Places & Spaces: Mapping Science
An International Exhibit
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Statewide IT Conference at Indiana University, Bloomington, IN
September 24, 2012

May 1–30, 2007: Exhibit is on display at the Monroe County Public Library, Bloomington, Indiana
Thanks to Margaret Harter, Julie Smith
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Find your way

Find collaborators, friends

Identify trends

Black Box

Take terra bytes of data
**Temporal Analysis**

Science evolves over time. Attributes values of scholarly research and their various symbols increase and decrease at different rates and require different rates to be observed in the internal and external environment. Temporal analysis is critical to examining the evolution of phenomena represented by a sequence of observations such as careers, trends, measurements, collections, and habits of others.

**Data**

A time series is a sequence of events or observations that are ordered in time. These can be measured to form a time series at any point in time or at a specific point in time that captures the characteristics of time series. This series may be made up of data from statistical models or from observational data. Temporal aggregation — that is, temporal statistics, years, years — are common.

**Algorithms**

Frequently, some form of filtering is applied to reduce noise and make patterns more evident. Trending images using a moving average of a certain width and zero or some approximation might be applied. The number of scholarly recordings is often plotted to give a feel for the temporal distribution of a variable. It might be done in a variety of ways to show the number of scholarly works that have been published in a time series. The trends might be made up of data from statistical models or from observational data. Temporal aggregation — that is, temporal statistics, years, years — are common.

**Topical Analysis**

The topic coverage and topical similarity of basic and aggregative units of science (such as institutions) can be derived from the data and related with them (papers, patents, articles). This analysis is important to identify the evolution of topics over time and to understand the impact of new topics on existing ones.

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**Algorithms**

Some algorithms are used to analyze the data and to identify the evolution of topics over time. These algorithms are based on statistical models and can be applied to derive the topical coverage and topical similarity of basic and aggregative units of science (such as institutions). The results of these algorithms can be used to understand the evolution of topics over time and to identify the impact of new topics on existing ones.

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**First Iteration of Exhibit (2005): The Power of Maps**

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

The first iteration of the "Power of Maps" demonstrates how maps help us to understand, navigate, and manage both physical and abstract knowledge spaces. Early maps of our world were certainly neither complete nor perfect, yet they proved invaluable for explorers. As keys to navigation, exploration, and communication, maps helped explorers find promising new lands while avoiding sea monsters.

Maps of science today are based on limited knowledge and therefore imperfect. In order to generate comprehensive maps that are entirely accurate and complete, we need to have a better understanding of the inter- and multidisciplinary, and multimedia scholarly knowledge spaces. The first pictures of Earth from space were experiential in the perception of life and the cosmos. As our understanding of science is increasing, we appreciate and apply scientific thinking in areas that may not have been explored before. The "Power of Maps" is an example of how maps can be used to explore the evolution of topics over time and to understand the impact of new topics on existing ones.

**Network Analysis**

The study of networks involves the analysis of the relationships between the nodes in a network. Network analysis can be used to study the evolution of topics over time and to understand the impact of new topics on existing ones. The results of network analysis can be used to identify the evolution of topics over time and to understand the impact of new topics on existing ones.
The Structure of Science


Four Existing Reference Systems Versus Six Potential Reference Systems

This iteration aims to inspire discussion about a common reference system for all existing scholarly knowledge. Throughout history, scientists have battled to agree on standardized reference systems for their respective fields of research. These standards are invaluable for indexing, storing, accessing, and managing scientific data efficiently.

Results include the description of the electromagnetic periodic table of elements, geographic projections, and systems, shown here. Note that the geographic maps from paper to geographic information systems (GIS) for public use and consumption.

In comparison to these four existing systems are six potential reference systems for scholarly knowledge. Each reference system is shown as a timeline and the geographic to the system used to identify the location of an author, paper, jurisdiction or contribution.
The Visual Elements Periodic Table

Evening Stars

How to Use a Sky Map

1. Check the date and time of night. Turn your map out under the dark sky, and keep turning clockwise around it. There are diagrams on the back of the map to help you do this.

2. Before you use the map, you need to know which direction north is. If you live near the north pole and the only stars you can see are the ones in your map, then the north pole is the one you want.

3. Let's do it! Point your thumb at the constellation (in this case, the Big Dipper) and move it clockwise around your map. If you put your thumb on the north pole of the sky, the Big Dipper will look like it's turning.
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. The map shows 376 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 80,000 papers referenced in this atlas. Clustering at each level was done using Lineral, a force-directed graph layout algorithm. These papers formed 53,000 clusters, 1,000 higher-level clusters, and finally the 376 paradigms. Although each paradigm contains an average of 1,000 papers, some are larger and some are smaller, as shown by the different spot sizes on the map.

The ring-one structure in formed by scientific paradigms is very robust. We have tested similar structures for different years, and for papers generated from scientific journals. "The Structure of Science", a galaxy map shows the first iteration of Fitz and Spinos, 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 trends to a discipline center, while this map can show the breadth and depth of disciplines that contribute to single paradigms. Because of the robust nature of the structure of science and its paradigms, we have placed our 376 scientific paradigms within a reference system containing 18 radially aligned rings. This allows the problem of each paradigm to be studied and available for lookup, for instance Field Mechanics paradoxes are in ring 03. 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. Field-growth is 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 common in the social sciences, ecological sciences, computer sciences, and mathematics. The red circles represent communities where consensus is reached relatively rapidly. This is more common in physics, chemistry, biochemistry, and many medical disciplines, very high circles (such as those in Astronomy, 1.84) represent communities where consensus is reached extremely quickly.

The map of scientific paradigms and its reference system can be used for multiple purposes. Communities, industries, companies, organizations, 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 finding areas and facts to the map that highlight scientific history, current advances and relationships between scientific paradigms.
Third Iteration of Exhibit (2007): The Power of Forecasts

Four Existing Forecasts Versus Six Science Forecasts

The third iteration of the exhibit compares and contrasts seismic hazard, economic, resource depletion, and epidemic forecast maps with maps forecasting the structure and evolution of science.

Real-time weather forecasts are served by the National Oceanic and Atmospheric Administration (NOAA) or the National Aeronautics and Space Administration (NASA). Computational models of the movements of tectonic plates help reduce losses due to earthquake and tsunami. Epidemic models make us understand and how actions far away affect us right here. Each catastrophic and sustainable futures for mankind.

Daily science and technology forecasts would serve the interests of top experts/institutions/countries, major activity frontiers, augmenting our knowledge and decision-making available on TV, in the press, and online?
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>Biology &amp; Chemistry</th>
<th>Francis H. C. CRICK</th>
<th>Albert EINSTEIN</th>
<th>Michael E. FISHER</th>
<th>Susan T. FISKE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweep through all 75 scientific paradigms</td>
<td>Science at the tiny scale of molecules</td>
<td>The science behind our long-term hopes</td>
<td>The interface between these two vital fields</td>
<td>Co-discovered DNA double helix</td>
<td>Renalized physics with relativity theories</td>
<td>Models critical phase transitions of matter</td>
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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 light 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 a science that cites the second, and the fourth lights a 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

**Topic Map: How Scientific Paradigms Relate**
Mapping Science Exhibit – 10 Iterations in 10 years

http://scimaps.org/

The Power of Maps (2005)

Science Maps for Economic Decision Makers (2008)


Science Maps for Science Policy Makers (2009)

The Power of Forecasts (2007)

Science Maps for Scholars (2010)

Science Maps as Visual Interfaces to Digital Libraries (2011)

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
- Center of Advanced European Studies and Research, Bonn, Germany
- Science Train, Germany
- Cultural Dimensions of Innovation, UCD Conference, Dublin, Ireland
Illuminated Diagram Display on display at the Smithsonian in DC.
http://scimaps.org/exhibit_info/#1D
Science Maps for Economic Decision Making

Four Existing Maps VERSUS Six Science Maps

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

Joseph Minard, Title: Europe Raw Cotton Imports in 1858, 1864 and 1865 (1866)
What insight needs to economic decision makers have?

What data views are most useful?
Science Maps for Science Policy Making

Four Existing Maps VERSUS Six Science Maps

(5th Iteration of Places & Spaces Exhibit - 2009)

Chemical Research & Development
Powers the U.S. Innovation Engine

INVESTMENT IN CHEMICAL SCIENCE R&D

$1 Billion
FEDERAL GOVERNMENT

$5 Billion
INDUSTRY FUNDING

$8 Billion
TAXES

$10 Billion
CHEMICAL INDUSTRY OPERATING INCOME

$40 Billion
GROWTH IN GNP

600,000
JOBS CREATED

TImELINE FROM CONCEPTION TO COMMERCIALIZATION

$1B + $5 Billion
20 YEARS

The Council for Chemical Research (CCR) was created by the U.S. Congress and is a coalition of about 200 research universities, companies, and scientific societies. CCR promotes the importance of chemical research and development and its impact on the economy. This image illustrates the economic impact of chemical research and development through a series of charts and graphs. The top chart shows the distribution of funding for chemical research and development, with a significant portion coming from industry. The middle chart depicts the timeline from conception to commercialization, highlighting the long-term benefits of chemical research. The bottom chart illustrates the economic impact, with $10 billion in chemical industry operating income and $40 billion in growth in GNP. The image clearly demonstrates the importance of chemical research and development in driving innovation and economic growth.
Science Maps for Scholars

Four Existing Maps VERSUS Six Science Maps

(6th Iteration of Places & Spaces Exhibit – 2010)
Science Maps as Visual Interfaces to Digital Libraries

Four Existing Maps
VERSUS
Six Science Maps

(7th Iteration of Places & Spaces Exhibit – 2011)

H.J.T. Ellingham (1948) A Chart Illustrating Some of the Relations between the Branches of Natural Science and Technology.
Design vs. Emergence: Visualization of Knowledge Orders


We would like to thank the map makers

References


Scharnhorst, Andrea, Börner, Katy, van den Besselaar, Peter (2011) Models of Science Dynamics. Springer Verlag

Related Talks

Monday

3:30pm
Online Interactive Map: Say goodbye to tabular representation
Chin Hua Kong and Katy Börner

5pm
Places & Spaces: Mapping Science
Katy Börner, Michael Stamper, and Samantha Hale

Tuesday

9:30am
Plug-and-play visualization with the Science of Science Tool
David Polley, Chin Hua Kong, and Katy Börner

11:30am
VIVO@IU: An overview
Robert Light, Chin Hua Kong, and Katy Börner
We are Hiring!

**Senior Software Engineer/Research Analyst (3IT)**  **IU Job #6839**
As Senior Software Engineer, you will perform research and programming for current and future externally funded research projects at the CNS Center. These projects include tools powered by the Cyberinfrastructure Shell (CIShell, [http://cishell.org](http://cishell.org)), an open-source software platform that supports the interchange of datasets and algorithms; MapIN, a map of Indiana's expertise and resources; and other online interactive maps and web sites. You will participate in the entire software development process, from the collection of user stories through planning, implementation, testing, deployment, and documentation. You will also be expected to participate in the training new developers, and the creation of educational material for workshops. As Senior Software Engineer, you will have a chance to help set the standards of our team in many areas, including code, teamwork, product direction, and process.

**Software Developer (2IT)**  **IU Job #6862**
As a Software Developer, you will work in a team of four to perform research and programming for current and future externally funded research projects at the CNS Center. The main focus will be on tools powered by the Cyberinfrastructure Shell (CIShell, [http://cishell.org](http://cishell.org)). CIShell is an open-source software platform, built on Java and OSGi that allows developers and scientists to easily exchange datasets and algorithms, and bundle them into custom tools that serve the particular needs of research communities. You will participate in the entire software development process, from the collection of user stories through planning, implementation, testing, deployment, and documentation.

All papers, maps, tools, talks, press are linked from [http://cns.iu.edu](http://cns.iu.edu)

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Mapping Science Exhibit Facebook: [http://www.facebook.com/mappingscience](http://www.facebook.com/mappingscience)