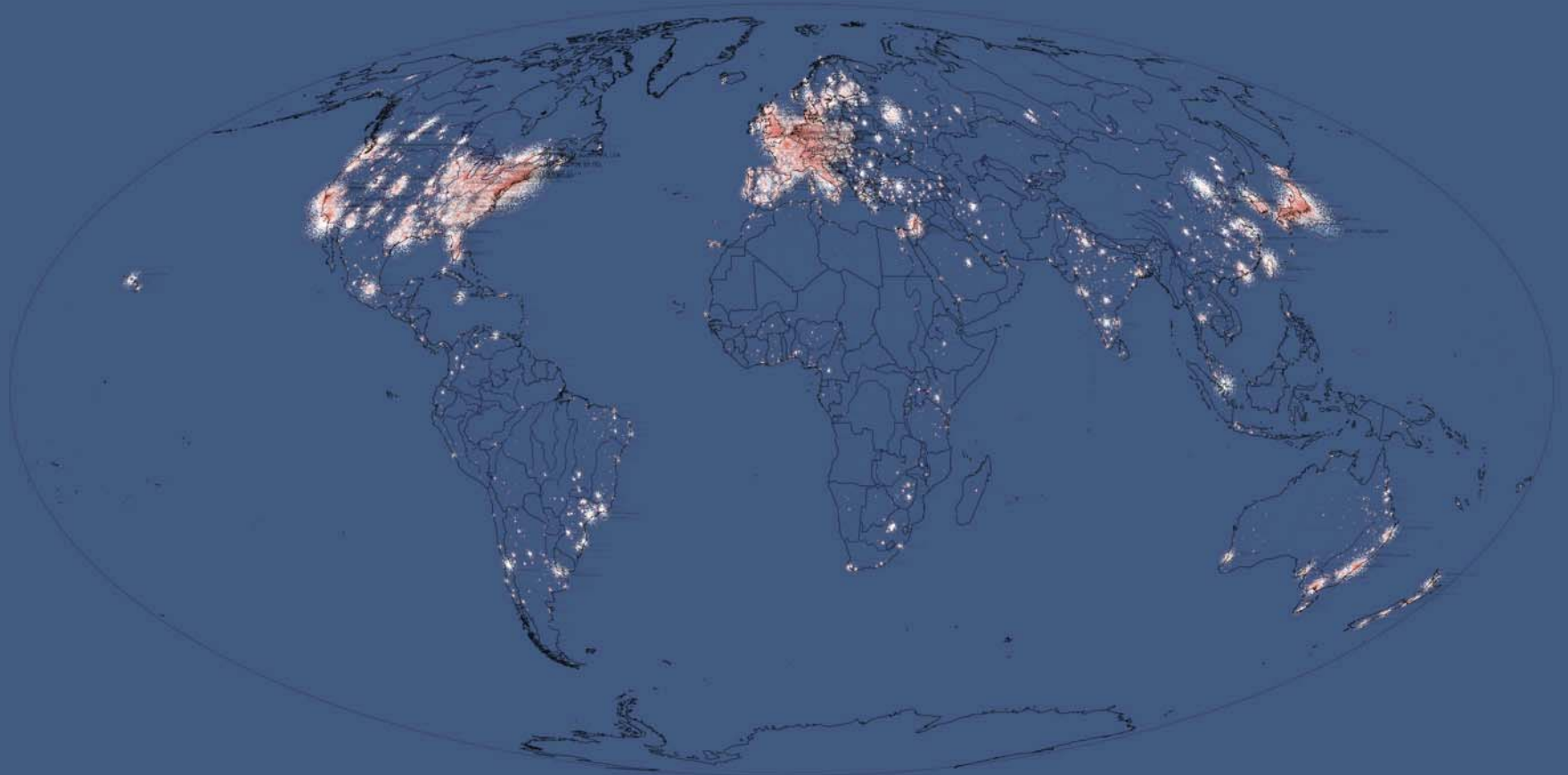
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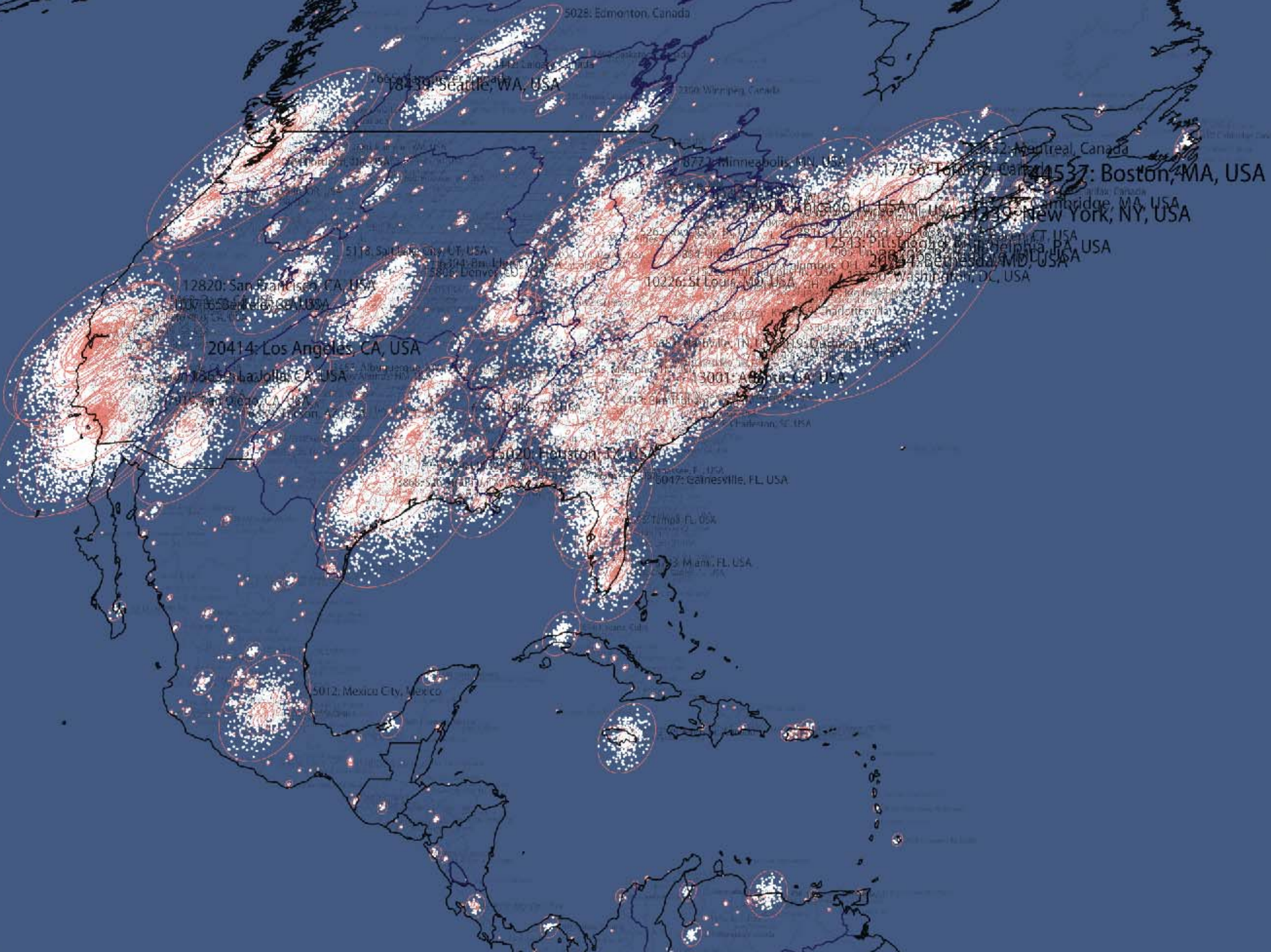
TOPIC MAP: HOW SCIENTIFIC PARADIGMS RELATE





GEOGRAPHIC MAP: WHERE SCIENCE GETS DONE





5028: Edmonton, Canada

18439: Seattle, WA, USA

7652: Montreal, Canada

8771: Minneapolis, MN, USA

17756: Toronto, Canada

44537: Boston, MA, USA

17330: New York, NY, USA

5118: Salt Lake City, UT, USA

12820: San Francisco, CA, USA

10171658: Denver, CO, USA

20414: Los Angeles, CA, USA

10171658: San Diego, CA, USA

10171658: Phoenix, AZ, USA

10226: St Louis, MO, USA

20004: Washington, DC, USA

13001: Atlanta, GA, USA

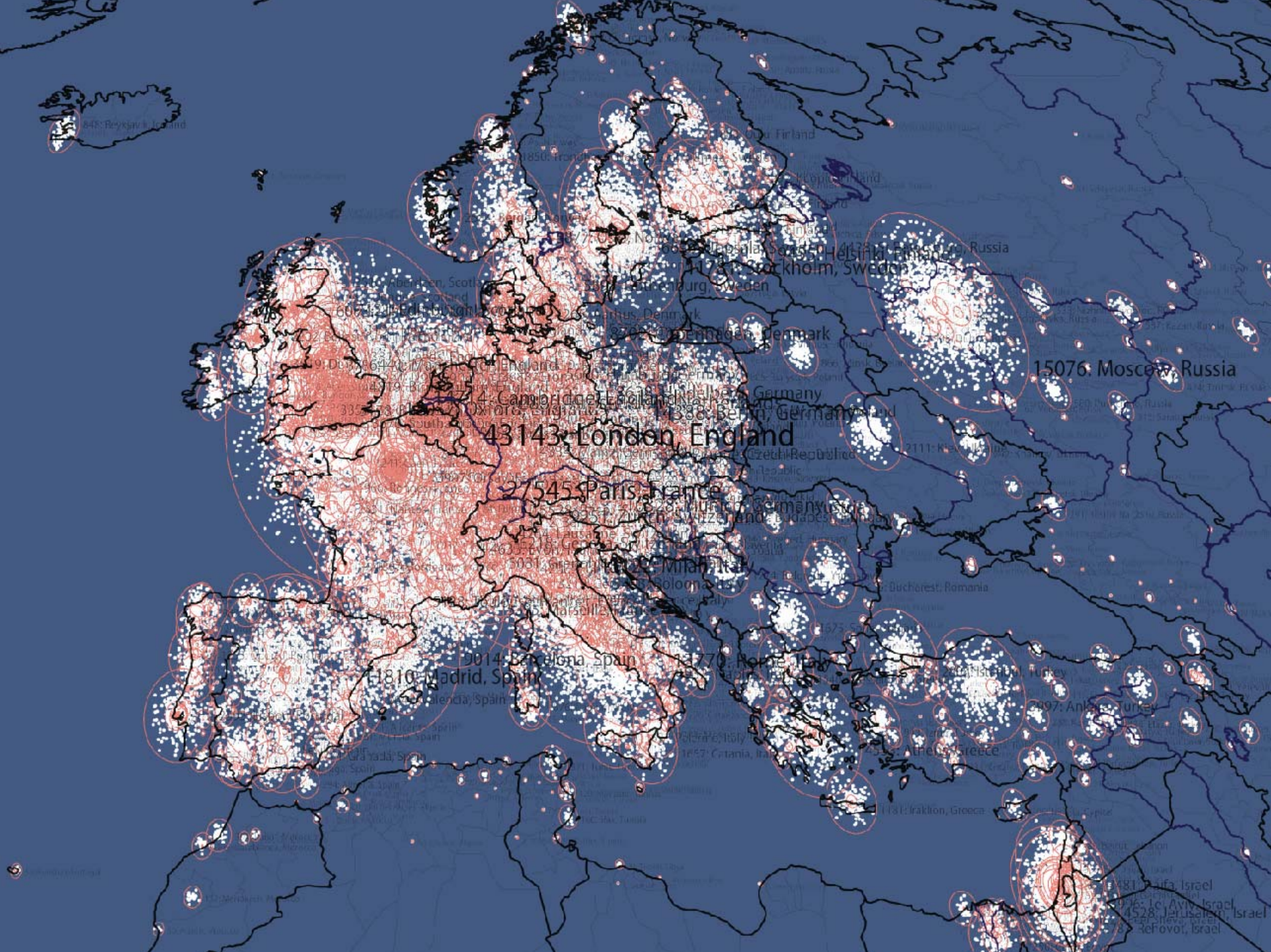
15020: Houston, TX, USA

15047: Gainesville, FL, USA

15071: Tallahassee, FL, USA

15072: Miami, FL, USA

5012: Mexico City, Mexico



15076: Moscow, Russia

43143: London, England

27545: Paris, France

1810: Madrid, Spain

9014: Barcelona, Spain

1770: Rome, Italy

2997: Ankara, Turkey

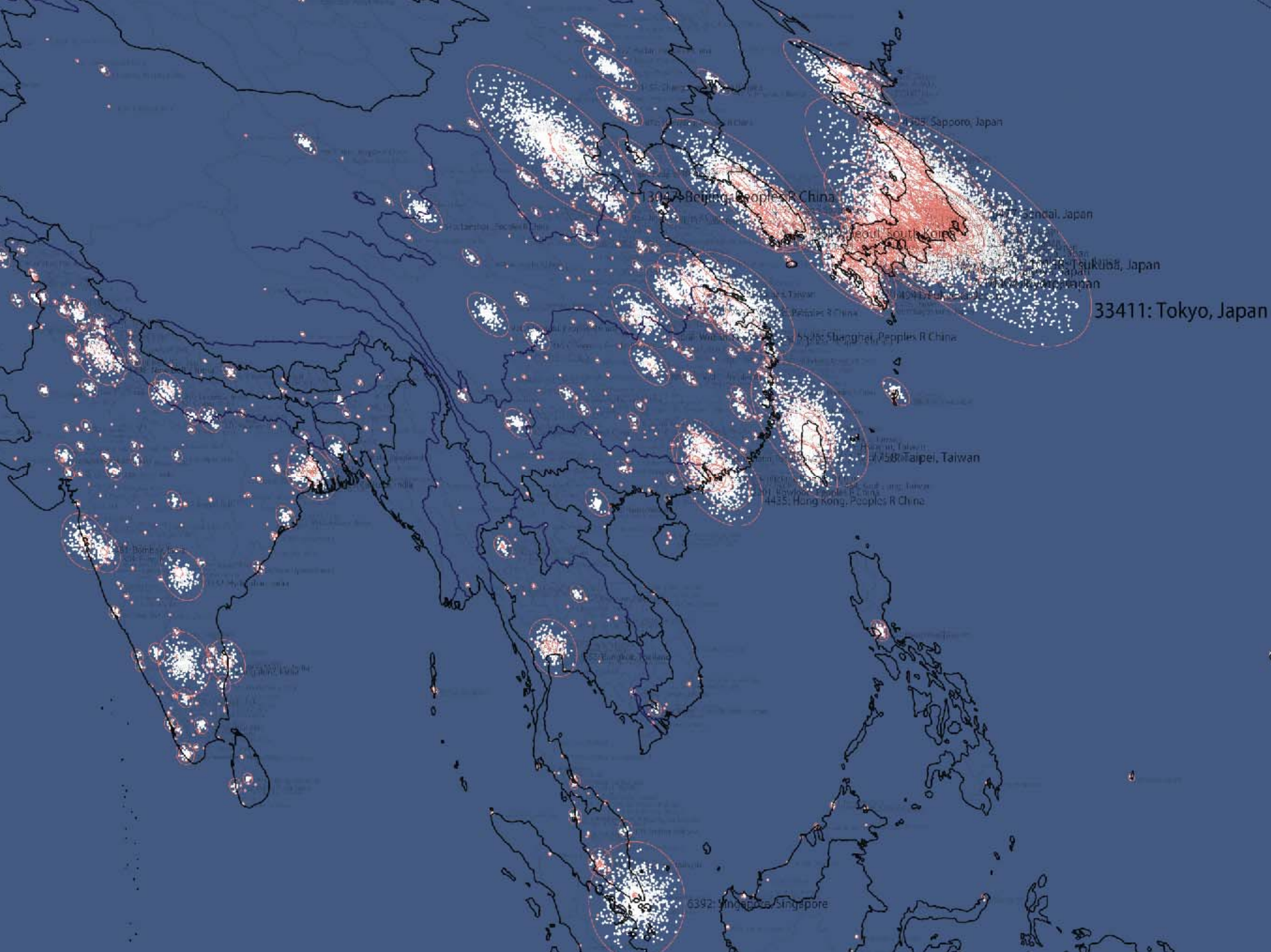
1532: Athens, Greece

181: Haifa, Israel

16: Tel Aviv, Israel

4528: Jerusalem, Israel

3: Erez, Israel





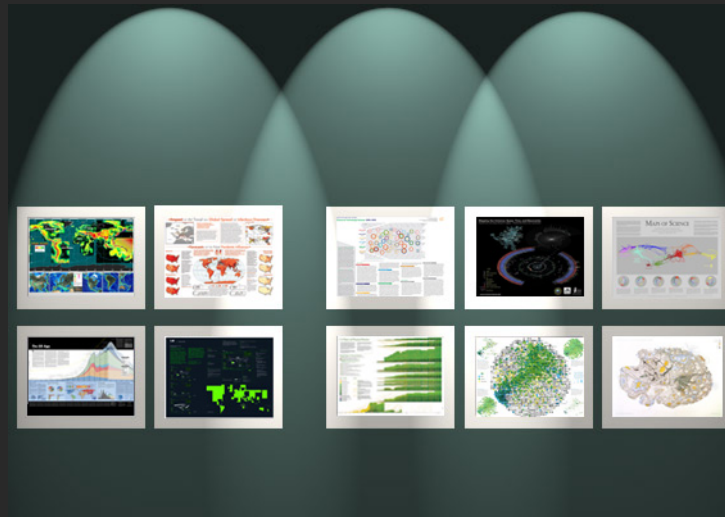
W. Bradford Paley
Scientific Mapmaker
Digital Image Design Incorporated
Dept. of Computer Science, Columbia University

Illuminated Diagram Display

<http://www.youtube.com/watch?v=bXABcOABG4E>

The Power of Forecasts

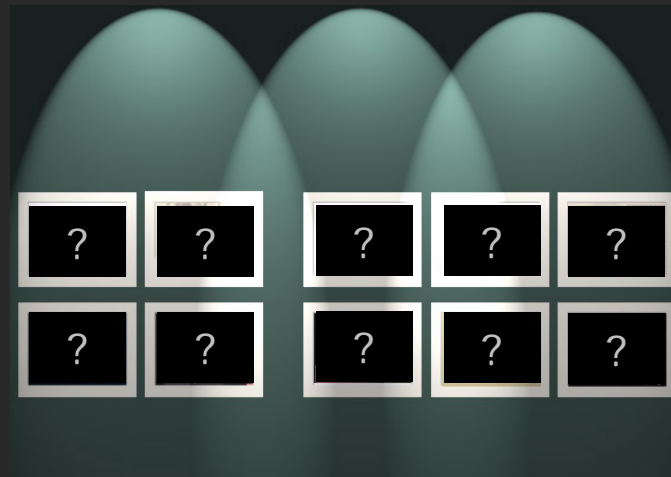
Four Existing Forecasts VERSUS Six Potential Science 'Weather' Forecasts



(3rd Iteration of Places & Spaces Exhibit - 2007)

Science Maps for Economic Decision Making

Four Existing Maps
VERSUS
Six Science Maps



(4th Iteration of Places & Spaces Exhibit - 2008)

Science Maps in Action

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

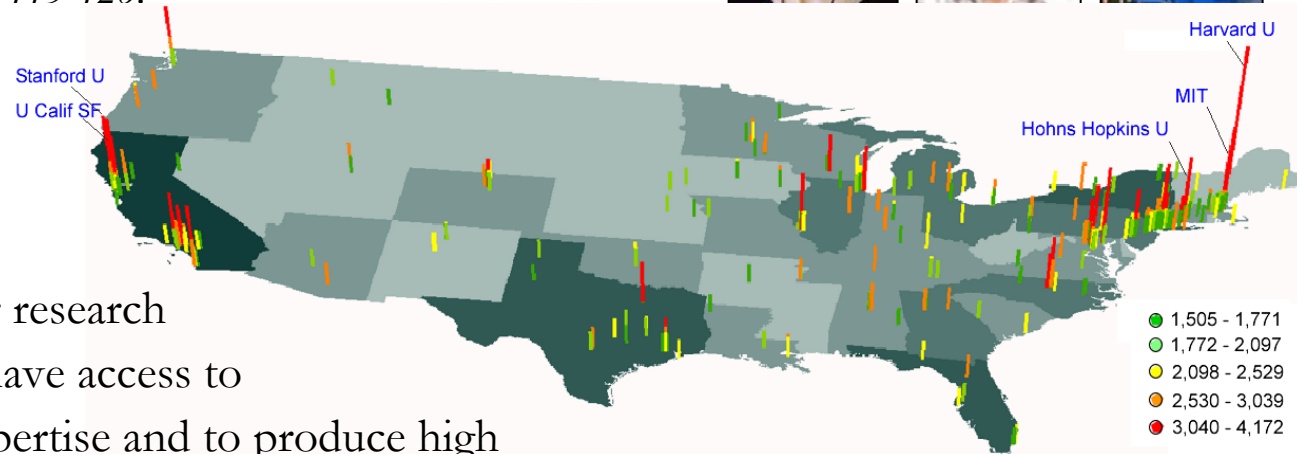
Research Institutions

Börner, Katy, Penumathy, 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.



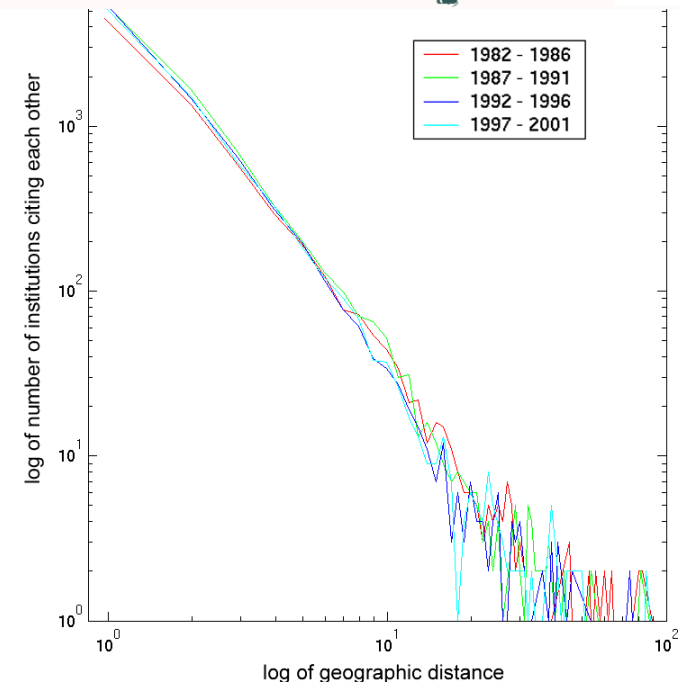
Research questions:

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:

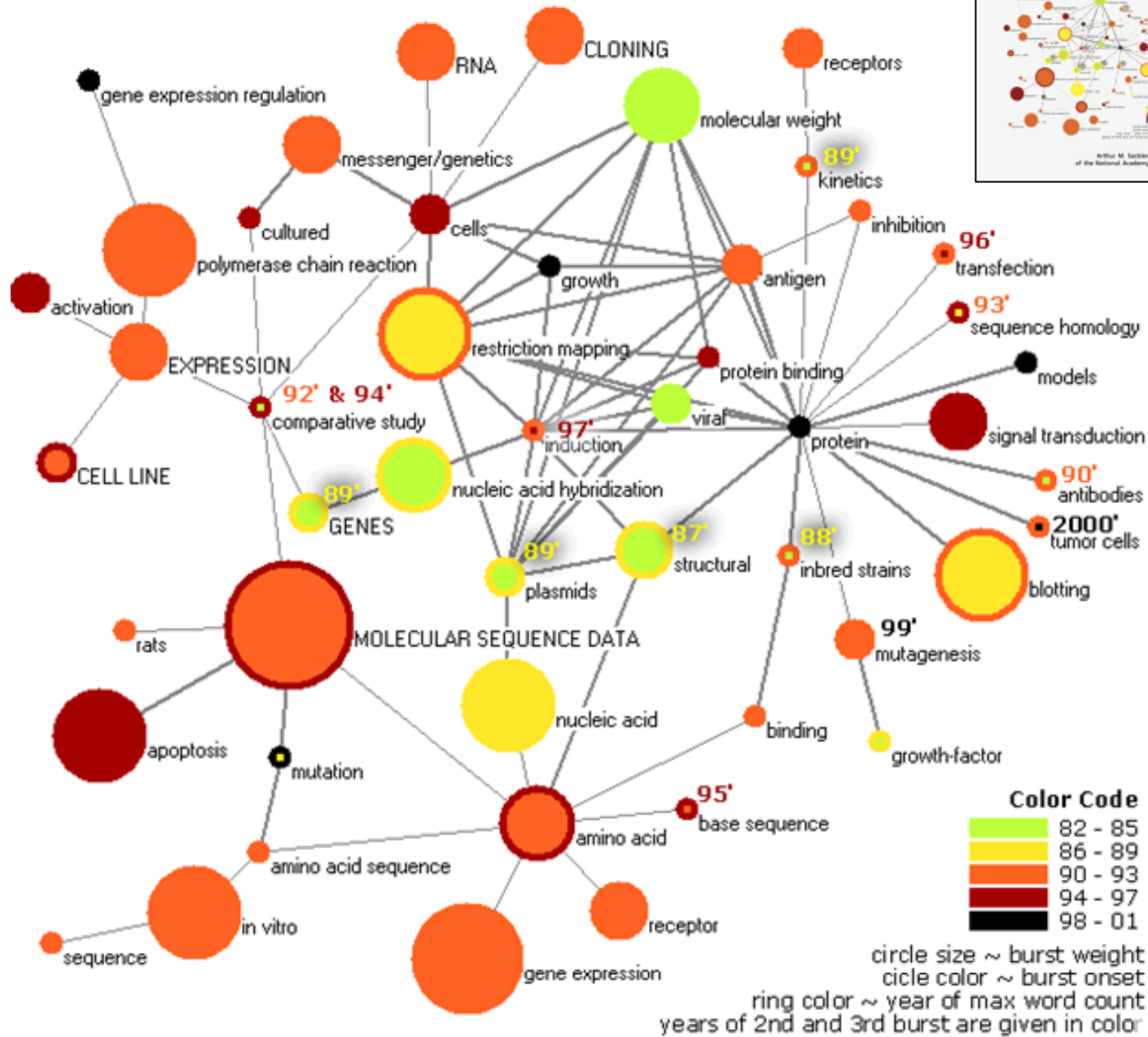
- Answer to Qs 1 + 2 is YES.
- Answer to Qs 3 is NO.
- Novel approach to analyzing the dual role of institutions as information producers and consumers and to study and visualize the diffusion of information among them.



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.*



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*)

113 Years of Physical Review

This visualization aggregates 100000 articles published in 100 volumes of Physical Review between 1915 and 2015. The 10,000 articles published from 1915 to 1918 make up the left portion of the map. In 1917 the Physical Review introduced the Physics and Astronomy Classification Scheme (PACS) codes and the visualization continues over the top row (PACS codes). The 20000 articles from 1919 to 2015, for which good citation data is not available, are mapped to the right side of the map. The blocks of articles from 2000 to 2015, for which good citation data is available, are not shown in this view.

Each vertical bar is a subfigure of articles in the journal that appear in it with height proportional to the number of citations, and each point is a subfigure of articles over the duration of the journal appearing in the volume.

On top of the tree map, all citations from the papers in early (see above PACS) codes in 2015 are mapped and then of top from the same year to the individual volume containing paper itself.

The small Nobel Prize medals indicate the 20 volumes containing the 20 papers appearing in Physical Review for 10 Nobel prizes between 1919 and 2015. Each year Thomson ISI provides three Nobel Prize winners in physics based on citation counts, high impact papers, and historical or thematic works of science recognition. Correct winners for Thomson ISI are highlighted.

Nobel Prizes in Physical Review

Year of Nobel Prize Winners Publication Year (indicated by color of each circle)

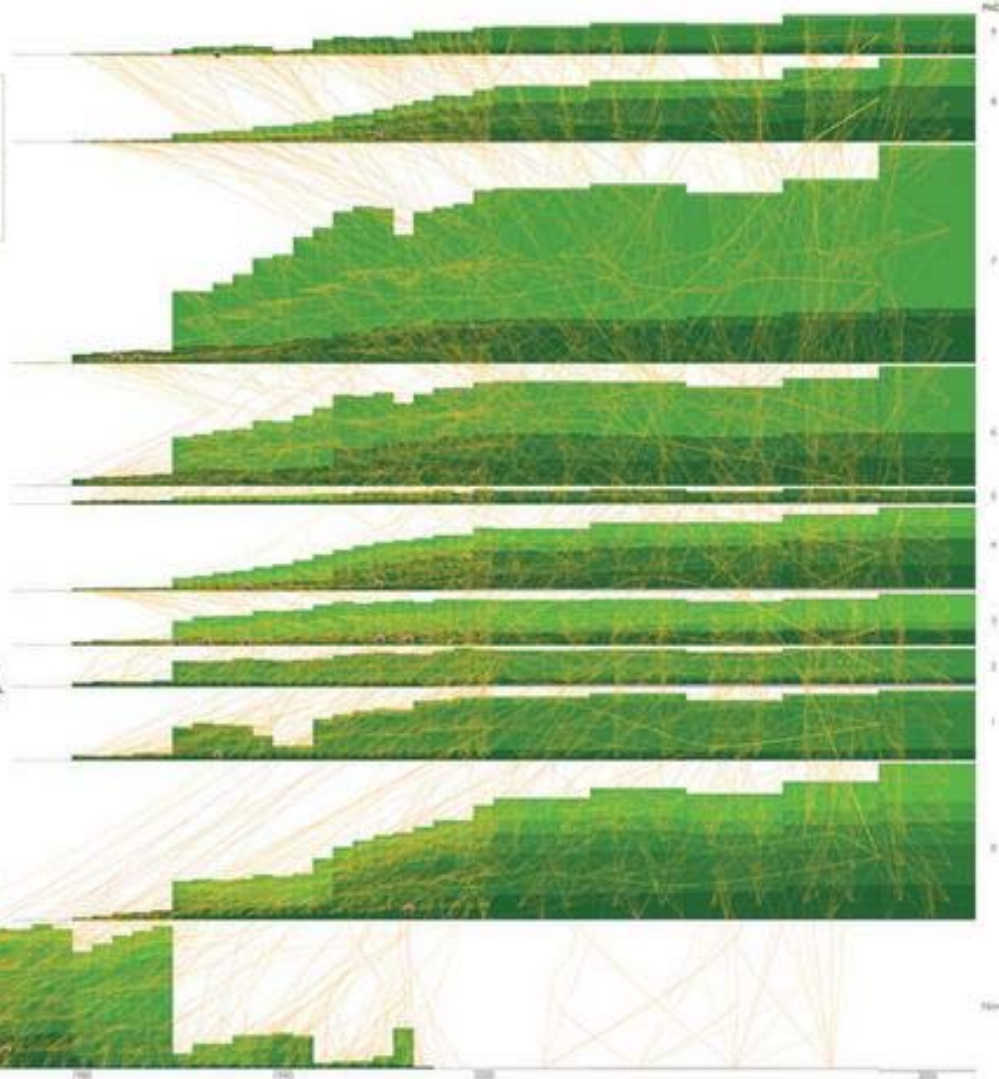
- 2004 Roy J. Chevalier, John L. Hall, and Theodor W. Hänsch (1917, 1917)
- 2004 David H. Green, H. David Pollock, and Frank Wilczek (1919)
- 2002 Anthony J. Leggett (1915)
- 2001 Raymond Davis Jr., Masatoshi Koshiba, and Riccardo Giacconi (1917, 1918, 1918)
- 2001 Eric A. Cornell, Wolfgang Ketterle, and Carl E. Wieman (1915, 1916)
- 1998 Robert B. Laughlin (1915, 1915)
- 1997 Steven Chu and William D. Phillips (1915, 1916, 1916)
- 1994 David H. Lee, Douglas D. Osheroff, and Robert C. Richardson (1915)
- 1991 Martin L. Perl (1915, 1917)
- 1994 Bertram F. Brinkhouse and Clifford G. Shull (1915, 1915)
- 1993 Jerome I. Friedman, Henry W. Kendall, and Richard E. Taylor (1917)

Bar Graph

- Physical Review
- Physical Review Series I
- Physical Review A
- Physical Review B
- Physical Review C
- Physical Review D
- Physical Review E
- Physical Review L
- Physical Review Special Topics Accelerated Beams
- Physical Review Physics Educational Research
- Physical Review Modern Physics

Lines

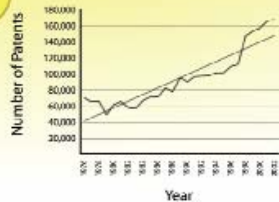
- PACS 0 General
- PACS 2 Interdisciplinary Physics and Related Areas of Science and Technology
- PACS 1 The Physics of Elementary Particles and Fields
- PACS 4 Electrodynamics, Optics, Acoustics, Heat, Transport, Classical Mechanics, and Fluid Dynamics
- PACS 2 Nuclear Physics
- PACS 3 Atomic and Molecular Physics
- PACS 5 Physics of Gases, Plasmas, and Electric Discharges
- PACS 9 Cosmology, Astrophysics, and Astrophysics
- PACS 6 Condensed Matter: Structure, Mechanical and Thermal Properties
- PACS 7 Condensed Matter: Electronic Structure, Electrical, Magnetic, and Optical Properties



Examining the Evolution and Distribution of Patent Classifications

1

Patents Granted Over the Last 20 Years



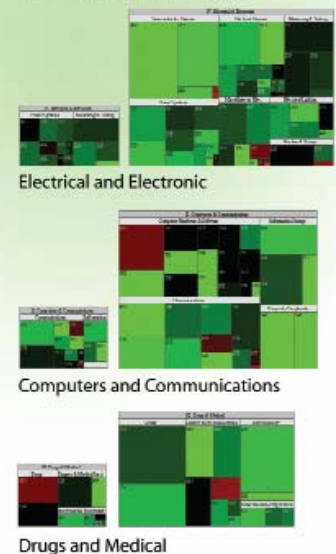
Top Classes 1978 - 1982		
Class	Title	Patents
280	Chemistry of Carbon Compounds	13,248
424	Drug Bio-Affecting and Body Treating Compositions	9,621
193	Compositions	6,868
191	Surgery	5,004
476	Stock Material or Miscellaneous Articles	4,991
75	Manufacturing and Testing	4,875
123	Internal-Combustion Engines	4,142
340	Communications/Electrical	4,043
354	Electrical Computers and Data Processing Systems	3,700
32	Metal Working	3,084
Total		50,105

Top Classes 1998 - 2002		
Class	Title	Patents
514	Drug Bio-Affecting and Body Treating Compositions	16,778
418	Chemical or Physical Manufacturing Process	12,775
415	Chemistry, Materials Biology and Microbiology	12,424
424	Drug Bio-Affecting and Body Treating Compositions	12,157
478	Stock Material or Miscellaneous Articles	11,514
357	Active Solid-State Devices (e.g., Transistors, Solid-State Diodes)	12,024
395	Information Processing System Organization	9,955
345	Computer Graphics Processing, Operator Interface Processing, and Selective Visual Display Systems	8,510
430	Optical Systems and Elements	5,151
385	Stels, Information Storage and Retrieval	6,202
Total		140,211

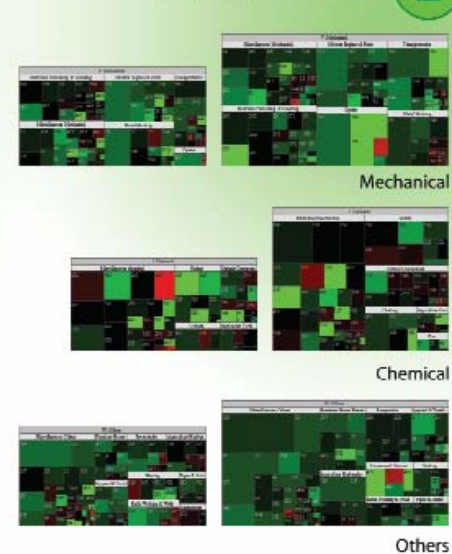
In the United States, each patent gets assigned to one out of more than 450 classes covering broad application domains. An examination of the size and growth of patent classes provides insight about patenting trends.

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.

Fast Growth Domains 1983 - 1987 / 1998 - 2002

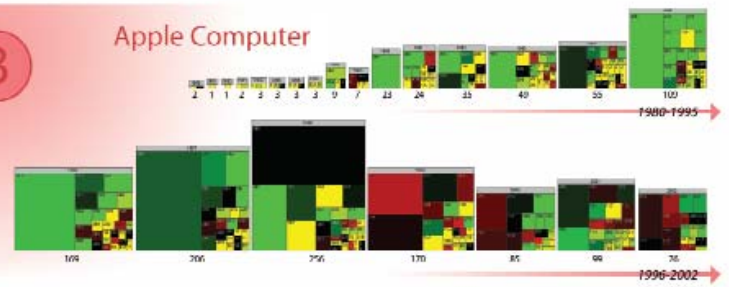


Slow Growth Domains 1983 - 1987 / 1998 - 2002



3

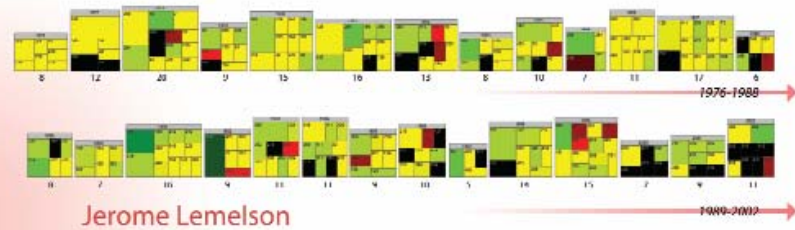
Apple Computer



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

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.

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.



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.

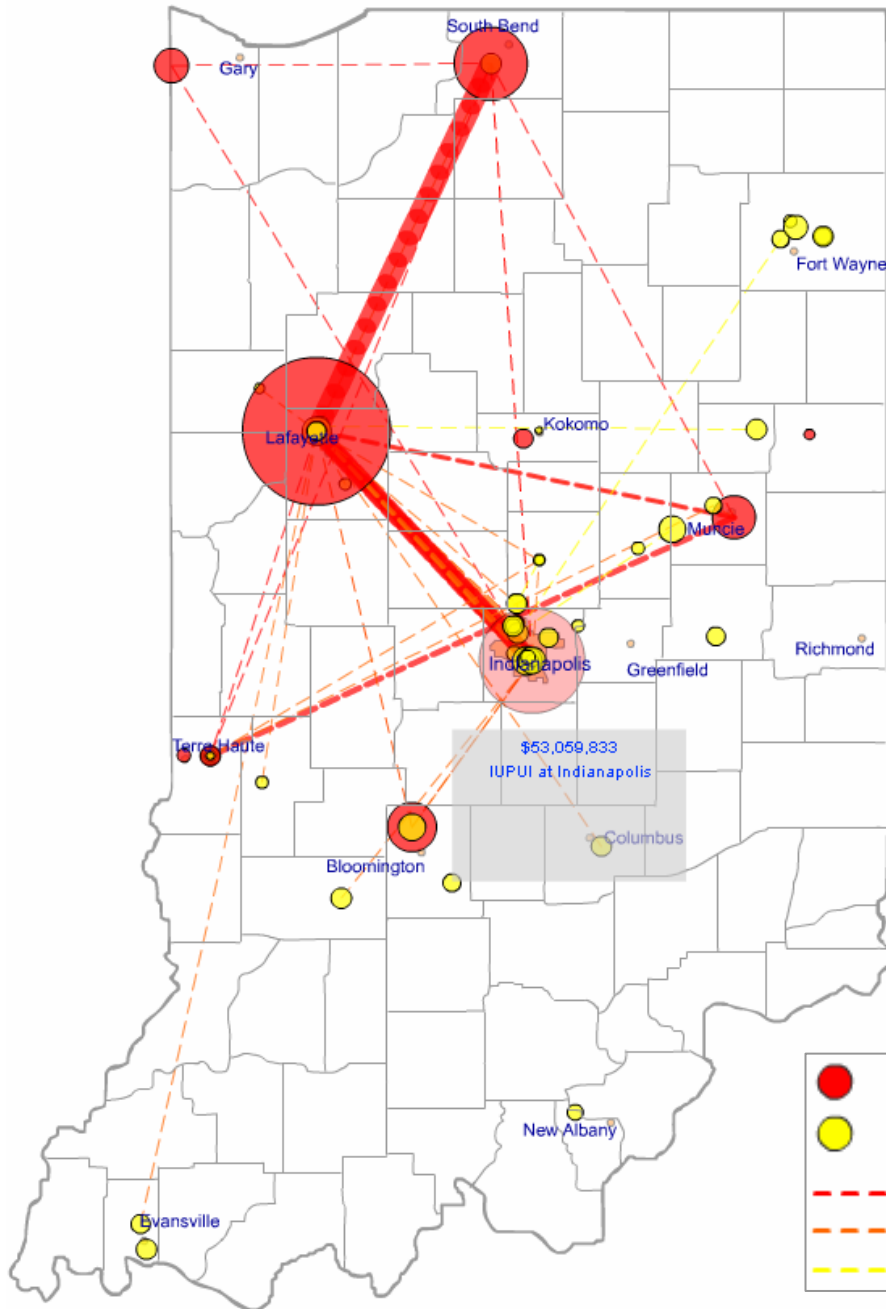


Kutz, Daniel O. Examining the Evolution and Distribution of Patent Classifications. Accepted for the Information Visualization Conference, London, UK, July 2004.

The material is based upon work supported by the National Science Foundation under Grant No. IIS-0238261.



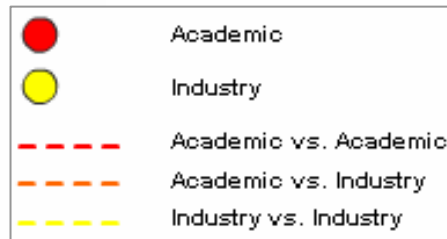
For more information, contact Katy Borner at katy@indiana.edu.



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

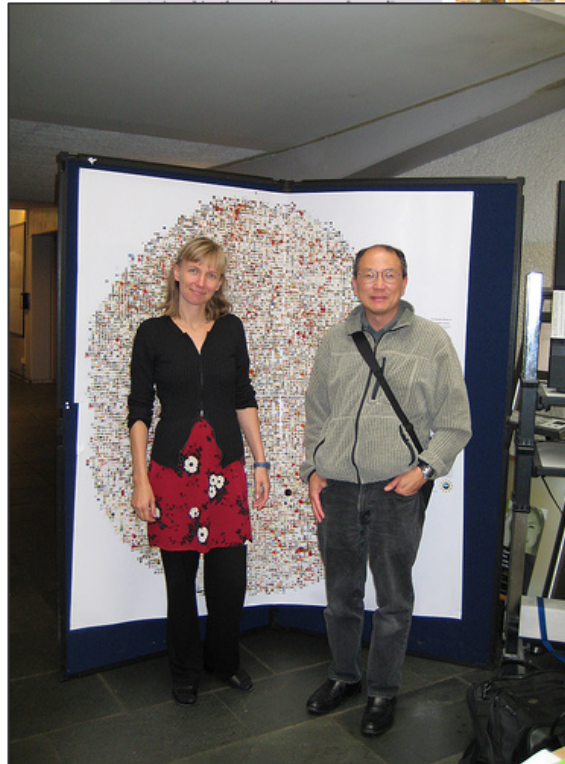


Second sight

Image: Bruce W. Herr and Todd M. Holloway

Power struggle

How do you keep track of the bubbling mass of information that is Wikipedia? This chaotic-looking mosaic is one attempt to show which topics are



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.



Science Related Wikipedian Activity

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

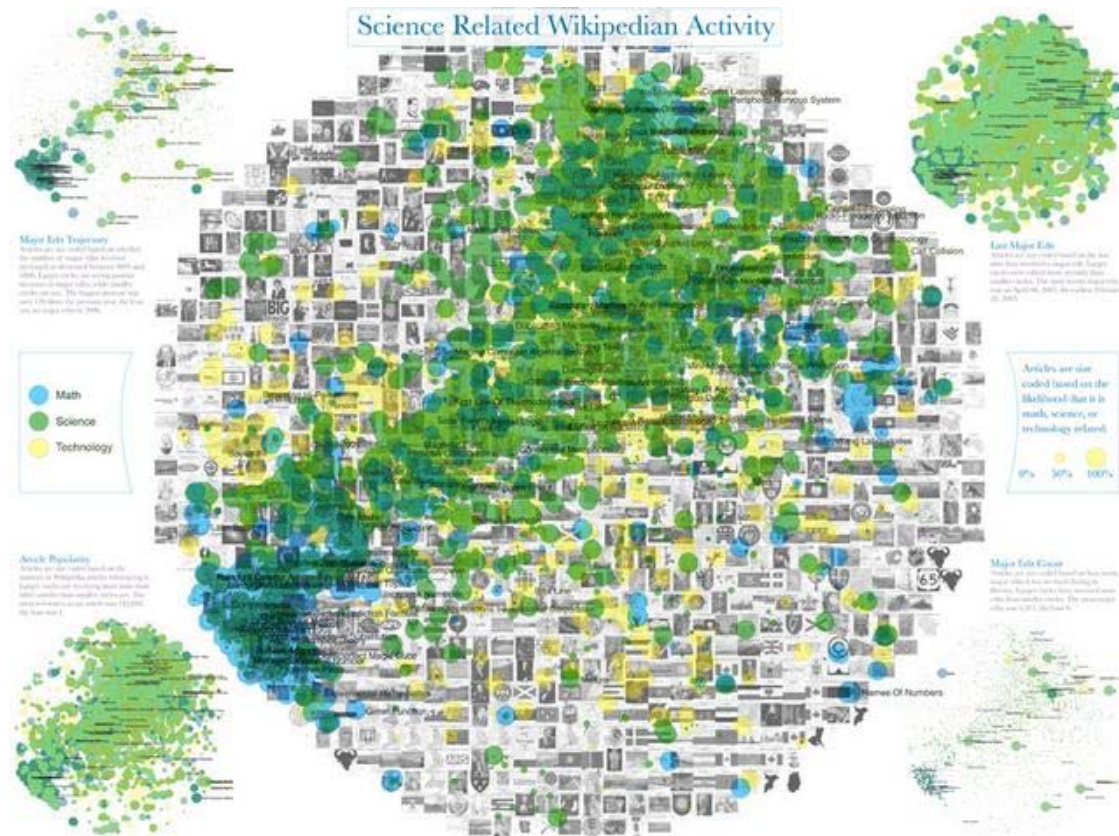
Same base map.

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 - Netscape

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http://scimaps.org/maps/neurovis/

Netscape Enter Search Terms Search Highlight Pop-Ups Blocked: 94 Form Fill Clear Browser History News

Society for Neuroscience, 2006 - Visual Bro...

**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 Pantel, Tommy Ingulfsen and Padhraic Smyth provided significant input for the theoretical and practical aspects of this study. We also acknowledge Katy Bomer at IU for all of her generous support for this project.

Map Data: Society for Neuroscience, 2006 - [Terms of Use](#)

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

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New Tab Society for Neuroscience, 2006 - Visual Bro...

Behavior, and Aetomy
Cognition and Behavior
Addictive and Drugs of Abuse
Cognition and Behavior
Behavior
Behavior and Anatomy
Human Cognition, Behavior and Anatomy Abuse
Cognition and Behavior
Cognitive, Emotional, and Behavioral State
Homeostatic and Neuroendocrine Systems
Cognition and Behavior
Cognition and Behavior
Cognitive, Emotional, and Behavioral State
Neurogenesis
Glutamate
Development
Disorders of the Nervous System
Neurodegenerative Disorders and Movement Dis
Cognitive, Emotional, and Behavioral State
Neurodegenerative Disorders and Movement Di
and Gated Ion Channels
Neurodegenerative Disorders and Movement Dis
Neurotoxicity, Inflammation, and Neuroprotect
Disorders of the Nervous System
Neurodegenerative Disorders and Movement Dis

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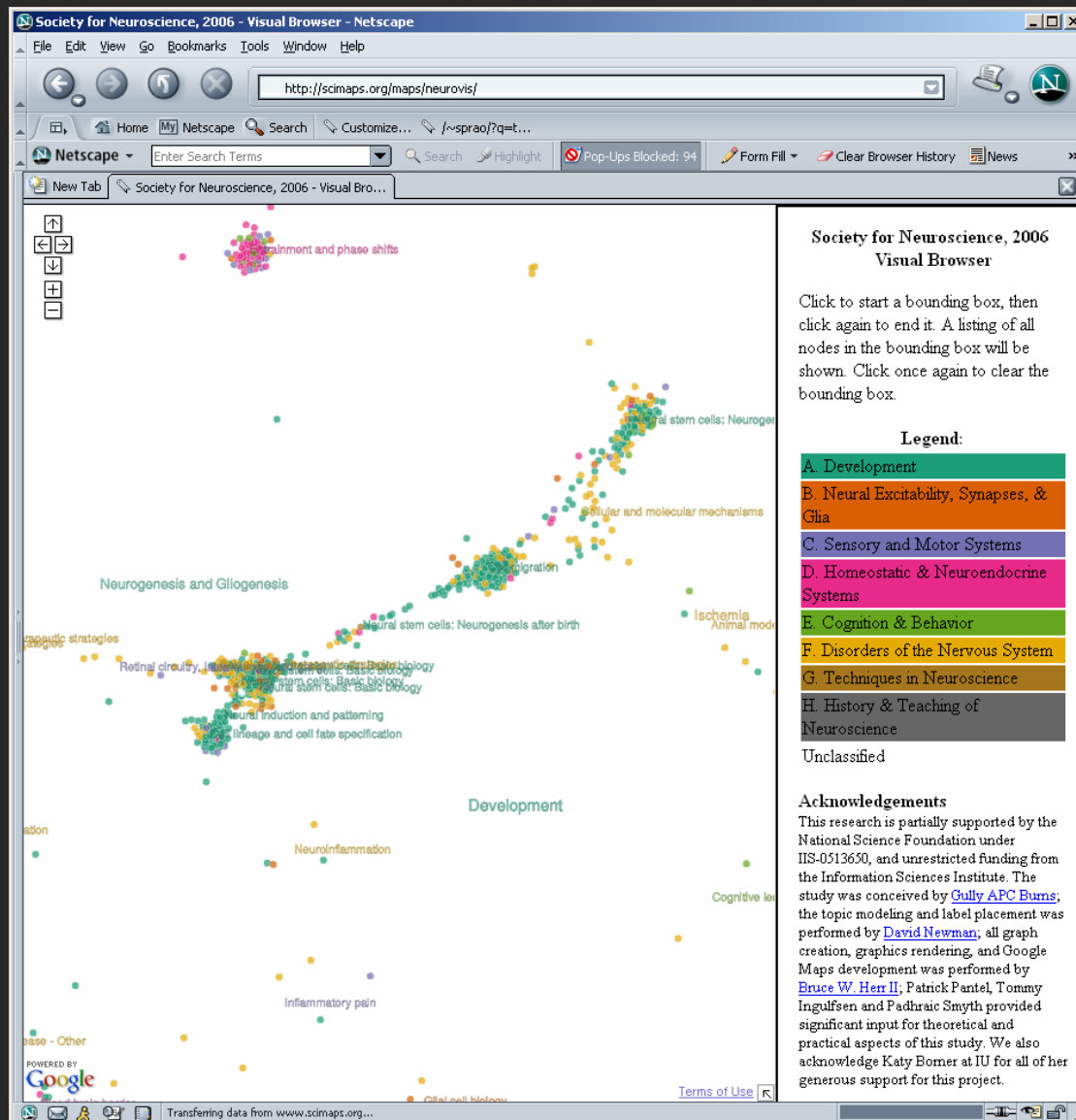
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Bruce W. Herr II, Gully Burns (USC), David Newman (UCI), Society for Neuroscience, 2006
 Visual Browser, 2007, <http://scimaps.org/maps/neurovis/>



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

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New Tab Society for Neuroscience, 2006 - Visual Bro...

Neurogenesis

HPG axis r

Neural stem cells: Neurogenesis after birth

Neuroinflammation

Development

Neuroinflammation

Axon growth and guidance: Other

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Society for Neuroscience, 2006
Visual Browser

2 matches in bounding box:

[228.22](#) - *Telencephalic Angiogenesis: Allegiance To Dorsove...* by A. Vasudevan P. G. Bhide

[221.12](#) - *Reduced Number Of Neural Stem Cells In The Embryo...* by Y. Fan M. Neumann S. Hong D. Lac P. Weinstein J.

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

Society for Neuroscience, 2006 - Visual Browser - Netscape

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Neurogenesis

HPG axis r

Neural stem cells: Neurogenesis after birth

Development

Neuroinflammation

Axon growth and guidance: Other

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Abstracts related to [Neuronal development and cell migration]

cell migration development zone brain cortical radial progenitor region developing migrate telencephalon postnatal migrating neocortex neuronal

(0.7%) [Multiple factors contribute to proper tangential migration during corticogenesis](#)

(0.7%) [RBP-1 maintains ependymal cell quiescence and inhibits neurogenesis in the adult brain](#)

(0.7%) [Alcohol exposure in utero affects the development of GABAergic cortical interneurons](#)

(0.7%) [Acute knockdown of amyloid precursor protein in the embryonic cortex inhibits neuronal migration](#)

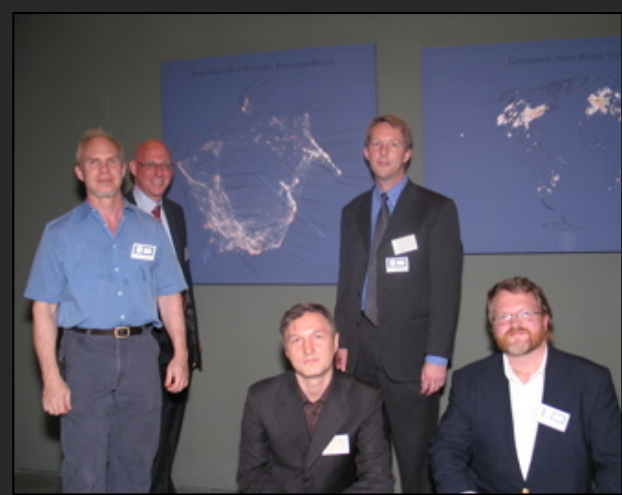
(0.7%) [Evolutionary aspects of p73 in Cajal-Retzius cells and the cortical hem](#)

(0.6%) [Reelin is necessary for appropriate migration into the cortical plate but not for proper radial glial morphology](#)

(0.6%) [Embryonic ePet-EYFP-labeled serotonergic neurons migrate by somal translocation from the ventricular zone to regions near the pia containing laminin](#)

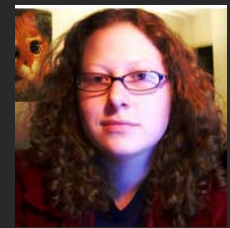
(0.6%) [Cortical stem cells coexist with striatal stem cells in the adult lateral ventricular](#)

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



Interested to get your own science map?
Contact the map makers!

katy@indiana.edu



The End.