Overview

Computational Scientometrics

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

Science of Science Cyberinfrastructures
- Scholarly Database (SDB)
- Network Workbench (NWB) Tool
- Science of Science (Sci²) Tool
- Mapping Science Exhibit
Computational Scientometrics:
Studying Science by Scientific Means


http://www.pnas.org/content/vol101/suppl_1/


http://scimaps.org/atlas
General Process of Analyzing and Mapping Science

<table>
<thead>
<tr>
<th>(1) Data Extraction</th>
<th>(2) Unit of Analysis</th>
<th>(3) Measures</th>
<th>(4) Similarity</th>
<th>(5) Ordination</th>
<th>(6) Display</th>
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<td>Searcher</td>
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<td>MEDLINE</td>
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<td>Funding</td>
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<td>Common Choices</td>
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<td>Author citations</td>
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<td>Co-citations</td>
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<td>By year</td>
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<td>Thresholds</td>
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<td>By counts</td>
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Latest ‘Base Map’ of Science


- 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

Funding patterns of the US Department of Energy (DOE)

Science map applications: Identifying core competency

Funding Patterns of the National Science Foundation (NSF)
Science map applications: Identifying core competency

Funding Patterns of the National Institutes of Health (NIH)

Opportunities

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

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

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

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

For Society
- Dramatically improved access to scientific knowledge and expertise.
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Information Diffusion Among Major U.S. Research Institutions

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

Contributions:
- Answer to Q1 is YES.
- Answer to Q2 is NO.
- Novel approach to analyzing the dual role of institutions as information producers and consumers and to study and visualize the diffusion of information among them.
20-Year PNAS Dataset (1982-2001)
Coverage in terms of time span, total number of papers, and complete author’s work

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

Information Sources (Export) and Sinks (Import)
Calculate ratio of the number of citations received by an institution divided by the sum of received citations and references made, multiplied by 100.

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

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

(Tobler, 1995)
**Geographic Location of Received Citations**

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

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

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

Dots indicate the five producers. Each has a different color, e.g., Harvard U is yellow. Dot area size depicts number of citations.

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

<table>
<thead>
<tr>
<th>Citing Institutions</th>
<th># Citations</th>
<th>Top Ten Producers</th>
</tr>
</thead>
</table>

Paper also shows top-5 producers and their top-10 consumers.
Changes in Citation Behavior Over Time

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

1982-1986: 1.94 (R=91.5%)
1987-1991: 2.11 (R=93.5%)
1992-1996: 2.01 (R=90.8%)
1997-2001: 2.01 (R=90.7%)

As time progresses and the amount of produced papers increases, space seems to matter more. Authors are more likely to cite papers generated by authors at close-by institutions.

Identifying Research Topics and Trends


Co-word space of the top 50 highly frequent and bursty words used in the top 10% most highly cited PNAS papers 1982-2001.

Words burst first before experiencing major usage. ‘Protein’ and ‘model’ are among the highly bursty terms in 98-01 and became major research topics since then.

Color Code
- 82 - 85
- 86 - 89
- 90 - 93
- 94 - 97
- 98 - 01

Circle size = burst weight
circle color = burst onset
ring color = year of main word count
years of 2nd and 3rd burst are given in color.
Modeling the Co-Evolving Author-Paper Networks


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

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

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

Model Assumptions

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

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

The TARL Model: The Effect of Parameters

- (0000) Topics
- (1000) Topics
- (0100) Co-Authors
- (0010) References

Topics lead to disconnected networks.

Co-authoring leads to fewer papers.
Counts for Papers and Authors

Counts for Citations

Table 2. Properties of co-author & paper citation networks, comprising number of nodes $n$, average node degree $\bar{k}$, path length $l$, clustering coefficient $c$, and power law exponent $\gamma$. Source references are given in the left column.

<table>
<thead>
<tr>
<th>Network</th>
<th>$n$</th>
<th>$\bar{k}$</th>
<th>$c$</th>
<th>$\gamma$</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-author networks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TANE</td>
<td>58,800</td>
<td>9.7</td>
<td>0.42</td>
<td></td>
<td>Newman</td>
</tr>
<tr>
<td>MEDLINE</td>
<td>1,520,571</td>
<td>18.1</td>
<td>4.6</td>
<td>0.046</td>
<td>7,000,000</td>
</tr>
<tr>
<td>SPRES</td>
<td>56,627</td>
<td>1.73</td>
<td>0.0</td>
<td>0.726</td>
<td>1.2</td>
</tr>
<tr>
<td>NUTIR</td>
<td>11,993</td>
<td>3.99</td>
<td>0.0</td>
<td>0.196</td>
<td></td>
</tr>
<tr>
<td>Math</td>
<td>78,929</td>
<td>3.9</td>
<td>0.0</td>
<td>0.199</td>
<td>2.5</td>
</tr>
<tr>
<td>Science &amp; Engineering</td>
<td>289,293</td>
<td>11.8</td>
<td>0.0</td>
<td>0.76</td>
<td>2.1</td>
</tr>
<tr>
<td>PNAS</td>
<td>385,915</td>
<td>8.97</td>
<td>3.49</td>
<td>0.199</td>
<td>2.54</td>
</tr>
<tr>
<td>Paper citation networks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PNAS</td>
<td>43,210</td>
<td>2.53</td>
<td>--</td>
<td>0.011</td>
<td>2.29</td>
</tr>
<tr>
<td>SIM</td>
<td>37,214</td>
<td>2.33</td>
<td>--</td>
<td>0.013</td>
<td>2.05</td>
</tr>
</tbody>
</table>
Topics: The number of topics is linearly correlated with the clustering coefficient of the resulting network: \[ C = 0.000073 \times \#\text{topics} \]. Increasing the number of topics increases the power law exponent as authors are now restricted to cite papers in their own topics area.

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

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

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Scholarly Database: Web Interface

Search across publications, patents, grants. Download records and/or (evolving) co-author, paper-citation networks.

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

Katy Börner: Mapping Science
Since March 2009:

Users can download networks:
- Co-author
- Co-investigator
- Co-inventor
- Patent citation
and tables for
burst analysis in NWB.

Scholarly Database: # Records, Years Covered

Datasets available via the Scholarly Database (* internally)

<table>
<thead>
<tr>
<th>Dataset</th>
<th># Records</th>
<th>Years Covered</th>
<th>Updated</th>
<th>Restricted Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medline</td>
<td>17,764,826</td>
<td>1898-2008</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>PhysRev</td>
<td>398,005</td>
<td>1893-2006</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>PNAS</td>
<td>16,167</td>
<td>1997-2002</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>USPTO</td>
<td>3,875,694</td>
<td>1976-2008</td>
<td>Yes*</td>
<td></td>
</tr>
<tr>
<td>NSF</td>
<td>174,835</td>
<td>1985-2002</td>
<td>Yes*</td>
<td></td>
</tr>
<tr>
<td>NIH</td>
<td>1,043,804</td>
<td>1961-2002</td>
<td>Yes*</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23,167,642</td>
<td>1893-2006</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

Aim for comprehensive time, geospatial, and topic coverage.
The Network Workbench (NWB) tool supports researchers, educators, and practitioners interested in the study of biomedical, social and behavioral science, physics, and other networks.

In Aug. 2009, the tool provides more 160 plugins that support the preprocessing, analysis, modeling, and visualization of networks.

It has been downloaded more than 35,000 times since December 2006.

### Project Details

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

**Software Team:**
- **Lead:** Micah Linnemeier
- **Members:** Patrick Phillips, Russell Duhon, Tim Kelley & Ann McCranie

**Previous Developers:** Weixia (Bonnie) Huang, Bruce Herr, Heng Zhang, Duygu Balcan, Bryan Hook, Ben Markines, Santo Fortunato, Felix Terkhorn, Ramya Sabbineni, Vivek S. Thakre & Cesar Hidalgo

**Goal:** Develop a large-scale network analysis, modeling and visualization toolkit for physics, biomedical, and social science research.

**Amount:** $1,120,926, NSF IIS-0513650 award

**Duration:** Sept. 2005 - Aug. 2009

**Website:** [http://nwb.slis.indiana.edu](http://nwb.slis.indiana.edu)

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### Project Details (cont.)

**NWB Advisory Board:**
- Jason Leigh (CI) [http://www.evl.uic.edu/spiff/](http://www.evl.uic.edu/spiff/)
- Neo Martinez (Biology) [http://online.sfsu.edu/~webhead/](http://online.sfsu.edu/~webhead/)
- Michael Macy, Cornell University (Sociology) [http://www.soc.cornell.edu/faculty/macy.shtml](http://www.soc.cornell.edu/faculty/macy.shtml)
- Ulrik Brandes (Graph Theory) [http://www.inf.uni-konstanz.de/~brandes/](http://www.inf.uni-konstanz.de/~brandes/)
- Mark Gerstein, Yale University (Bioinformatics) [http://bioinfo.mbb.yale.edu/](http://bioinfo.mbb.yale.edu/)
- Tom Snijders, University of Groningen [http://stat.gamma.rug.nl/snijders/](http://stat.gamma.rug.nl/snijders/)
- Noshir Contractor, Northwestern University [http://www.spcomm.uiuc.edu/nosh/](http://www.spcomm.uiuc.edu/nosh/)
CIShell – Serving Non-CS Algorithm Developers & Users

Developers

CIShell

Users

CIShell Wizards

IVC Interface

CIShell

NWB Interface

CIShell – Builds on OSGi Industry Standard

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

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

- A standardized, component oriented, computing environment for networked services.
- Successfully used in the industry from high-end servers to embedded mobile devices since 8 years.
- Alliance members include IBM (Eclipse), Sun, Intel, Oracle, Motorola, NEC and many others.
- Widely adopted in open source realm, especially since Eclipse 3.0 that uses OSGi R4 for its plugin model.

Advantages of Using OSGi

- Any CIShell algorithm is a service that can be used in any OSGi-framework based system.
- Using OSGi, running CIShells/tools can 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.
NWB Tool: Supported Data Formats

**Personal Bibliographies**
- Bibtex (.bib)
- Endnote Export Format (.enw)

**Data Providers**
- Web of Science by Thomson Scientific/Reuters (.isi)
- Scopus by Elsevier (.scopus)
- Google Scholar (via Publish or Perish save as CSV, Bibtex, EndNote)
- Awards Search by National Science Foundation (.nsf)

**Scholarly Database** (all text files are saved as .csv)
- Medline publications by National Library of Medicine
- NIH funding awards by the National Institutes of Health (NIH)
- NSF funding awards by the National Science Foundation (NSF)
- U.S. patents by the United States Patent and Trademark Office (USPTO)
- Medline papers – NIH Funding

**Network Formats**
- NWB (.nwb)
- Pajek (.net)
- GraphML (.xml or .graphml)
- XGMML (.xml)

**Burst Analysis Format**
- Burst (.burst)

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

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NWB Tool: Algorithms (July 1st, 2008)
See [https://nwb.slis.indiana.edu/community](https://nwb.slis.indiana.edu/community) and handout for details.
NWB Tool: Output Formats

- NWB tool can be used for data conversion. Supported output formats comprise:
  - CSV (.csv)
  - NWB (.nwb)
  - Pajek (.net)
  - GraphML (.xml or .graphml)
  - XGMML (.xml)
  - GUESS
    Supports export of images into common image file formats.
  - Horizontal Bar Graphs
  - saves out raster and ps files.

Sci² Tool for Science of Science Research and Practice

Acknowledgments
This work is supported in part by the Cyberinfrastructure for Network Science center and the School of Library and Information Science at Indiana University, the National Science Foundation under Grant No. 3EE-0728311 and HSS-0539000, and the James S. McDonnell Foundation.
Preprocessing
- Extract Top N% Records
- Extract Top N Records
- Normalize Text
- Slice Table by Line
- Extract Top Nodes
- Extract Nodes Above or Below Value
- Delete Isolates
- Extract top Edges
- Extract Edges Above or Below Value
- Remove Self Loops
- Trim by Degree
- MST-Pathfinder Network Scaling
- Fast Pathfinder Network Scaling
- Snowball Sampling (in nodes)
- Node Sampling
- Edge Sampling
- Symmetrize
- Dichotomize
- Multipartite Joining
- Geocoder
- Extract ZIP Code

Modeling
- Random Graph
- Watts-Strogatz
- Small World
- Barabási-Albert Scale-Free
- TAR

Analysis
- Network Analysis Toolkit (NAT)
- Node Degree
- Degree Distribution
- K-Nearest Neighbor (Java)
- Watts-Strogatz Clustering Coefficient
- Watts Strogatz Clustering Coefficient over K
- Diameter
- Average Shortest Path
- Shortest Path Distribution
- Node Betweenness Centrality
- Weak Component Clustering
- Global Connected Components
- Extract K-Core
- Annotate K-Coreness
- HITS

Weighted & Undirected
- Clustering Coefficient
- Nearest Neighbor Degree
- Strength vs Degree
- Degree & Strength
- Average Weight vs End-point Degree
- Strength Distribution
- Weight Distribution
- Randomize Weights
- Blondel Community Detection
- HITS
- Unweighted & Directed
- Node Indegree
- Node Outdegree
- Indegree Distribution
- Outdegree Distribution
- K-Nearest Neighbor
- Single Node in-Out Degree Correlations
- Dyad Reciprocity
- Arc Reciprocity
- Adjacency Transitivity
- Weak Component Clustering
- Strong Component Clustering

Visualization
- GnuPlot
- GUESS
- Image Viewer
- Radial Tree/Graph (prefuse alpha)
- Radial Tree/Graph with Annotation
  (prefuse beta)
- Tree View (prefuse beta)
- Tree Map (prefuse beta)
- Force Directed with Annotation
  (prefuse beta)
- Fruchterman-Reingold with Annotation
  (prefuse beta)
- DrL (VxOrd)
- Specified (prefuse beta)

Scientometrics
- Remove ISI Duplicate Records
- Remove Rows with Multitudinous Fields
- Detect Duplicate Nodes
- Update Network by Merging Nodes
- Extract Directed Network
- Extract Paper Citation Network
- Extract Author Paper Network
- Extract Co-Occurrence Network
- Extract Word Co-Occurrence Network
- Extract Co-Author Network
- Extract Reference Co-Occurrence
  (Bibliographic Coupling) Network
- Extract Document Co-Citation Network

Textual
- Burst Detection

Sci² Tool: Algorithms
See https://nwb.slis.indiana.edu/community

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

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

General Network extraction

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Sci² Tool

Plugins that render into Postscript files:

Sci Maps

Geo Maps

Horizontal Time Graphs


Temporal: Horizontal Bargraphs

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

Text, e.g., title

Start date

End date
 Topic Mapping: UCSD Science Map

Journal locations for FourNetSciResearchersusi

342 journal references matched out of 361 found.

These 342 references are associated with 13 of 13 disciplines of science and 238 of 534 research specialties in the UCSD Map of Science.

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Science of Science Cyberinfrastructure

Provided by the Cyberinfrastructure for Networked Science Center at Indiana University.

Introduction

E. O. W. was written in Crossword: The View of the Universe (1963). "Features that distinguish science from pseudoscience are reproducibility, economy, measurement, learning, and beauty." Please see Science's current applications at the A Diagram: A deeper look at the Visualisation of Concept Discovery. For Workshop: A general introduction to the needs and the resources provided here.

Needs Analysis

As part of the "Science: An Introduction to Scientific Research," Grant numbers 520-031333 and 520-031334 is a series of interviews with science policy makers. Interviews with leaders in space science and engineering. Interviews are conducted to identify who will make a significant contribution to science policy at various levels, including government, state, and local levels. Data compilation will start in October 2008 and resulting report can be ordered by sending a request to Tom Przeworski (tom.p@indiana.edu).

Conceptualization of Science


Scholarly Database

The Science of Science Cyberinfrastructure (SOCS) at Indiana University aims to serve researchers and scholars interested in the analysis, modeling, and visualization of large-scale scholarly datasets. The database currently provides access to over 20 million papers, patents, and grants. Resulting datasets can be downloaded in bulk. Register for free access at https://wdb-ai.Indiana.edu.

Cyberinfrastructure

The Science of Science Cyberinfrastructure (SOCS) at Indiana University aims to serve researchers and scholars interested in the analysis, modeling, and visualization of large-scale scholarly datasets. The database currently provides access to over 20 million papers, patents, and grants. Resulting datasets can be downloaded in bulk. Register for free access at https://wdb-ai.Indiana.edu.

http://sci.slis.indiana.edu
Mapping Science Exhibit – 10 Iterations in 10 years

The Power of Maps (2005)


The Power of Forecasts (2007)

Science Maps for Economic Decision Makers (2008)

Science Maps for Science Policy Makers (2009)

Science Maps for Scholars (2010)

Science Maps for Science Policy Makers (2009)

Science Maps for Kids (2012)

Science Forecasts (2013)

How to Lie with Science Maps (2014)

Exhibit has been shown in 72 venues on four continents. Currently at:
- NSF, 10th Floor, 4201 Wilson Boulevard, Arlington, VA
- Wallenberg Hall, Stanford University, CA
- Center of Advanced European Studies and Research, Bonn, Germany
- Science Train, Germany.

Illuminated Diagram Display


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

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

<table>
<thead>
<tr>
<th>All Topics</th>
<th>Nanotechnology</th>
<th>Sustainability</th>
<th>Science</th>
<th>Chemistry</th>
<th>Nanotechnology in Science and Society</th>
<th>Francis H. C. Crick</th>
<th>Albert Einstein</th>
<th>Michael E. Fisher</th>
<th>Susan T. Fiske</th>
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<tbody>
<tr>
<td>Energy through all scientific disciplines</td>
<td>Soldier</td>
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A single person's spreading influence is shown as a series of four spotlights. First, we light only topics and places related to that person's work. Then we shift to people that are still highly cited today. The second spotlight shows who cited that original work. Note that the third-generation impact extends to far more topics than did the original work. The fourth spotlight shows who cited the second, and the fourth lights science that cites the third.

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

http://www.expedition-zukunft.de
Debut of 5th Iteration of Mapping Science Exhibit at MEDIA X was on May 18, 2009 at Wallenberg Hall, Stanford University, [http://mediax.stanford.edu](http://mediax.stanford.edu), [http://scaleindependentthought.typepad.com/photos/scimaps](http://scaleindependentthought.typepad.com/photos/scimaps)

This is the only mockup in this slide show.

Everything else is available today.