

Mapping Our Collective Scholarly Knowledge

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Symposium Honoring John T. Bruer
Knight Executive Conference Center, Washington University, St. Louis, MO
May 29, 2015

Olivier H. Beauchesne, 2011. Map of Scientific Collaborations from 2005-2009.

Computed Using Data from Elsevier's Scopus

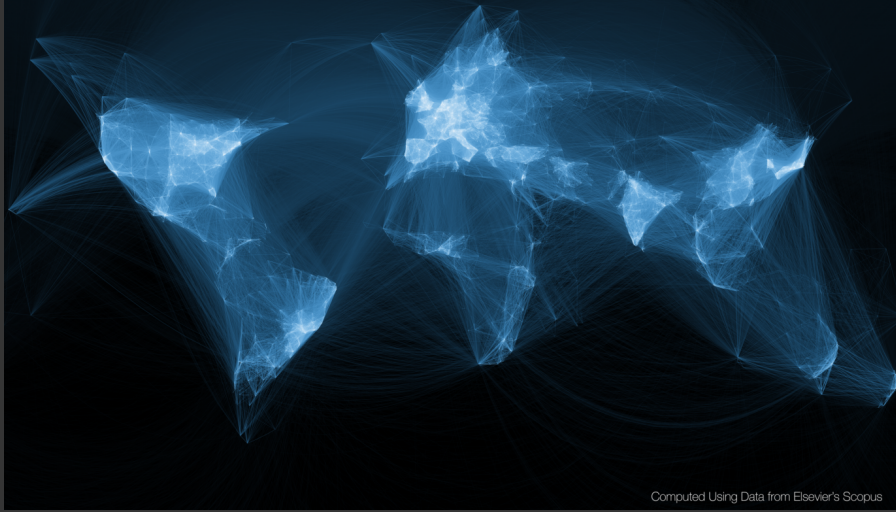
Humanexus

[Watch the official trailer »](#)



Producer/Script Writer: Katy Börner, Designer/Artist: Ying-Fang Shen, Sound Artist: Norbert Herber, 2013.
<http://cns.iu.edu/humanexus>

Map of Scientific Collaborations from 2005-2009



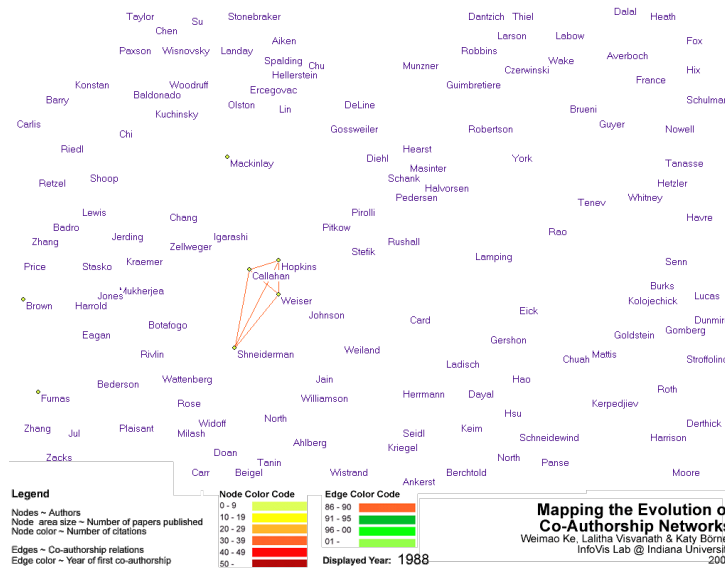
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Olivier H. Beauchesne, 2011. Map of Scientific Collaborations from 2005-2009.

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Mapping the Evolution of Co-Authorship Networks

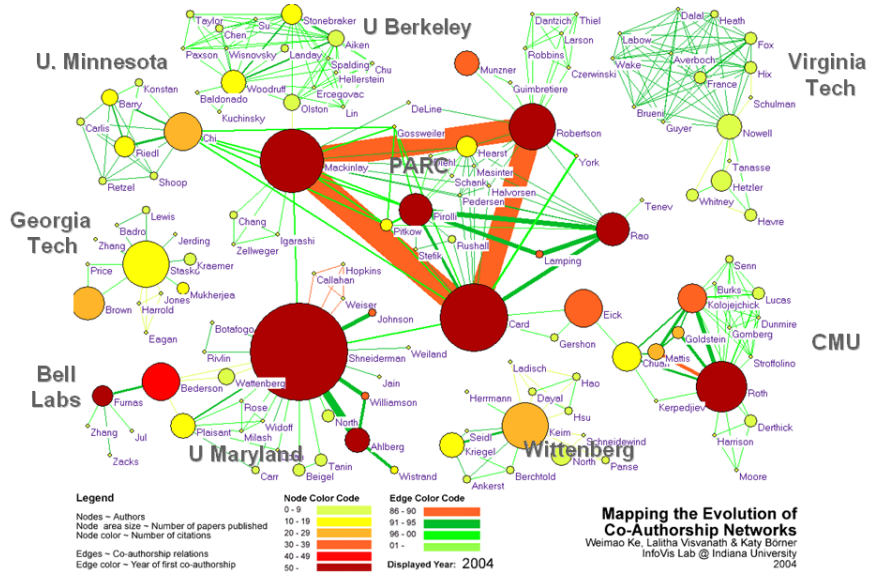
Ke, Visvanath & Börner. 2004. Won 1st prize at the IEEE InfoVis Contest.



4

Mapping the Evolution of Co-Authorship Networks

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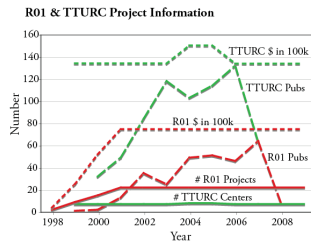


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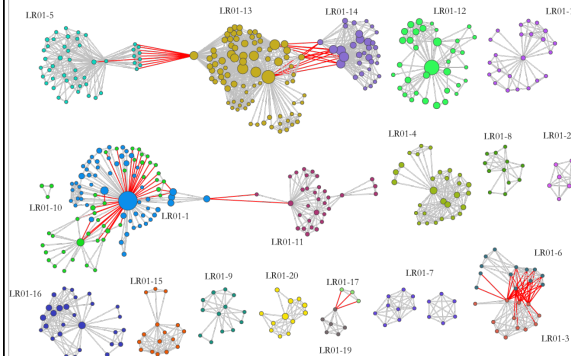
Mapping Transdisciplinary Tobacco Use Research Centers Publications

Compare R01 investigator-based funding with TTURC Center awards in terms of number of publications and evolving co-author networks.

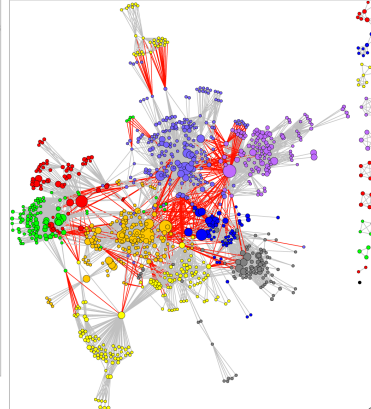
Stipelman, Hall, Zoss, Okamoto, Stokols, Börner, 2014.
 Supported by NIH/NCI Contract HHSN261200800812



Longitudinal R01 Co-Authorship Network



TTURC Co-Authorship Network



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The Global 'Scientific Food Web'

Mazloumian, Amin, Dirk Helbing, Sergi Lozano, Robert Light, and Katy Börner. 2013. "Global Multi-Level Analysis of the 'Scientific Food Web'". *Scientific Reports* 3, 1167. <http://cns.iu.edu/docs/publications/2013-mazloumian-food-web.pdf>

Contributions:

Comprehensive global analysis of scholarly knowledge production and diffusion on the level of continents, countries, and cities.

Quantifying knowledge flows between 2000 and 2009, we identify global sources and sinks of knowledge production. Our knowledge flow index reveals, where ideas are born and consumed, thereby defining a global 'scientific food web'.

While Asia is quickly catching up in terms of publications and citation rates, we find that its dependence on knowledge consumption has further increased.

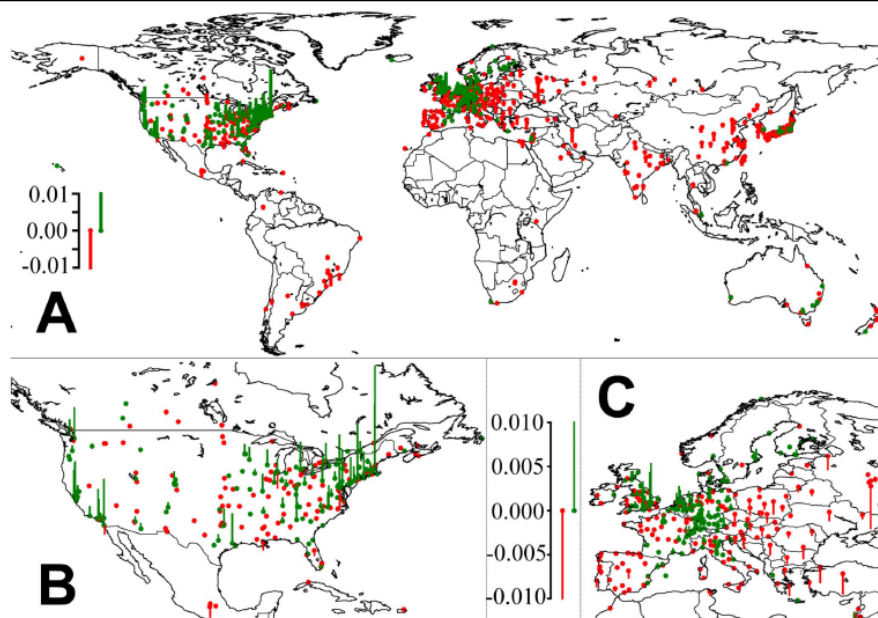
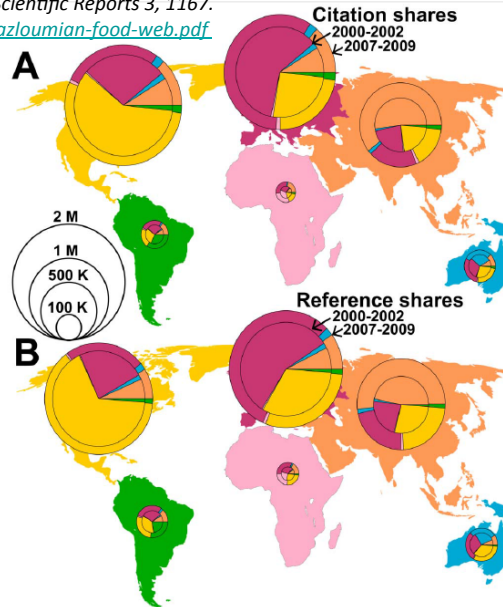


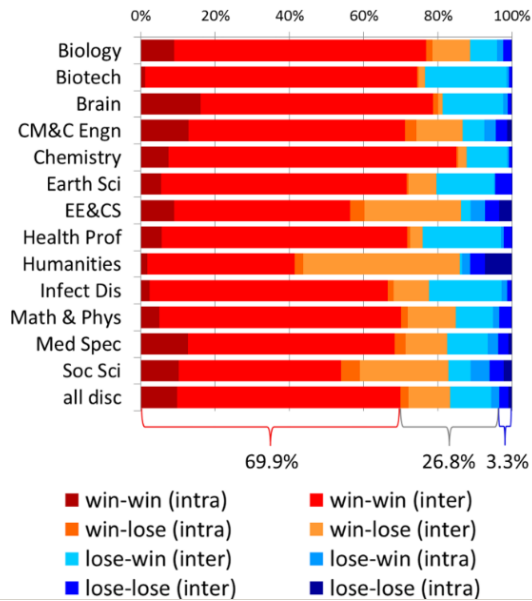
Figure 2 | World map of the greatest knowledge sources and sinks, based on our scientific fitness index. Green bars indicate that the number of citations received is over-proportional, red that the number of citations received is lower than expected (according to a homogeneous distribution of citations over all cities that have published more than 500 papers). It can be seen that most scientific activity occurs in the temperate zone. Moreover, areas of high fitness tend to be areas that are performing economically well (but the opposite does not hold).

Long-Distance Interdisciplinarity Leads to Higher Scientific Impact

Larivière, Vincent, Stefanie Hausstein, and Katy Börner. 2015. PLOS ONE DOI: 10.1371.

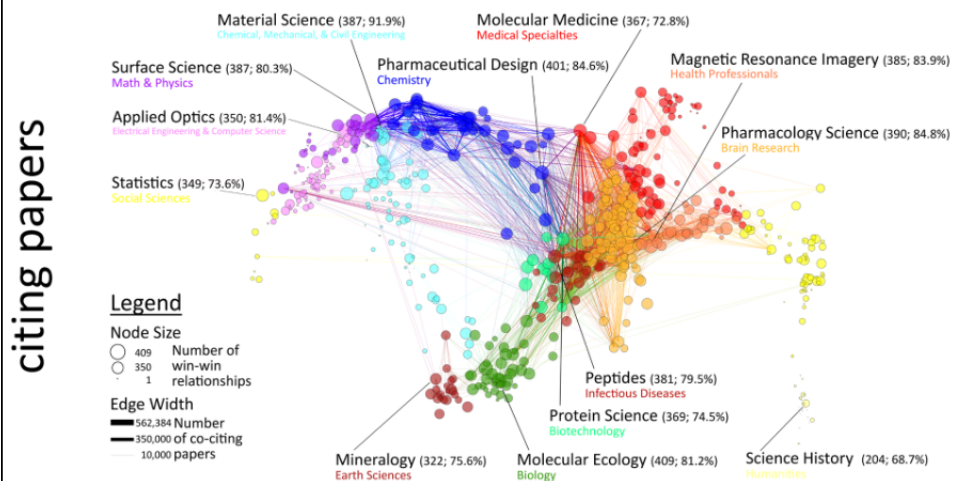
Data: 9.2 million interdisciplinary research papers published between 2000 and 2012 .

Results: majority (69.9%) of co-cited interdisciplinary pairs are “win-win” relationships, i.e., papers that cite them have higher citation impact and there are as few as 3.3% “lose-lose” relationships. UCSD map of science is used to compute “distance.”



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A1 Number of papers citing win-win relationships (≥10,000 citing papers)

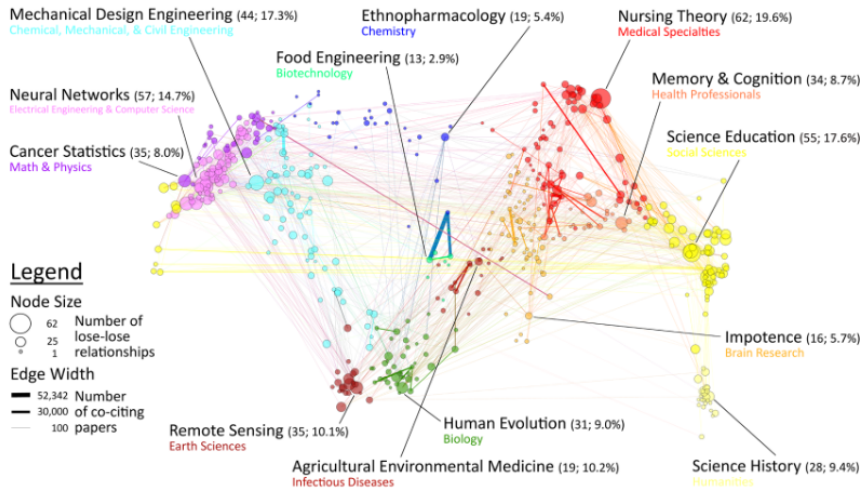


2,940 (5.19%) of 56,614 win-win edges

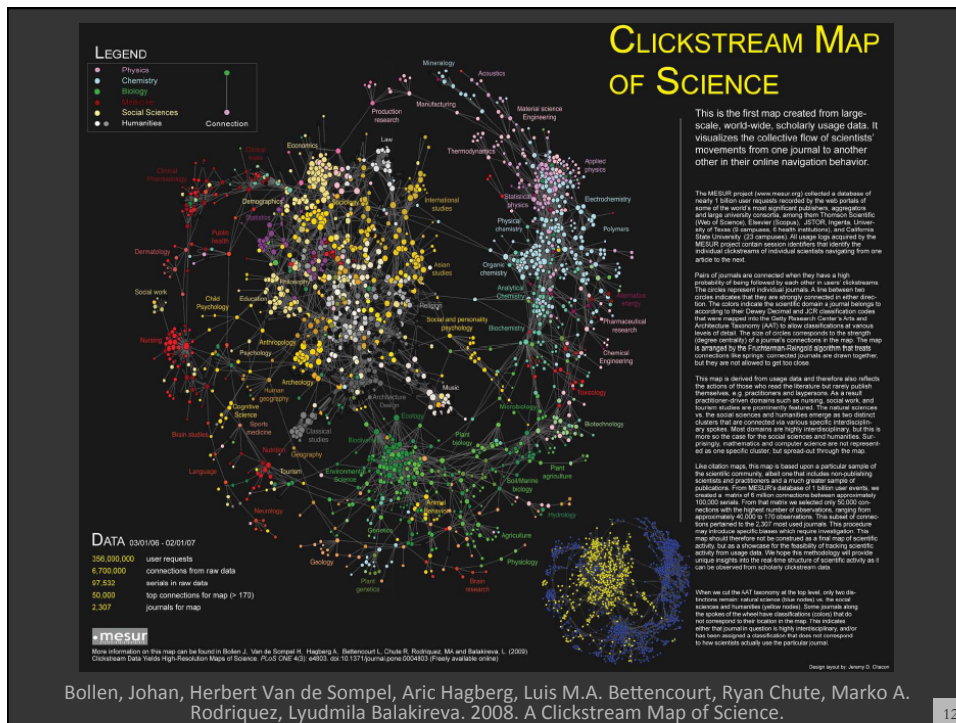
node color: discipline | edge color: mix of adjacent nodes | labels: subdiscipline with highest number of win-win relationships per discipline (number and percentage of win-win relationships)

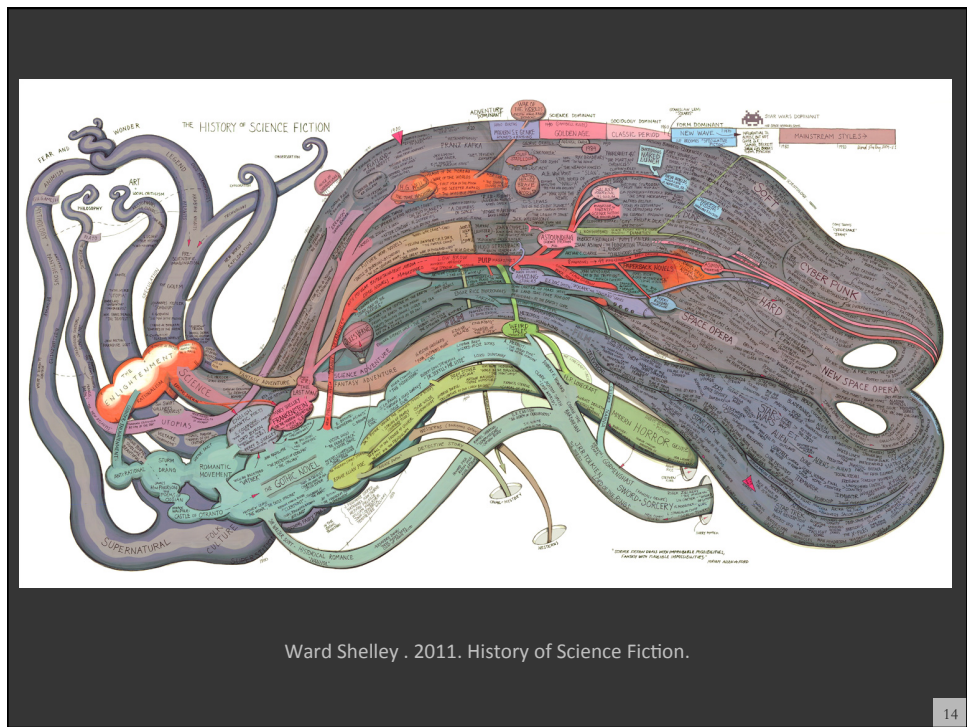
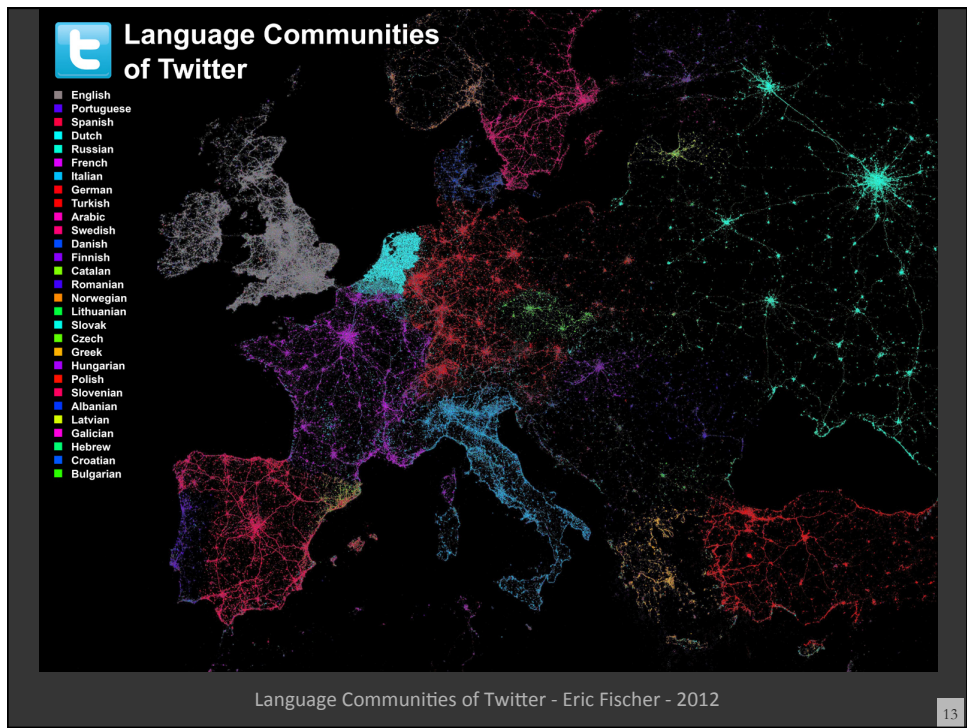
10

B1 Number of papers citing lose-lose relationships (≥ 100 citing papers)



1,204 (44.4%) of 2,712 lose-lose edges
 node color: discipline | edge color: mix of adjacent nodes | labels: subdiscipline with highest number of lose-lose relationships per discipline (number and percentage of lose-lose relationships)

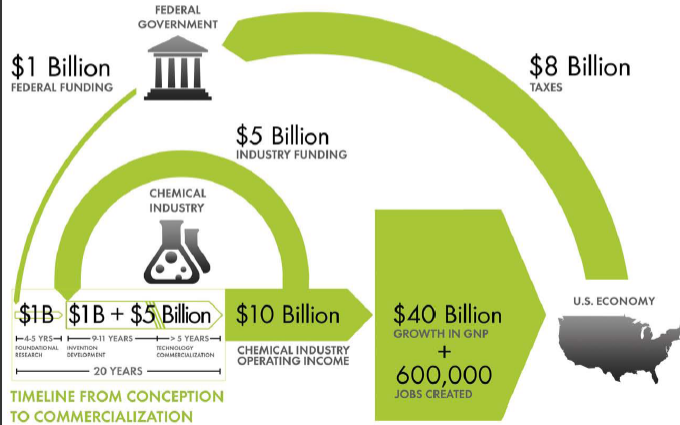




Chemical Research & Development Powers the U.S. Innovation Engine

Macroeconomic Implications of Public and Private R&D Investments in Chemical Sciences

INVESTMENT IN CHEMICAL SCIENCE R&D

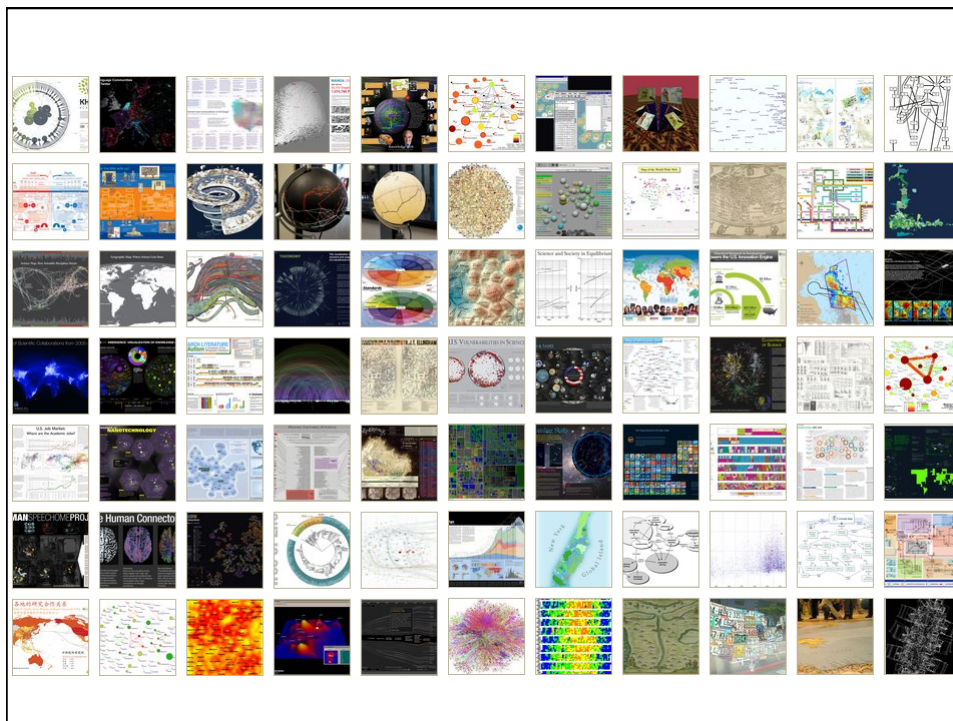


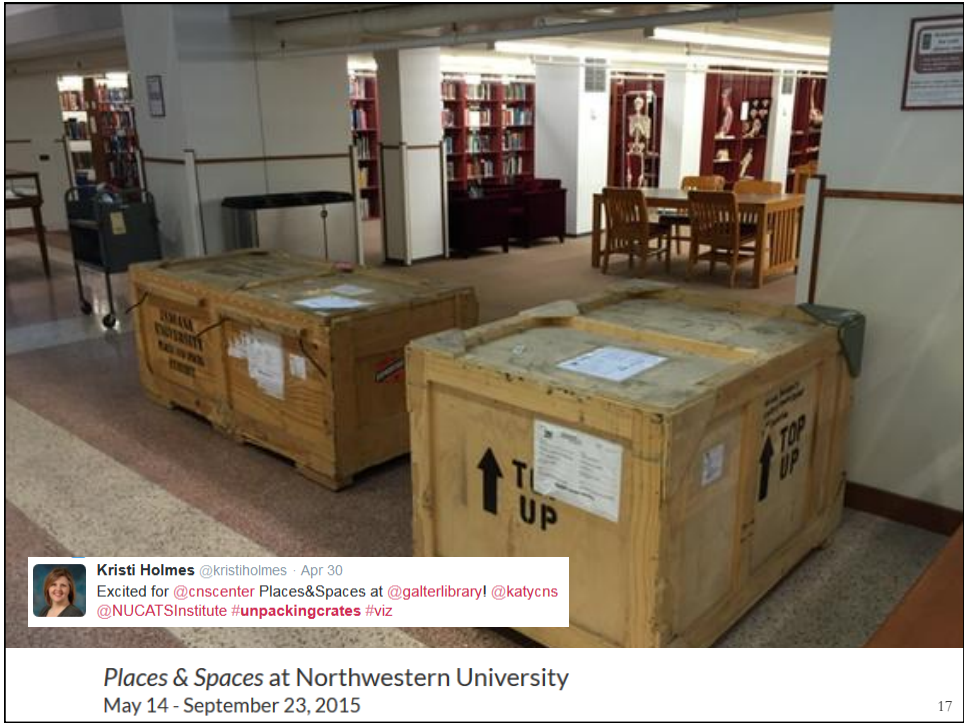
The Council for Chemical Research (CCR)

has provided the U.S. Congress and government policy makers with important results regarding the impact of Federal Research & Development (R&D) investments on U.S. innovation and global competitiveness through its commissioned 5-year two phase study. To take full advantage of typically brief access to policy makers, CCR developed the graphic below as a communication tool that details the complex data produced by these studies in direct, concise and clear terms.

The design shows that an input of \$1B in federal investment, leveraged by \$5B industry investment, brings new technologies to market and results in \$10B of operating income for the chemical industry, \$40B growth in the Gross National Product (GNP) and further impacts the US economy by generating approximately 600,000 jobs, along with a return of \$8B in taxes. Additional details, also reported in this CCR studies, are depicted in the map to the left. This map clearly shows the two R&D investment cycles; the shorter industry investment at the innovation stage to commercialization cycle; and the longer federal investment cycle which begins in basic research and culminates in national economic and job growth along with the increase tax base that in turn is available for investment in basic research.

Council for Chemical Research. 2009. Chemical R&D Powers the U.S. Innovation Engine. Washington, DC. Courtesy of the Council for Chemical Research.





Geographic Map: Where Science Gets Done

North America, Central America, South America, Africa, Europe, Asia, Oceania, Antarctica

Science Map: How Scientific Disciplines Relate

Math & Physics, Chemistry, Health Professionals, Social Sciences, Biotechnology, Medicine, Agricultural, Chemical, Mechanical & Civil Engineering, Electrical Engineering & Computer Science, Infectious Diseases, Brain Research, Earth Sciences, Biology, Humanities

Copyright © 2008 The Regents of the University of California

About

This Illuminated Diagram display adds the flexibility of an interactive program to the incredibly high data density of a print. This technique is generally useful when there is too much pertinent data to be displayed on a screen but the data is relatively stable. The computer can direct the eye to what's important by using projectors or screens as smart spotlights, animating the research impact of individuals, giving a "grand tour" of science, or highlighting query results (as when you touch the lectern or use the keyboard) with an overlay of moving light.

Top Five Continents

- North America - 4,000 records
- South & East Asia - 3,589
- Australia - 2,431
- Africa - 2,206
- South America - 1,562

Top Five Scientific Disciplines

- Math & Physics - 4,000 records
- Health Professionals - 3,589
- Social Sciences - 2,431
- Agricultural, Chemical, Mechanical & Civil Engineering - 2,208
- Humanities - 1,562

Search

The keyboard supports retrieval and display of papers based on their Medical Subject Headings (MeSH) and MeSH qualifier terms. If multiple terms are entered in a field, they are automatically combined using "OR". So, "breast cancer" matches any record with "breast" or "cancer" in that field. You can put AND between terms to combine with "AND". Thus "breast AND cancer" would only match records that contain both terms. Double quotation can be used to match compound terms, e.g. "breast cancer" retrieves records with the phrase "breast cancer", and not records where "breast" and "cancer" are both present, but the exact phrase.

Q	W	E	R	T	Y	U	I	O	P
A	S	D	F	G	H	J	K	L	"
Z	X	C	V	B	N	M			
Space									Go

People & Topics
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<http://placesmaps.org>

Geographic Map: Where Science Gets Done

North America, Central America, South America, Africa, Europe, Asia, Oceania, Antarctica

Science Map: How Scientific Disciplines Relate

Math & Physics, Chemistry, Health Professionals, Social Sciences, Biotechnology, Medicine, Agricultural, Chemical, Mechanical & Civil Engineering, Electrical Engineering & Computer Science, Infectious Diseases, Brain Research, Earth Sciences, Biology, Humanities

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Elinor Ostrom - Nobel Prize in Economic Sciences 2009
 Born: 7 August 1933, New York, NY, USA
 Affiliation at the time of the award: Indiana University, Bloomington, IN, USA, Arizona State University, Tempe, AZ, USA
 Prize motivation: "for her analysis of economic governance, especially the commons"
 Field: Economic governance
 Contribution: Challenged the conventional wisdom by demonstrating how local property can be successfully managed by local commons without any regulation by central authorities or privatization.


Interact




Select any location on the Geographic Map location (by brushing your finger over an area on the lectern's touch screen) and topics studied in that area will highlight on the Science Map: the brighter a topic glows, the more papers on that topic originated in the selected area. Conversely, touching a scientific area in the Science Map illuminates places on the Geographic Map where that topic is studied. People and topic buttons support the exploration of publication output by selected Nobel laureates and particular lines of research using MEDLINE data from 2000-2009.

Cancer	Cloning	HIV	Robert G. Edwards	Roger D. Kornberg	Elinor Ostrom
Obesity	Quality of Life	Smoking	Stanley B. Prusiner	Ahmed H. Zewail	View All


Keyword Search
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<http://placesmaps.org>


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Hidalgo, César A., Bailey Kilinger, Albert-László Barabási, and Ricardo Hausmann. 2007. See also The Product Space map from Phase I of Places & Spaces.

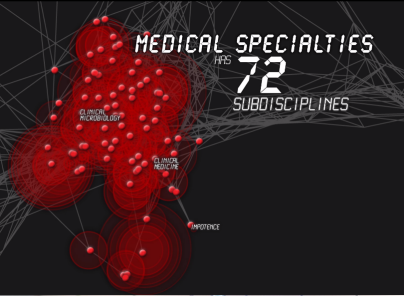
Call for Macroscopic Tools for the *Places & Spaces: Mapping Science* Exhibit (2015)

<http://scimaps.org/call>


Themes for the upcoming iterations/years are:

- 11th Iteration (2015): Macroscopes for Interacting With Science
- 12th Iteration (2016): Macroscopes for Making Sense of Science
- 13th Iteration (2017): Macroscopes for Forecasting Science
- 14th Iteration (2018): Macroscopes for Economic Decision Makers
- 15th Iteration (2019): Macroscopes for Science Policy Makers
- 16th Iteration (2020): Macroscopes for Scholars

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MEDICAL SPECIALTIES
72 SUBDISCIPLINES





MAP OF SCIENCE: FORECASTING LARGE TRENDS IN SCIENCE

COLLABORATIVE EFFICIENCY: 0.6 0.7 0.8 0.9 1


DISCIPLINARY OUTPUT:

- PHYSICS & ASTRONOMY
- ENGINEERING, CHEMISTRY & COMPUTATIONAL SCIENCE
- BIOMEDICAL RESEARCH
- PHYSICS
- INVESTMENT SCIENCE
- COMPUTER SCIENCE
- PHYSICAL SCIENCE
- HEALTH PROFESSIONALS
- BIOMEDICAL RESEARCH
- HEALTH SCIENCE
- PHYSICS
- PHYSICAL SCIENCE & COMPUTATIONAL SCIENCE





SCIENTIFIC COLLABORATIONS BETWEEN WORLD CITIES



DISCIPLINARY OUTPUT

PHYSICS & ASTRONOMY

ELECTRONICAL ENGINEERING & TECHNOLOGY

HEALTH

Modelling Our Collective Scholarly Knowledge

NEWSFOCUS

Making Every Scientist a Research Funder

When it comes to using peer review to distribute research dollars, Johan Bollen favors radical simplicity.

Over the years, many scientists have suggested that the current system could be improved by changing the composition of the review panels, tweaking the interactions among reviewers, or revising how the proposals are scored. But Bollen, a computer scientist at Indiana University, Bloomington, would simply award all eligible researchers a block grant—and then require them to give some of it away to colleagues they judge most deserving.

That radical step, described in a paper Bollen and four Indiana colleagues recently posted on *EMBO Reports*, retains peer review's core concept of tapping into the views of the most knowledgeable researchers. But it would eliminate the huge investment in time and money required to submit proposals and assemble panels to judge them.

Bollen's process would be almost instantaneous: In a version of expert-directed crowdsourcing, scientists would fill out a form once a year listing their favored researchers, and a predetermined portion of their annual grant money—a total of, say, 50%—would then be transferred to their choices.

"So many scientists spend so much time on peer review, and there's a high level of frustration," Bollen explains. "We already know who the best people are. And if you're doing good work, then you deserve to receive support."

Others are skeptical. "I've known Johan for a long time and have the highest regard for his ability as an out-of-the-box thinker," says Stephen Griffin, a retired National Science Foundation (NSF) program manager who's now a visiting professor of information sciences at the University of Pittsburgh in Pennsylvania. "But there are a number of issues he doesn't address."

Those sticking points include the likely mismatch between what researchers need and what their colleagues give them; the absence of any replacement for the overhead payments in today's grants, which support infrastructure at host institutions; and the dearth of public accountability for the billions of dollars that would flow from public coffers to individuals. "Scientists aren't really equipped to be a funding agency," Griffin notes.

Bollen acknowledges that the process would need safeguards to ensure that scientists don't reward their friends or punish their enemies. But his analysis suggests that the U.S. research landscape would not look all that different if his radical proposal were adopted.

Drawing upon citation data in 37 million papers over 20 years, the Indiana researchers conducted a simulation premised on the idea that scientists would reallocate their federal dollars according to how often they cited their peers. The simulation, he says, yielded a funding pattern "similar in shape to the actual distribution" at NSF and the National Institutes of Health for the past decade—at a fraction of the overhead required by the current system.

—JDM

February 7, 2014

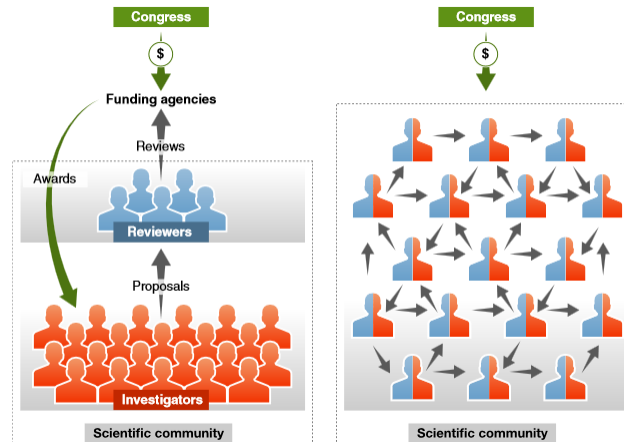
Science 7 February 2014: Vol. 343 no. 6171 p. 598

DOI: 10.1126/science.1234567

<http://www.sciencemag.org/content/343/6171/598.full?sid=4f40a7f0-6ba2-4ad8-a181-7ab394fe2178>

From funding agencies to scientific agency: Collective allocation of science funding as an alternative to peer review

Bollen, Joban, David Crandall, Damion Junk, Ying Ding, and Katy Börner. 2014. *EMBO Reports* 15 (1): 1-121.



Existing (left) and proposed (right) funding systems. Reviewers in blue; investigators in red.

In the proposed system, all scientists are both investigators and reviewers: every scientist receives a fixed amount of funding from the government and discretionary distributions from other scientists, but each is required in turn to redistribute some fraction of the total they received to other investigators.

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Assume

Total funding budget in year y is t_y

Number of qualified scientists is n

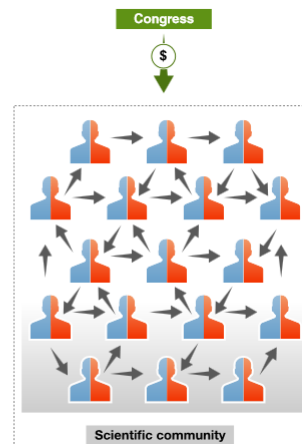
Each year,

the funding agency deposits a fixed amount into each account, equal to the total funding budget divided by the total number of scientists: t_y/n .

Each scientist must distribute a fixed fraction of received funding to other scientists (no self-funding, COIs respected).

Result

Scientists collectively assess each others' merit based on different criteria; they "fund-rank" scientists; highly ranked scientists have to distribute more money.



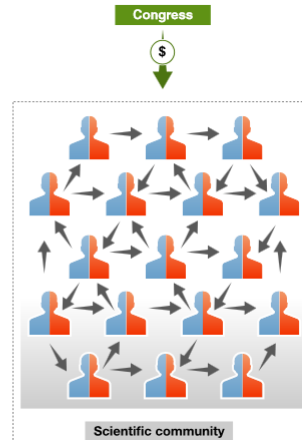
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Example:

Total funding budget in year is 2012 NSF budget
Given the number of NSF funded scientists, each receives a \$100,000 basic grant.
Fraction is set to 50%

In 2013, scientist S receives a basic grant of \$100,000 plus \$200,000 from her peers, i.e., a total of \$300,000.
In 2013, S can spend 50% of that total sum, \$150,000, on her own research program, but must donate 50% to other scientists for their 2014 budget.

Rather than submitting and reviewing project proposals, S donates directly to other scientists by logging into a centralized website and entering the names of the scientists to donate to and how much each should receive.



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Model Run and Validation:

Model is presented in <http://arxiv.org/abs/1304.1067>
It uses **citations as a proxy** for how each scientist might distribute funds in the proposed system.

Using 37M articles from TR 1992 to 2010 Web of Science (WoS) database, we extracted **770M citations**. From the same WoS data, we also determined 4,195,734 unique author names and we took

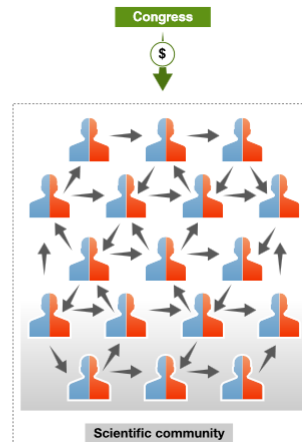
the **867,872 names** who had authored at least one paper per year in any five years of the period 2000–2010.

For each pair of authors we determined the number of times one had cited the other in each year of our citation data (1992–2010).

NIH and NSF funding records from IU’s Scholarly Database provided 347,364 grant amounts for 109,919 unique scientists for that time period.

Simulation run begins in year 2000, in which every scientist was given a fixed budget of $B = \$100k$. In subsequent years, scientists distribute their funding in proportion to their citations over the prior 5 years.

The model yields funding patterns similar to existing NIH and NSF distributions.



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Model Efficiency:

Using data from the Taulbee Survey of Salaries Computer Science (<http://cra.org/resources/taulbee>) and the National Science Foundation (NSF) the following calculation is illuminating:

If four professors work four weeks full-time on a proposal submission, labor costs are about \$30k. With typical funding rates below 20%, about five submission-review cycles might be needed resulting in a total expected labor cost of **\$150k**.

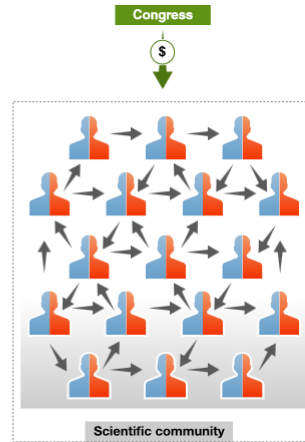
The average NSF grant is **\$128k** per year.

U.S. universities charge about 50% overhead (ca. \$42k), leaving about **\$86k**.

In other words, the four professors lose **\$150k-\$86k=\$64k** of paid research time by obtaining a grant to perform the research.

That is, U.S. universities should forbid professors to apply for grants—if they can afford to forgo the indirect dollars.

To add: Time spent by researchers to review proposals. In 2012 alone, NSF convened more than 17,000 scientists to review 53,556 proposals.



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References

Börner, Katy, Chen, Chaomei, and Boyack, Kevin. (2003). **Visualizing Knowledge Domains**. In Blaise Cronin (Ed.), *ARIST*, Medford, NJ: Information Today, 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/

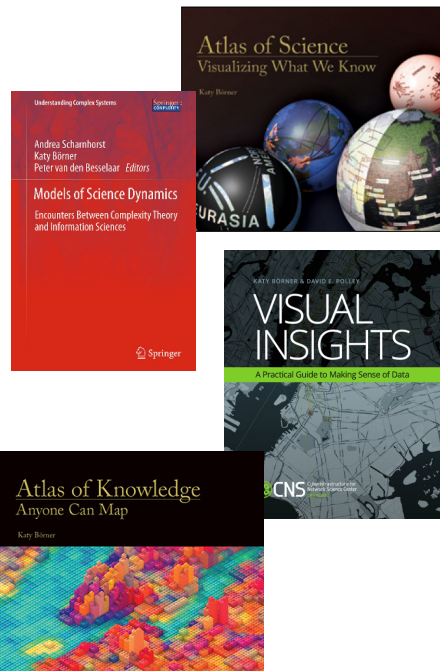
Börner, Katy (2010) **Atlas of Science: Visualizing What We Know**. The MIT Press. <http://scimaps.org/atlas>

Scharnhorst, Andrea, Börner, Katy, van den Besselaar, Peter (2012) **Models of Science Dynamics**. Springer Verlag.

Katy Börner, Michael Conlon, Jon Corson-Rikert, Cornell, Ying Ding (2012) **VIVO: A Semantic Approach to Scholarly Networking and Discovery**. Morgan & Claypool.

Katy Börner and David E Polley (2014) **Visual Insights: A Practical Guide to Making Sense of Data**. The MIT Press.

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Tasks

LEVELS

MICRO: Individual Level
about 1–1,000 records
page 6

MESO: Local Level
about 1,001–100,000 records
page 8

MACRO: Global Level
more than 100,000 records
page 10



TYPES

TYPE	MICRO: Individual Level	MESO: Local Level	MACRO: Global Level
Statistical Analysis page 44	Knowledge Cartography page 135	Productivity of Russian life sciences research teams page 105	Science and Society in Equilibrium Number of scientists versus population and R&D costs versus GDP page 105
WHEN: Temporal Analysis page 48	Visualizing decision-making processes page 95	Key events in the development of the video tape recorder page 85	Increased travel and communication speed page 85
WHERE: Geospatial Analysis page 52	Cell phone usage in Milan, Italy page 109	Victorian poetry in Europe page 137	Ecological footprint of countries page 99
WHAT: Topical Analysis page 56	Evolving patent holdings of Apple, Computer, Inc. and Jerome Lemelson page 89	Evolving networks in nanotechnology page 139	Product space showing co-export patterns of countries page 95
WITH WHOM: Network Analysis page 60	World Finance Corporation network page 87	Electronic and new media art networks page 155	World-wide scholarly collaboration networks page 157



See page 5

Micro: Individual Level

This grand review of significant findings derived from micro-level studies. Theoretical, empirical or practical studies with social, psychological, or other variables, from which properties or relations are then extracted. The increasing availability of other important data, such as new, track number, social media data, offers an opportunity to obtain a richer and more real-time understanding of R&D developments. In addition to organizing the breadth of data sets studied, that availability also increases the depth of studies by raising the skill set for specific studies, such as statistical comparison, or pairing advanced algorithms to specific cases. Statement analysis, also called opinion mining, is now commonly applied toward understanding how new ideas and products are perceived and addressed in different markets.

What is your paper if you want to be included in the *Atlas of Knowledge*?

Personal Analytics
Personal, personal, and behavioral analytics are becoming more and more important in the study of group processes. This is because of the increasing availability of data from social media and other sources. This data is often used to study individual and group behavior. This data is often used to study individual and group behavior. This data is often used to study individual and group behavior.

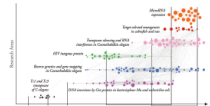


Fig. 6. Science and Technology Plan

Quantifying Science
Highly cited research in life, social, and other fields, such as those related to health care, are often analyzed in terms of the number of citations they receive. This is often done to assess the impact of the research. This is often done to assess the impact of the research. This is often done to assess the impact of the research.

Academic Products Analytics
Academic products analytics is a new field of study that focuses on the analysis of academic products. This is often done to assess the impact of the research. This is often done to assess the impact of the research. This is often done to assess the impact of the research.

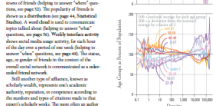


Fig. 7. Science and Technology Plan

Commercial Product Analytics
Commercial product analytics is a new field of study that focuses on the analysis of commercial products. This is often done to assess the impact of the research. This is often done to assess the impact of the research. This is often done to assess the impact of the research.

Emerging
Emerging technologies are those that are currently in development but have not yet been widely adopted. This is often done to assess the impact of the research. This is often done to assess the impact of the research. This is often done to assess the impact of the research.



Fig. 8. Science and Technology Plan

Worldwide Scholarly Collaboration Networks
Worldwide scholarly collaboration networks are those that connect researchers from different countries. This is often done to assess the impact of the research. This is often done to assess the impact of the research. This is often done to assess the impact of the research.

Product Space
Product space is a new field of study that focuses on the analysis of products. This is often done to assess the impact of the research. This is often done to assess the impact of the research. This is often done to assess the impact of the research.

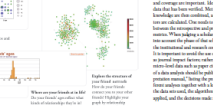
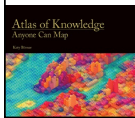


Fig. 9. Science and Technology Plan



See pages 6-7

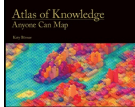
Insight Need Types page 26	Data Scale Types page 28	Visualization Types page 30	Graphic Symbol Types page 32	Graphic Variable Types page 34	Interaction Types page 26
<ul style="list-style-type: none"> • categorize/cluster • order/rank/sort • distributions (also outliers, gaps) • comparisons • trends (process and time) • geospatial • compositions (also of text) • correlations/relationships 	<ul style="list-style-type: none"> • nominal • ordinal • interval • ratio 	<ul style="list-style-type: none"> • table • chart • graph • map • network layout 	<ul style="list-style-type: none"> • geometric symbols <ul style="list-style-type: none"> • point • line • area • surface • volume • linguistic symbols <ul style="list-style-type: none"> • text • numerals • punctuation marks • pictorial symbols <ul style="list-style-type: none"> • images • icons • statistical glyphs 	<ul style="list-style-type: none"> • spatial <ul style="list-style-type: none"> • position • retinal <ul style="list-style-type: none"> • form • color • optics • motion 	<ul style="list-style-type: none"> • overview • zoom • search and locate • filter • details-on-demand • history • extract • link and brush • projection • distortion



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Graphic Variable Types Versus Graphic Symbol Types

	Table	Line	Area	Volume	Linguistic Symbols Text, Numeral, Punctuation Marks	Pictorial Symbols Images, Icons, Statistical Glyphs
Shape	Line, Area, Volume	Line, Area, Volume	Line, Area, Volume	Line, Area, Volume	Text, Numeral, Punctuation Marks	Images, Icons, Statistical Glyphs
Color	Color	Color	Color	Color	Color	Color
Size	Size	Size	Size	Size	Size	Size
Position	Position	Position	Position	Position	Position	Position
Form	Form	Form	Form	Form	Form	Form
Optics	Optics	Optics	Optics	Optics	Optics	Optics
Motion	Motion	Motion	Motion	Motion	Motion	Motion
Background	Background	Background	Background	Background	Background	Background

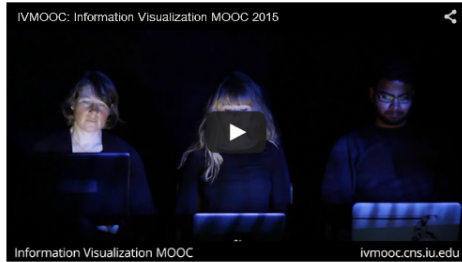


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Overview

This course provides an overview about the state of the art in information visualization. It teaches the process of producing effective visualizations that take the needs of users into account.

The course can be taken for three Indiana University credits as part of the **Online Data Science Program**, as part of the Information and Library Science M.S. program, and as part of the online Data Science M.S. Program offered by the School of Informatics and Computing. Students seeking enrollment information should contact Rhonda Spencer at 812-855-2018, ilsmain@indiana.edu or datasci@indiana.edu.



Register for Course

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- Among other topics, the course covers:
- Data analysis algorithms that enable extraction of patterns and trends in data
 - Major temporal, geospatial, topical, and network visualization techniques
 - Discussions of systems that drive research and development.

Register for free at <http://ivmooc.cns.iu.edu>. Class restarts January, 2016.

All papers, maps, tools, talks, press are linked from <http://cns.iu.edu>
 These slides will soon be at <http://cns.iu.edu/presentations>

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