

Scalable Multi-Scale Visual Analytical Tools for Health Science

Robert Light and Daniel O'Donnell

Cyberinfrastructure for Network Science Center
School of Informatics and Computing, Indiana University, USA

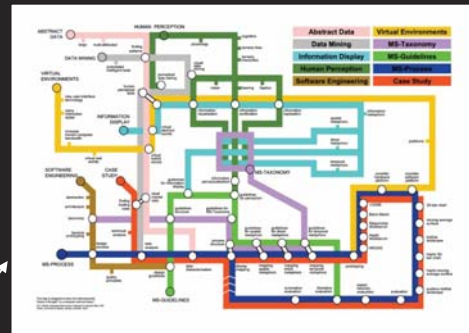
Center for Computational Research, SUNY Buffalo
March 29, 2016

Language Communities of Twitter - Eric Fischer - 2012



Terra bytes of data

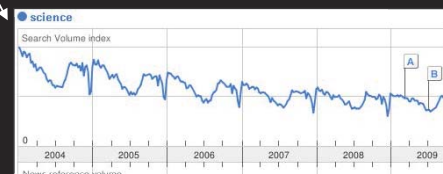
Descriptive &
Predictive
Models



Find your way



Find collaborators, friends



Identify trends

Descriptive Models

Multiple levels: Micro ... Macro

Answering: When? Where? What? With Whom?

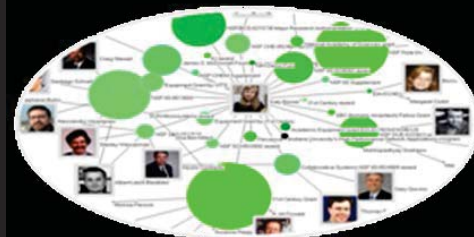
3

Different Levels of Abstraction/Analysis

Macro/Global
Population Level



Meso/Local
Group Level



Micro
Individual Level



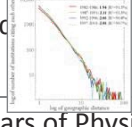
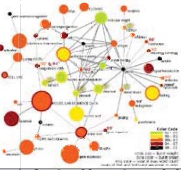





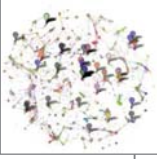

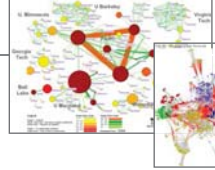
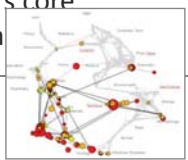
4

Type of Analysis vs. Level of Analysis

	Micro/Individual (1-100 records)	Meso/Local (101–100,000 records)	Macro/Global (100,000 < records)
Statistical Analysis/Profiling	Individual person and their expertise profiles	Larger labs, centers, universities, research domains, or states	All of NSF, all of USA, all of science.
Temporal Analysis (When?)	Funding portfolio of one individual	Mapping topic bursts in 20-years of PNAS	113 Years of Physics Research
Geospatial Analysis (Where?)	Career trajectory of one individual	Mapping a states intellectual landscape	PNAS publications
Topical Analysis (What?)	Base knowledge from which one grant draws.	Knowledge flows in Chemistry research	VxOrd/Topic maps of NIH funding
Network Analysis (With Whom?)	NSF Co-PI network of one individual	Co-author network	NIH's core competency

5

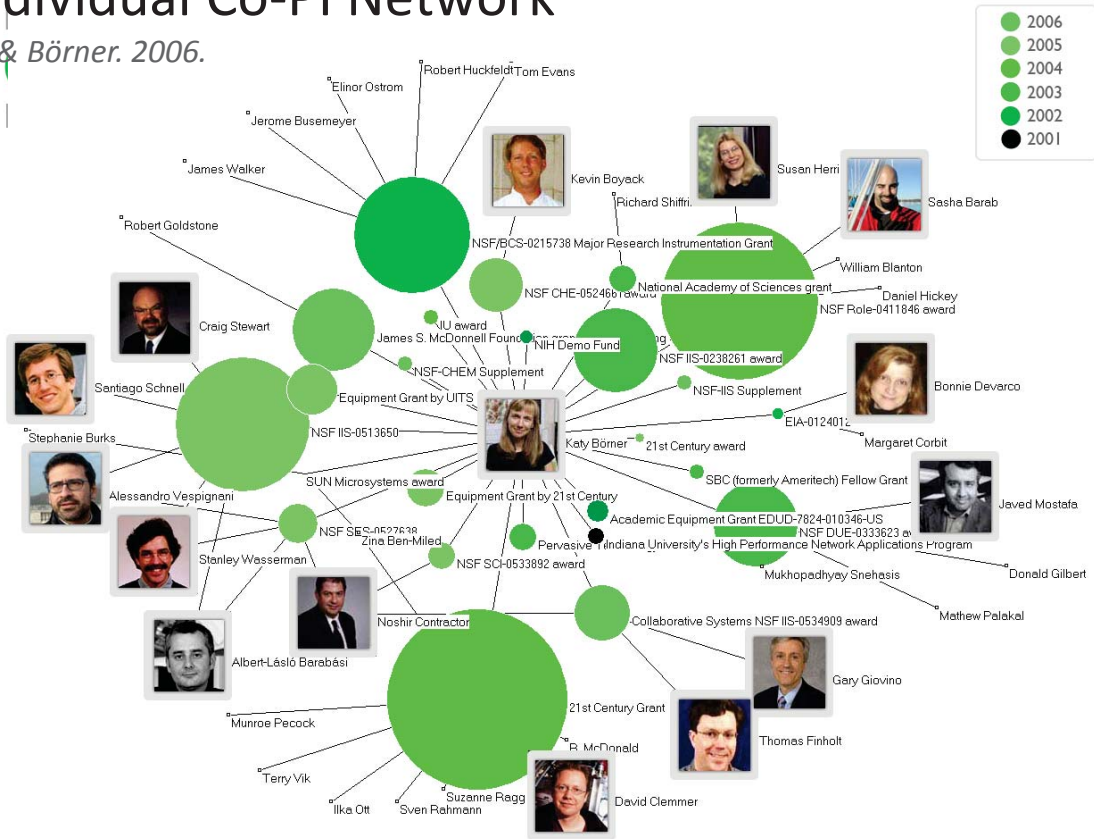
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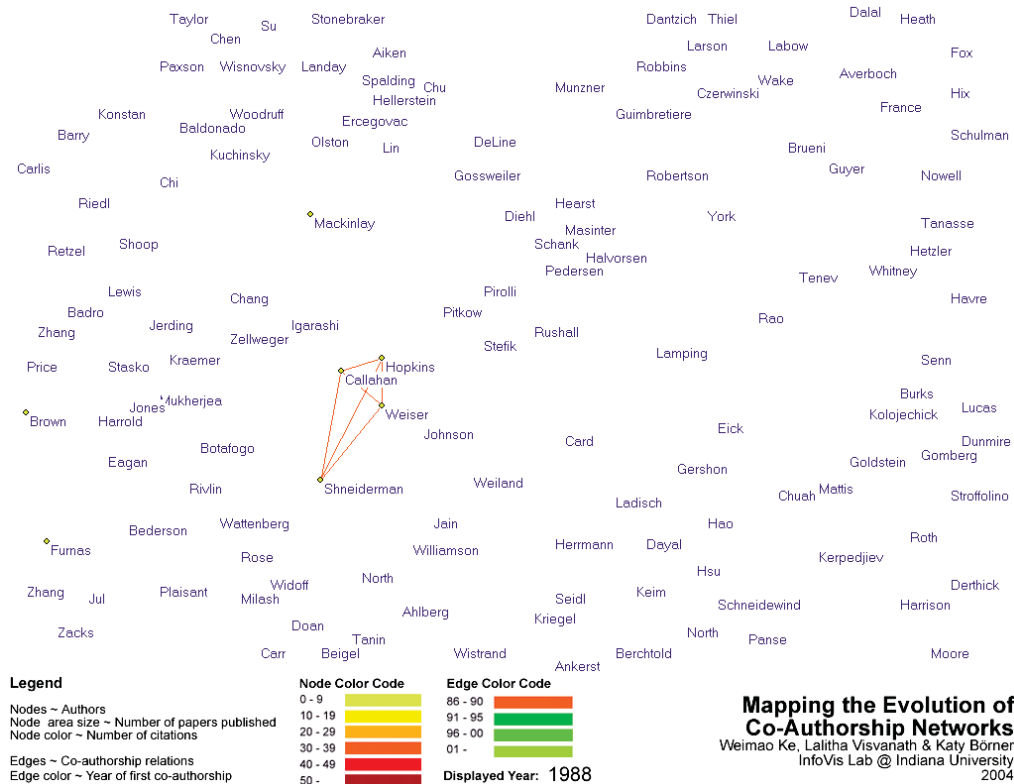
Individual Co-PI Network

Ke & Börner. 2006.



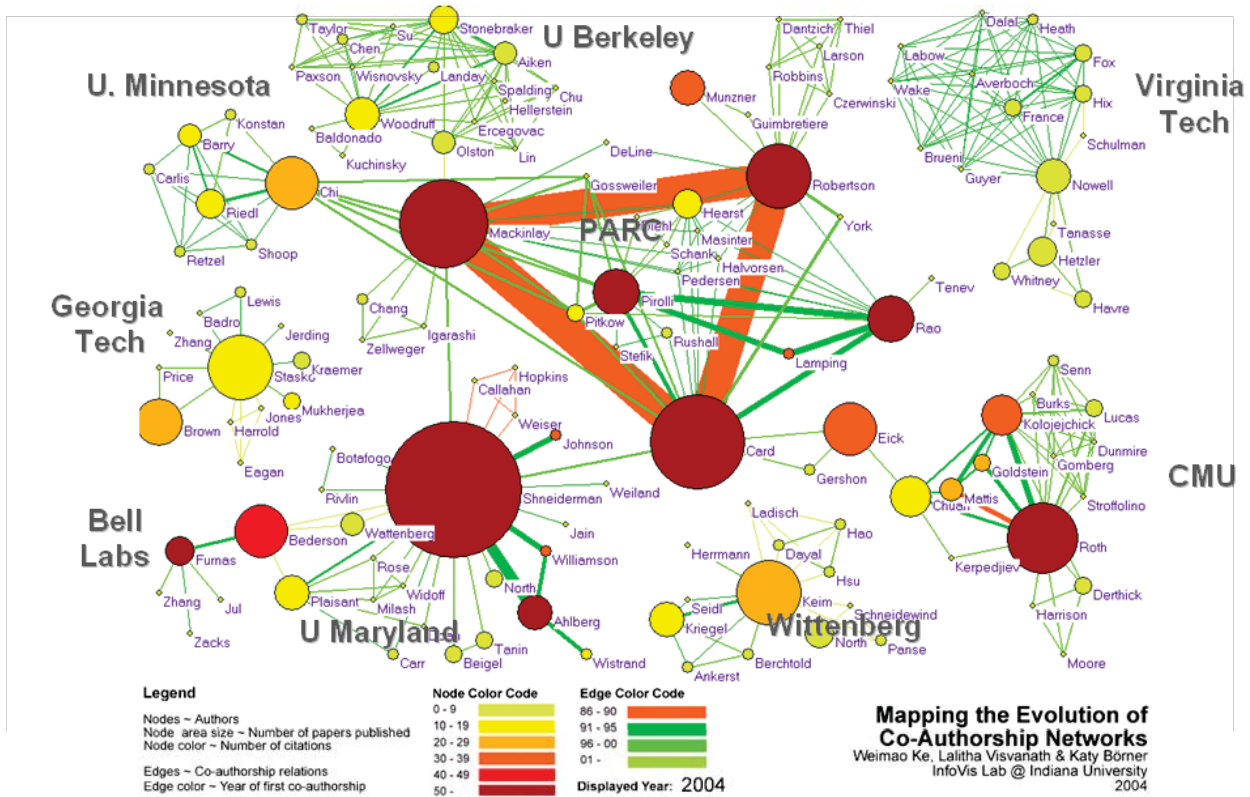
Mapping the Evolution of Co-Authorship Networks

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

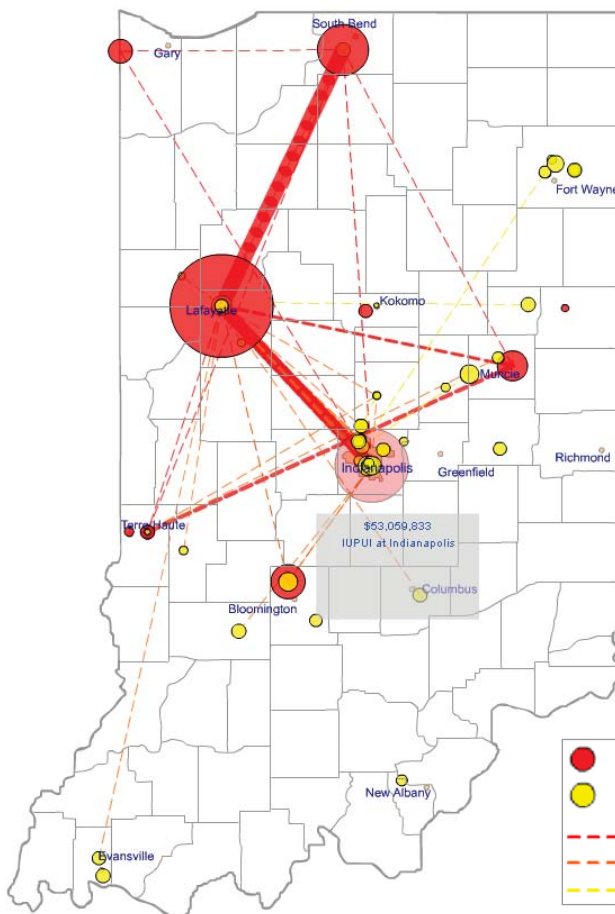


Mapping the Evolution of Co-Authorship Networks 2

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



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Mapping Indiana's Intellectual Space

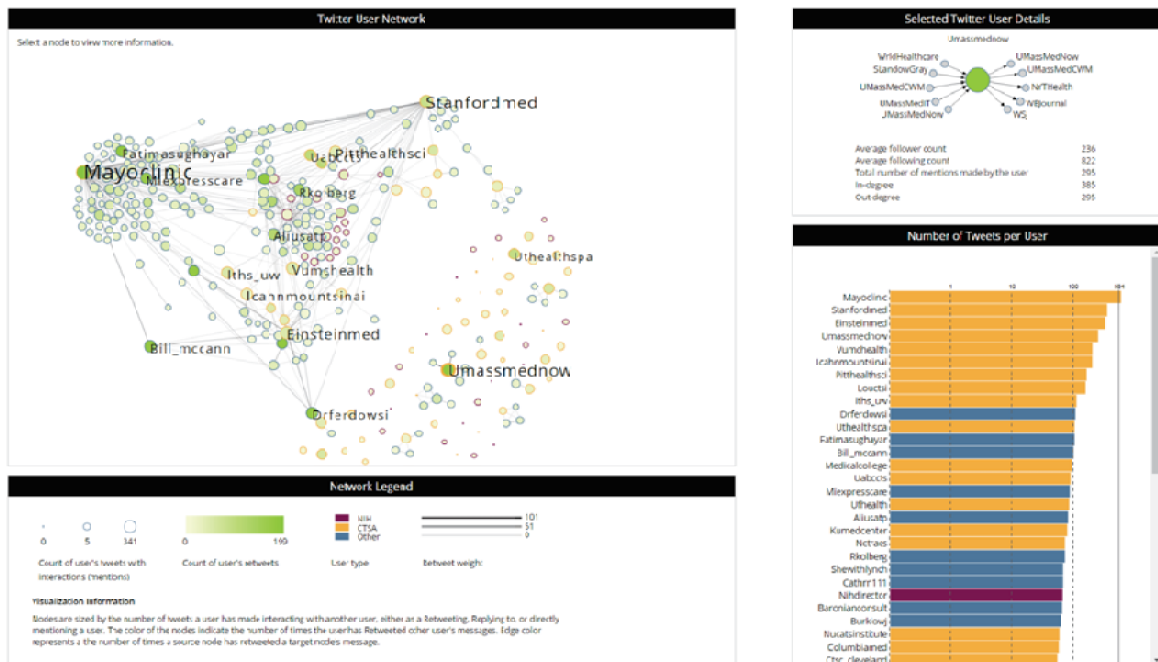
Identify

- Pockets of innovation
- Pathways from ideas to products
- Interplay of industry and academia

3

Twitter Network of NIH and STSI User Accounts

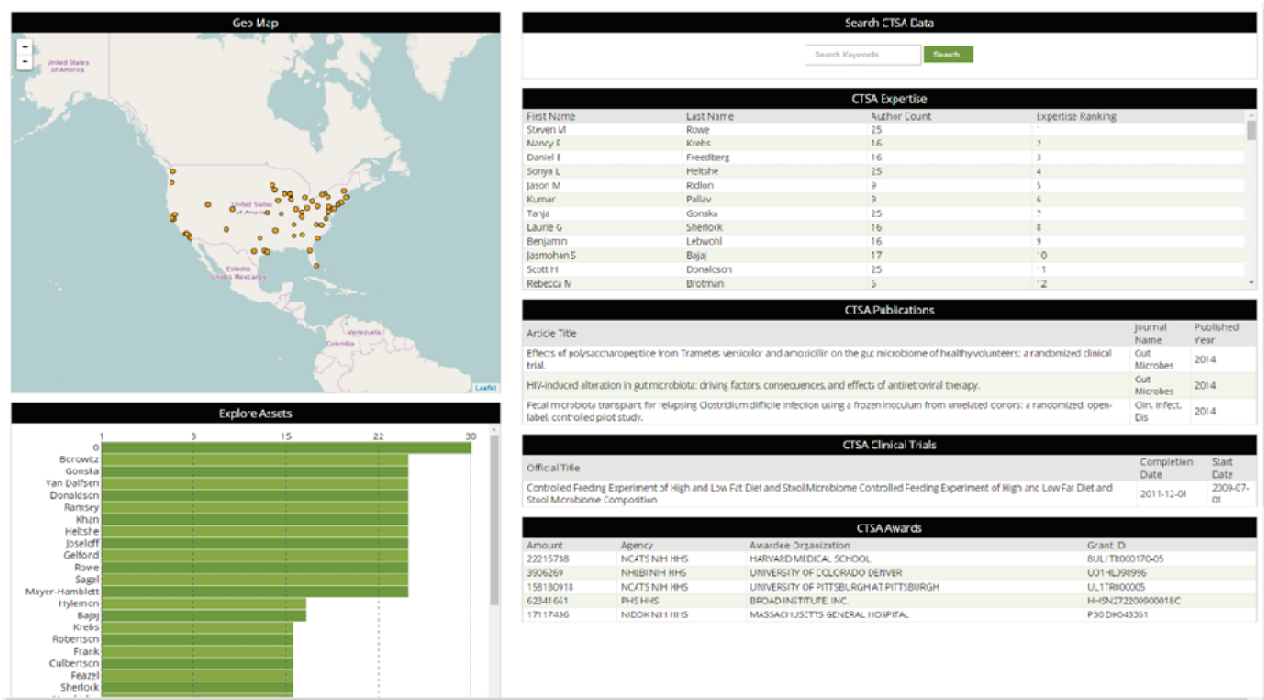
Tang, Börner, Liu, Light, & Simpson. 2016. SMS-VAT: A Scalable Multi-Scale Visual Analytical Tool



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CTSI Expertise Visualization

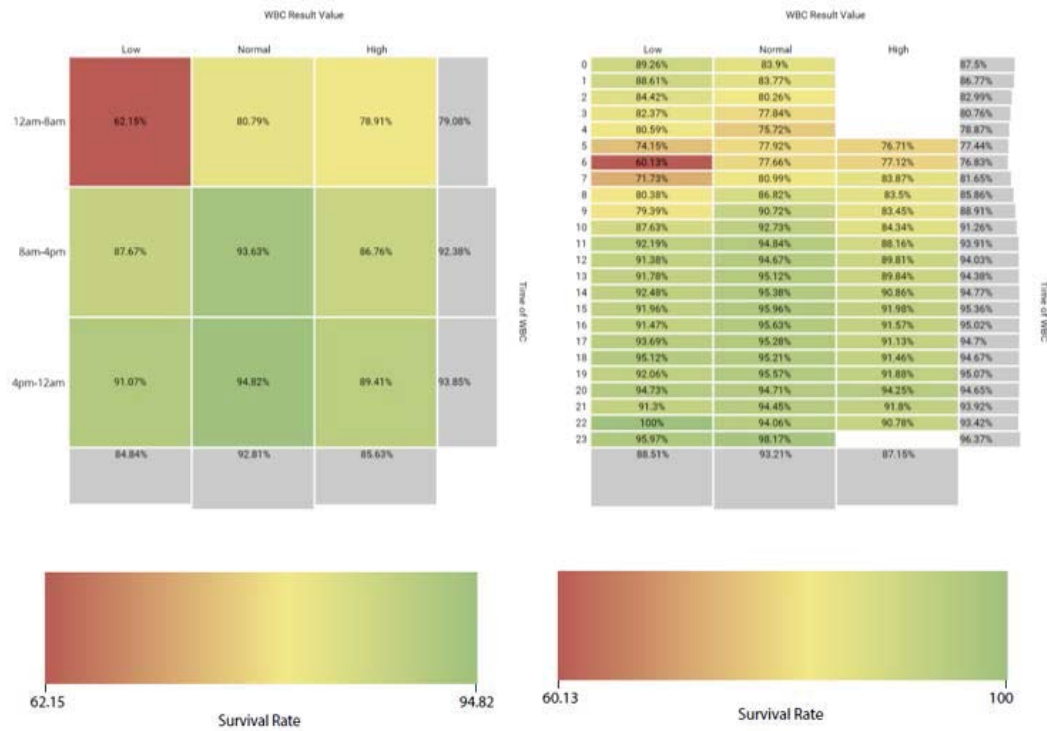
Tang, Börner, Liu, Light, & Simpson. 2016. SMS-VAT: A Scalable Multi-Scale Visual Analytical Tool



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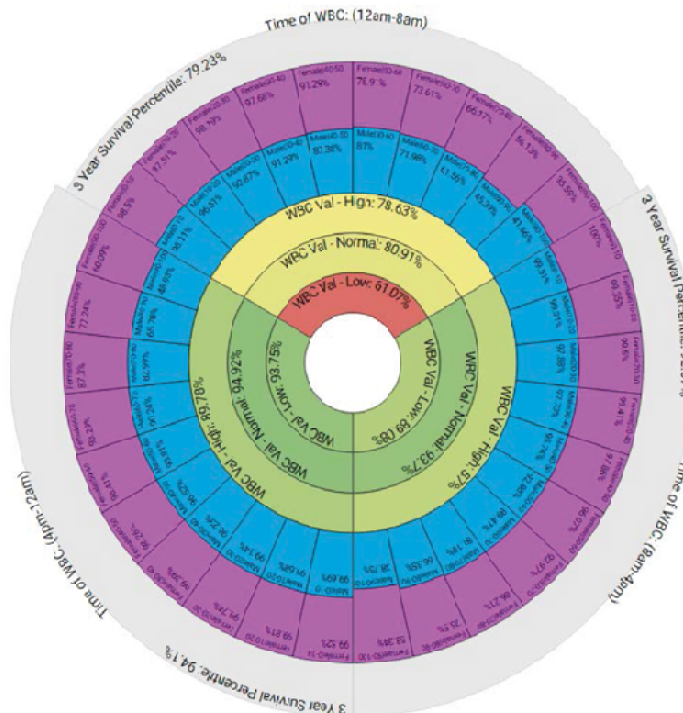
Mapping Big Biomedical Data

Weber and Börner. 2015. *Visualizing Healthcare System Dynamics in Biomedical Big Data*



Mapping Big Biomedical Data

Weber and Börner. 2015. *Visualizing Healthcare System Dynamics in Biomedical Big Data*



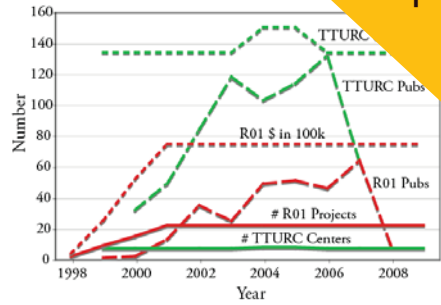
Mapping Transdisciplinary Tobacco Use Research Centers Publications

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

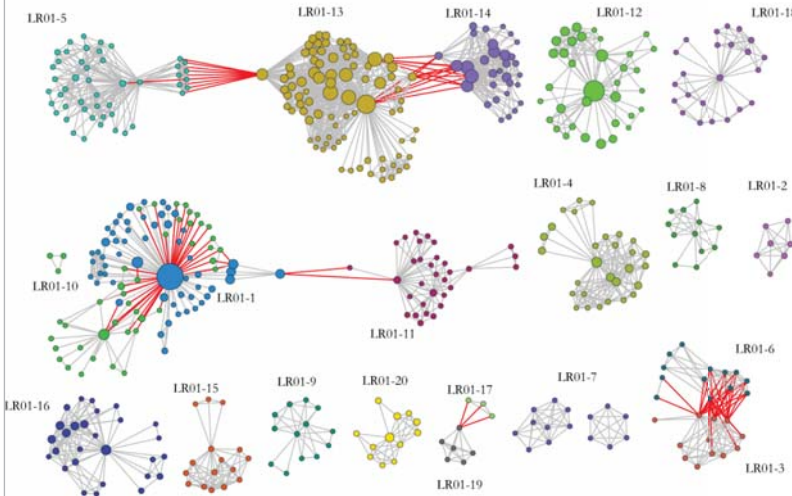
Stipelman, Hall, Zoss, Okamoto, Stokols, Börner, 2014.

Supported by NIH/NCI Contract HHSN261200800812

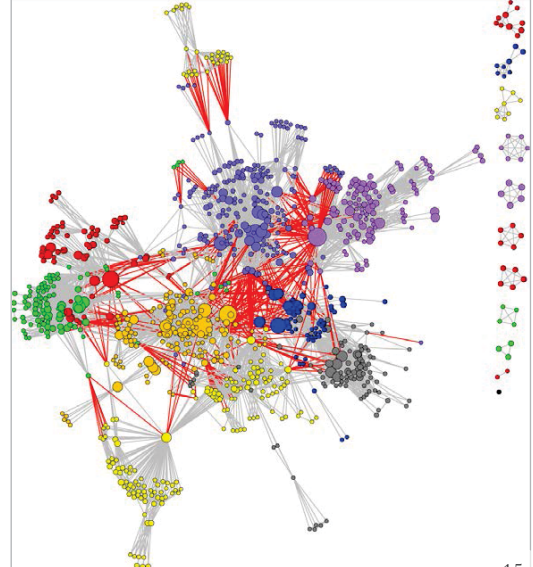
R01 & TTURC Project Information



Longitudinal R01 Co-Authorship Network



TTURC Co-Authorship Network



Research Collaborations by the Chinese Academy of Sciences

Huang, Duhon, Hardy & Börner



中科院与世界各地的研究合作关系

黄维霞, Russell J. Duhon, Elisha F. Hardy, Katy Börner, Indiana University, USA
 数据支持: 中国科学院国家科学图书馆科学前沿分析中心
 金碧辉, 岳婷



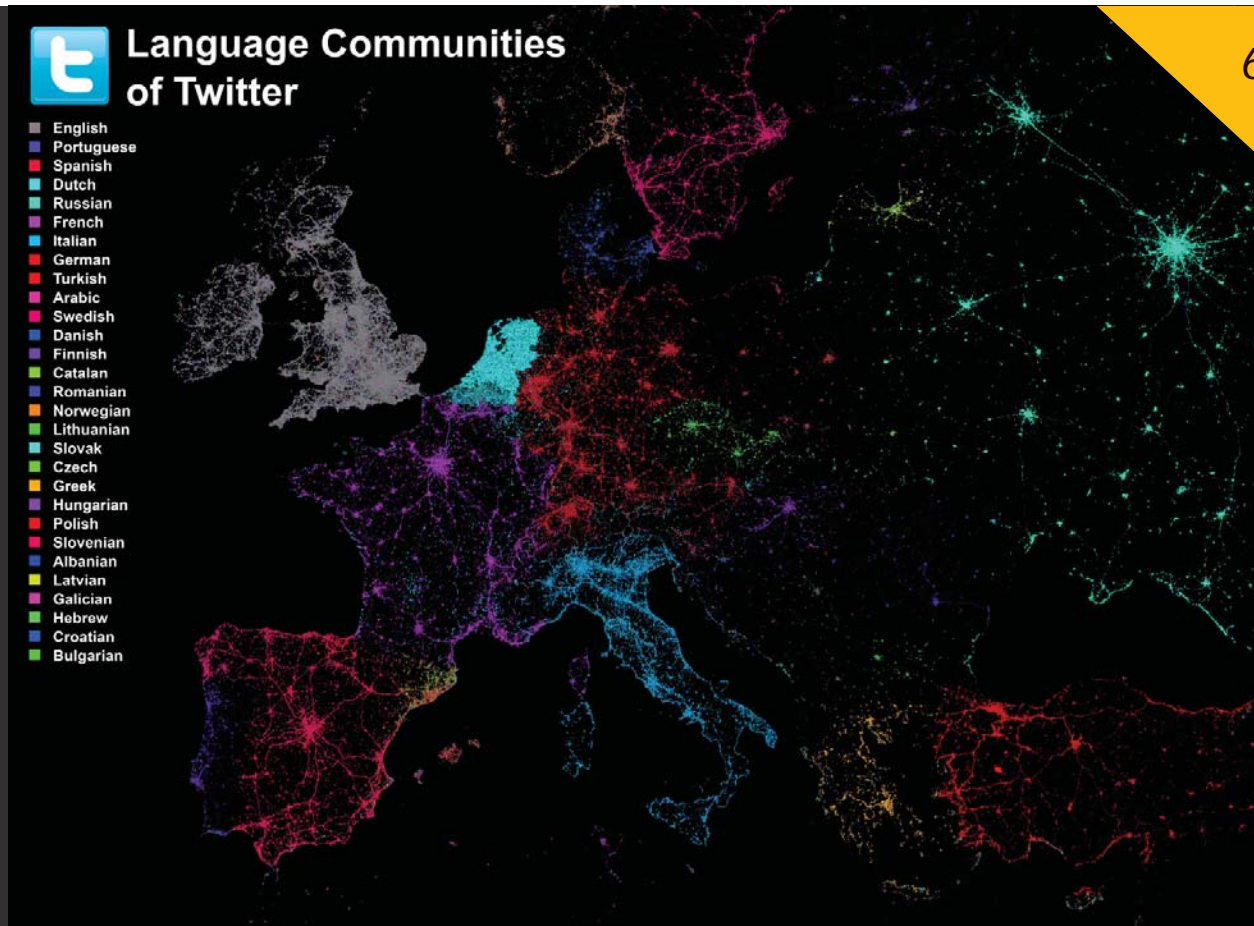
上海地区中科院各院所





Language Communities of Twitter

- English
- Portuguese
- Spanish
- Dutch
- Russian
- French
- Italian
- German
- Turkish
- Arabic
- Swedish
- Danish
- Finnish
- Catalan
- Romanian
- Norwegian
- Lithuanian
- Slovak
- Czech
- Greek
- Hungarian
- Polish
- Slovenian
- Albanian
- Latvian
- Galician
- Hebrew
- Croatian
- Bulgarian



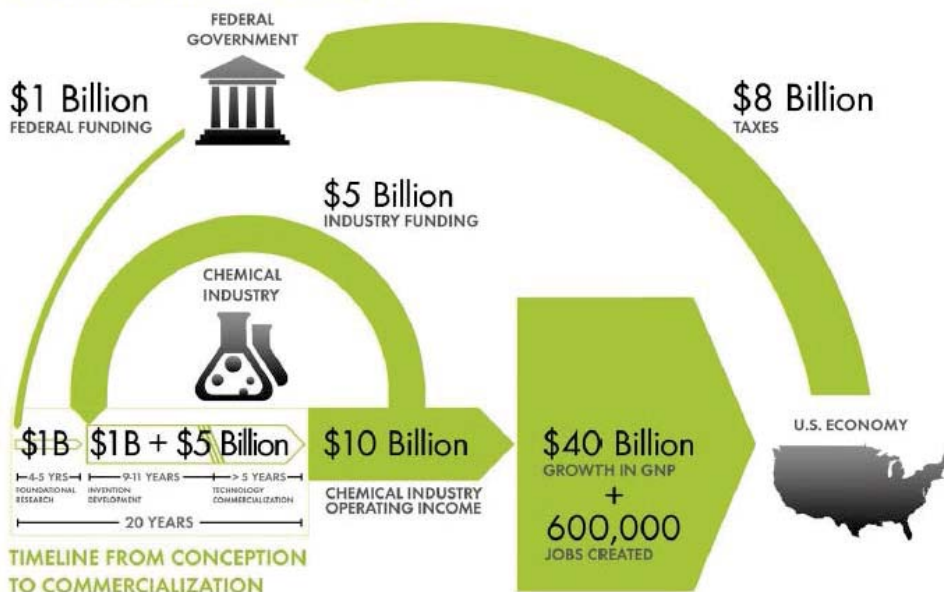
Language Communities of Twitter - Eric Fischer - 2012

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 distills 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 the 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.

Empowering Anyone to Visualize STI

Example: The Information Visualization MOOC

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Information Visualization MOOC 2015



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.

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 Course

Already registered? [Click here](#) to go to the course.

Forgot your password? [Click here](#) to reset it.

Register for free at <http://ivmooc.cns.iu.edu>. Class restarted in January 13, 2015.

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Course Schedule

Part 1: Theory and Hands-On

- **Session 1** – Workflow Design and Visualization Framework
- **Session 2** – “When:” Temporal Data
- **Session 3** – “Where:” Geospatial Data
- **Session 4** – “What:” Topical Data

Mid-Term

- **Session 5** – “With Whom:” Trees
- **Session 6** – “With Whom:” Networks
- **Session 7** – Dynamic Visualizations and Deployment

Final Exam

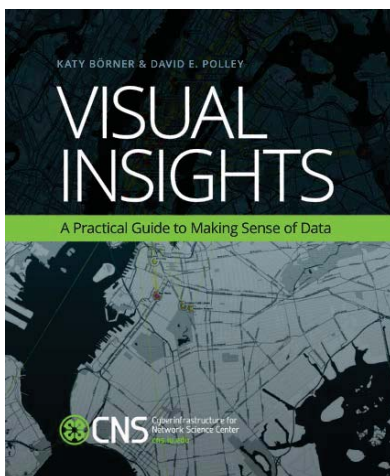


Part 2: Students work in teams on client projects.

Final grade is based on Class Participation (10%), Midterm (30%), Final Exam (30%), and Client Project(30%).

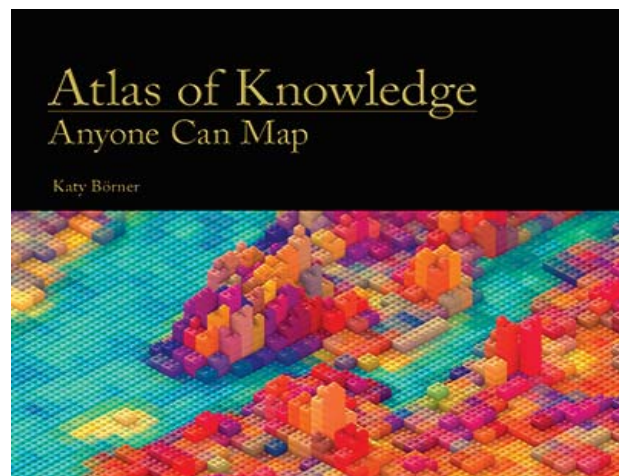
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Books Used in the IVMOOC



Teaches timely knowledge:

Advanced algorithms, tools, and hands-on workflows.



Teaches timeless knowledge:

Visualization framework—exemplified using generic visualization examples and pioneering visualizations.

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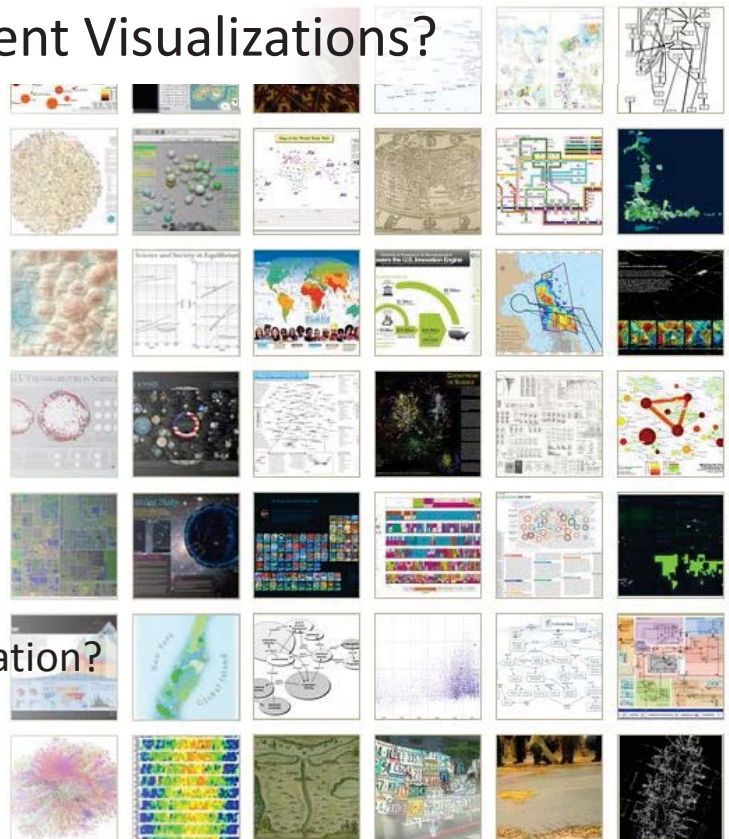
Visualization Frameworks



How to Classify Different Visualizations?





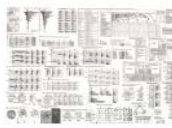
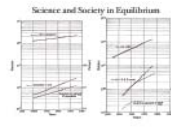


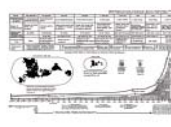
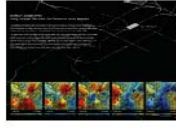








By

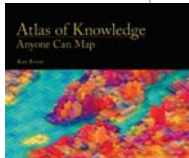
- User insight needs?
- User task types?
- Data to be visualized?
- Data transformation?
- Visualization technique?
- Visual mapping transformation?
- Interaction techniques?
- Or ?



Tasks

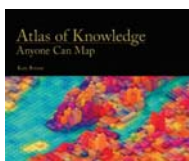
LEVELS

	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			
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 GNP. page 103
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 speeds page 83
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 journal networks in nanotechnology page 159	 Product space showing co-export patterns of countries page 93
WITH WHOM: Network Analysis page 60	 World Finance Corporation network page 87	 Electronic and new media art networks page 133	 World-wide scholarly collaboration networks page 157



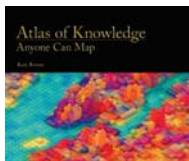
See page 5

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



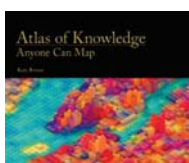
See page 24

Basic Task Types								
Bertin, 1967	Wehrend & Lewis, 1996	Few, 2004	Yau, 2011	Rendgen & Wiedemann, 2012	Frankel, 2012	Tool: Many Eyes	Tool: Chart Chooser	Börner, 2014
selection	categorize			category				categorize/ cluster
order	rank	ranking					table	order/rank/ sort
	distribution	distribution					distribution	distributions (also outliers, gaps)
	compare	nominal comparison & deviation	differences		compare and contrast	compare data values	comparison	comparisons
		time series	patterns over time	time	process and time	track rises and falls over time	trend	trends (process and time)
		geospatial	spatial relations	location		generate maps		geospatial
quantity		part-to- whole	proportions		form and structure	see parts of whole, analyze text	composition	compositions (also of text)
association	correlate	correlation	relationships	hierarchy		relations between data points	relationship	correlations/ relationships



See page 26

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See page 24

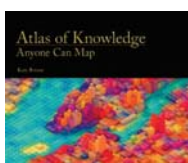
Visualization Types (Reference Systems)

1. **Charts:** No reference system—e.g., Wordle.com, pie charts
2. **Tables:** Categorical axes that can be selected, reordered; cells can be color coded and might contain proportional symbols. Special kind of graph.
3. **Graphs:** Quantitative or qualitative (categorical) axes. Timelines, bar graphs, scatter plots.
4. **Geospatial maps:** Use latitude and longitude reference system. World or city maps.
5. **Network layouts:** Node position might depends on node attributes or node similarity. **Trees:** hierarchies, taxonomies, genealogies. **Networks:** social networks, migration flows.

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Types

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
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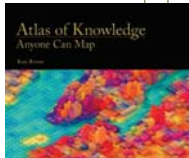


See page 25

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Graphic Variable Types Versus Graphic Symbol Types

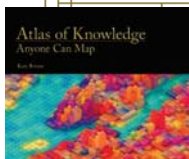
			Geometric Symbols		
			Point	Line	Area
Spatial	x	quantitative			
	y	quantitative			
	z	quantitative			
Form	Size	quantitative	NA (Not Applicable)		
	Shape	qualitative	NA		
	Rotation	quantitative	NA		
	Curvature	quantitative	NA		
	Angle	quantitative	NA		
	Closure	quantitative	NA		
Color	Value	quantitative			
	Hue	qualitative			
	Saturation	quantitative			



See page 36

Graphic Variable Types Versus Graphic Symbol Types

		Point	Line	Geometric Symbols	Surface	Volume	Linguistic Symbols	Pictorial Symbols
Spatial	x							
	y							
	z							
Form	Size	NA (Not Applicable)						
	Shape	NA						
	Rotation	NA						
	Curvature	NA						
	Angle	NA						
	Closure	NA						
Color	Value							
	Hue							
	Saturation							
Texture	spacing							
	contiguity							
	patterns							
	orientation	NA						
	coarseness							
	blur							
	transparency							
	shading							
	stereoscopic depth							
	blinking							



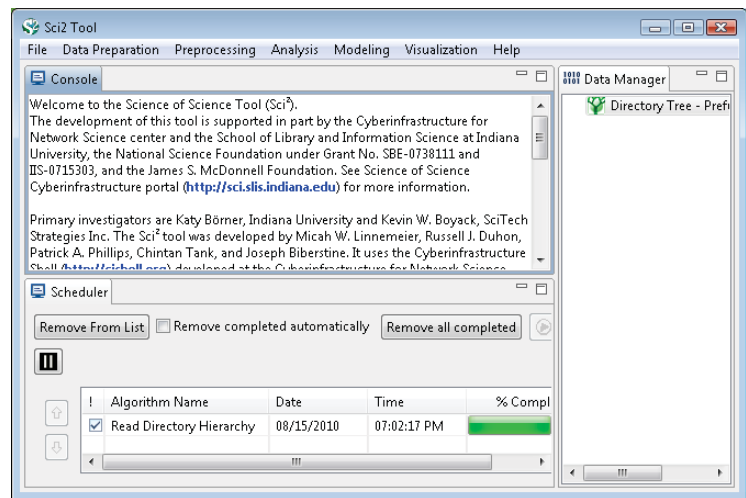
See pages 36-39

Sci2 Tool – OSGi/CIShell-based Macroscopic

Download for free at <http://sci2.cns.iu.edu>

Use

- **Menu** to read data, run algorithms.
- **Console** to see work log, references to seminal works.
- **Data Manager** to select, view, save loaded, simulated, or derived datasets.
- **Scheduler** to see status of algorithm execution.

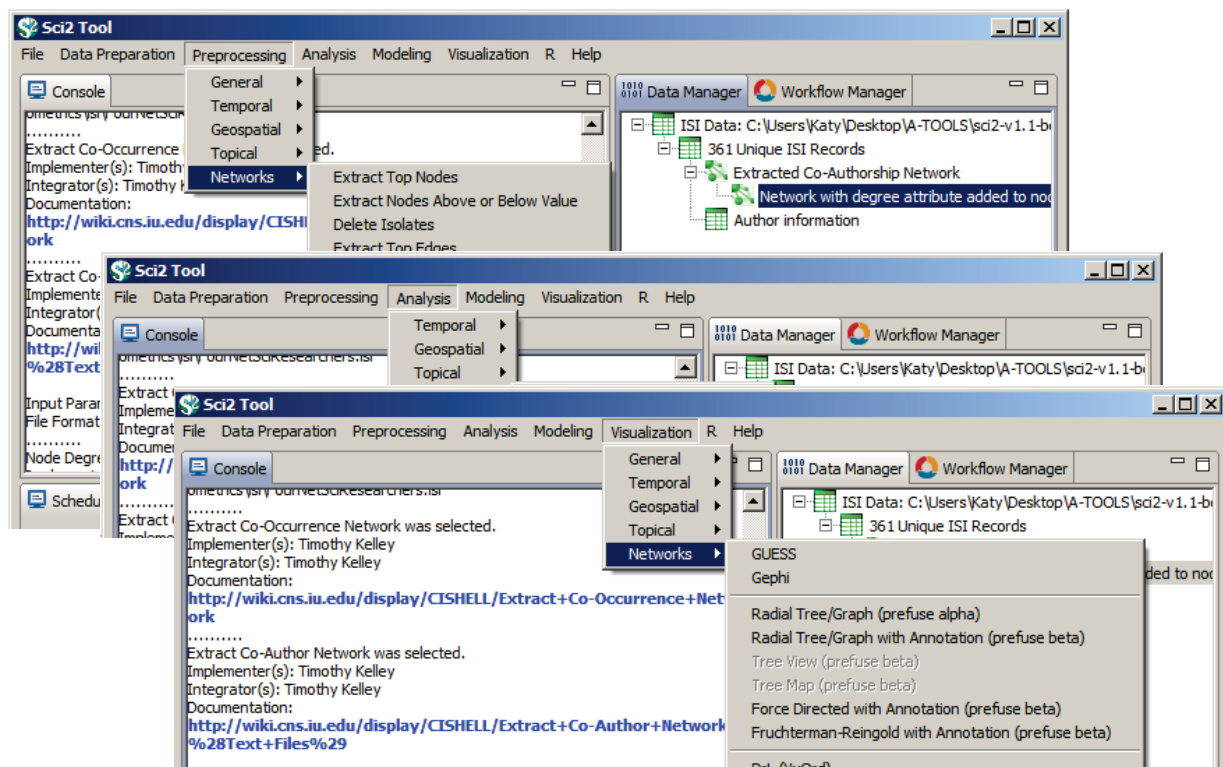


All workflows are recorded into a log file (see /sci2/logs/...), and can be re-run for easy replication. If errors occur, they are saved in a error log to ease bug reporting.

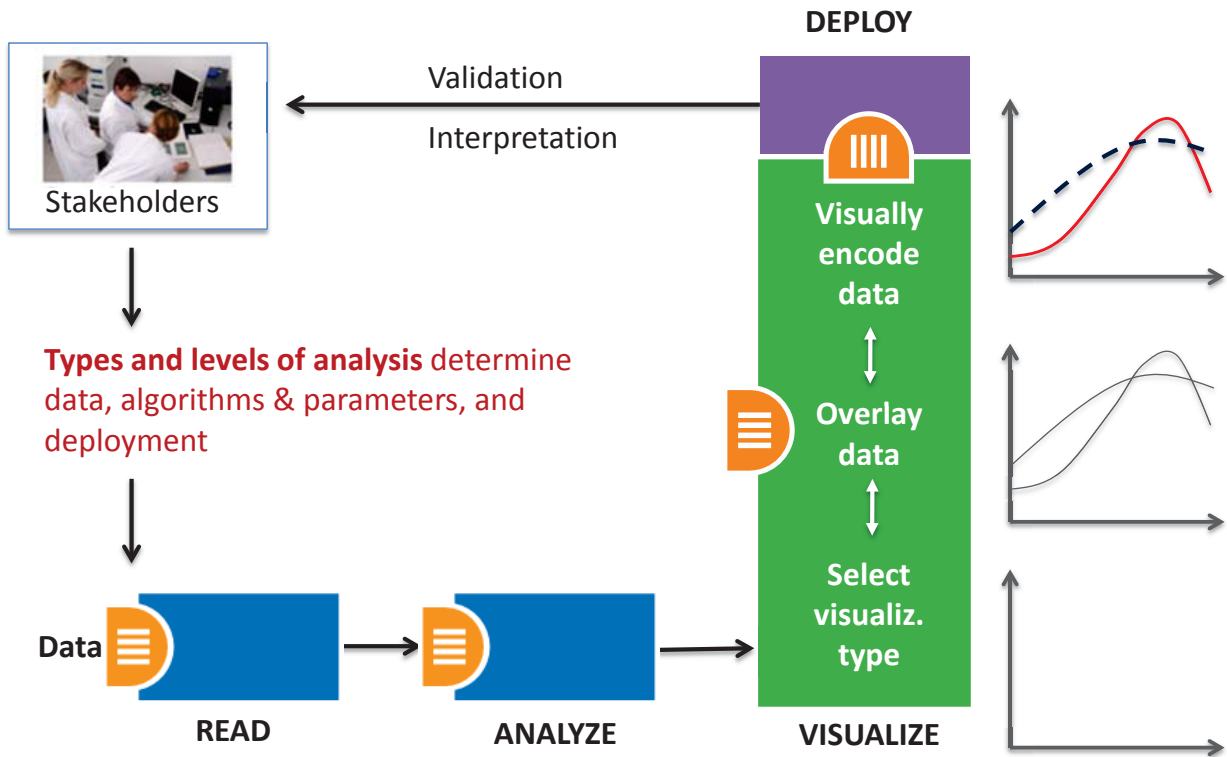
All algorithms are documented online; workflows are given in Sci2 Manual at <http://sci2.wiki.cns.iu.edu>

Sci2 Tool Interface Components

Download for free at <http://sci2.cns.iu.edu>

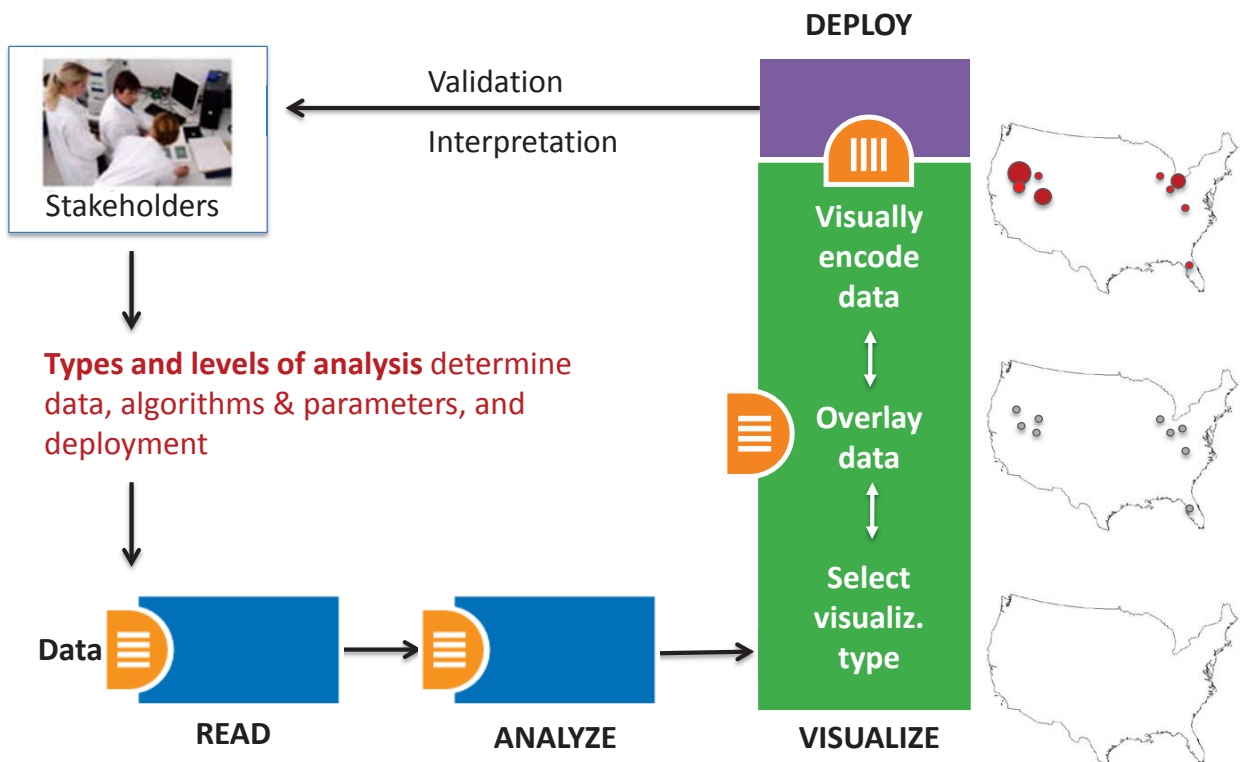


Needs-Driven Workflow Design



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Needs-Driven Workflow Design



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Load **One** File and Run **Many** Analyses and Visualizations

Times Cited	Publication Year	City of Publisher	Country	Journal Title (Full)	Title	Subject Category	Authors
12	2011	NEW YORK	USA	COMMUNICATIONS OF THE ACM	Plug-and-Play Macroscopes	Computer Science	Borner, K
18	2010	MALDEN	USA	CTS-CLINICAL AND TRANSLATIONAL SCIENCE	Advancing the Science of Team Science	Research & Experimental Medicine	Falk-Krzesinski, HJ Borner, K Contractor, NJ Fiore, SM Hall, KL Keyton, J Spring, B Stokols, D Trochim, W Uzzi, B
13	2010	WASHINGTON	USA	SCIENCE TRANSLATIONAL MEDICINE	A Multi-Level Systems Perspective for the Science of Team Science	Cell Biology Research & Experimental Medicine	Borner, K Contractor, NJ Falk-Krzesinski, HJ Fiore, SM Hall, KL Keyton, J Spring, B Stokols, D Trochim, W Uzzi, B

Statistical Analysis—p. 44

Location	Count	# Citations
Netherlands	13	292
United States	9	318
Germany	11	36
United Kingdom	1	2

Temporal Burst Analysis—p. 48



Geospatial Analysis—p. 52



Geospatial Analysis—p. 52



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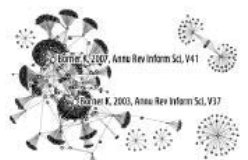
Load **One** File and Run **Many** Analyses and Visualizations

Times Cited	Publication Year	City of Publisher	Country	Journal Title (Full)	Title	Subject Category	Authors
12	2011	NEW YORK	USA	COMMUNICATIONS OF THE ACM	Plug-and-Play Macroscopes	Computer Science	Borner, K
18	2010	MALDEN	USA	CTS-CLINICAL AND TRANSLATIONAL SCIENCE	Advancing the Science of Team Science	Research & Experimental Medicine	Falk-Krzesinski, HJ Borner, K Contractor, NJ Fiore, SM Hall, KL Keyton, J Spring, B Stokols, D Trochim, W Uzzi, B
13	2010	WASHINGTON	USA	SCIENCE TRANSLATIONAL MEDICINE	A Multi-Level Systems Perspective for the Science of Team Science	Cell Biology Research & Experimental Medicine	Borner, K Contractor, NJ Falk-Krzesinski, HJ Fiore, SM Hall, KL Keyton, J Spring, B Stokols, D Trochim, W Uzzi, B

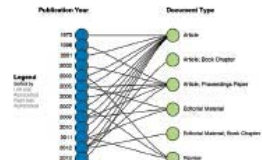
Topical Analysis—p. 56



Paper Citation Network—p. 60



Bi-Modal Network—p. 60



Co-author and many other bi-modal networks.

38

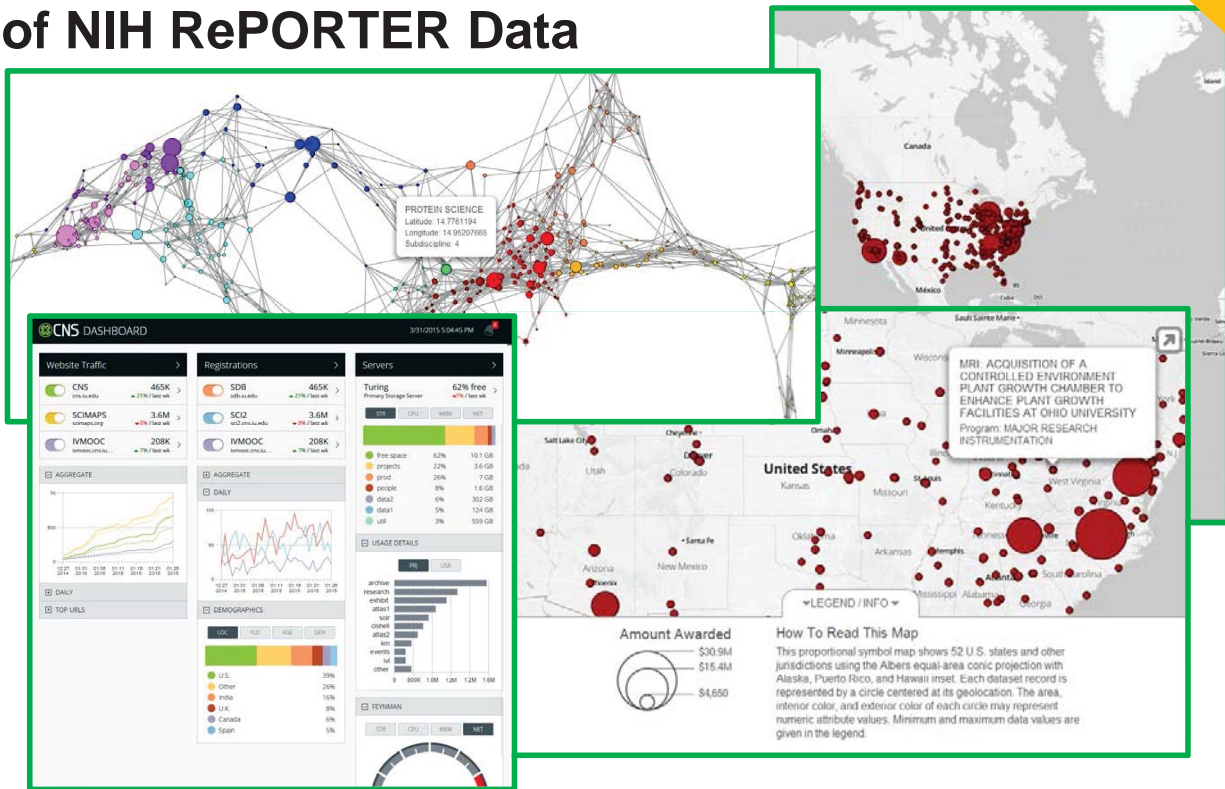
Existing Interfaces for Health-related Data

- 9) NIH RePORTER: Visual Interface to Biomedical Funding Data in U.S.
- 10) CShell/Sci2 World and Science Visualizations of NIH RePORTER Data
- 11) NIH RePORTER: NIH Map
- 12) BBSRC: Visual Interface to Biomedical Funding Data in UK
- 13) IAI Multidimensional Analysis
- 14) Scraawl: Twitter Analysis
- 15) Illuminated Diagram: Searchable World and Science Maps

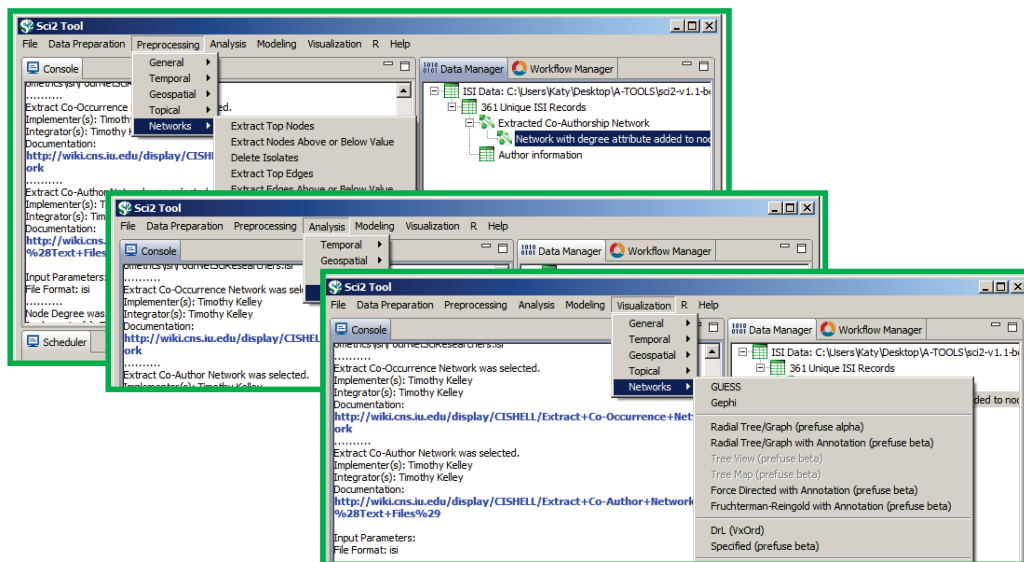
NIH RePORTER: Visual Interface to Biomedical Funding Data in US



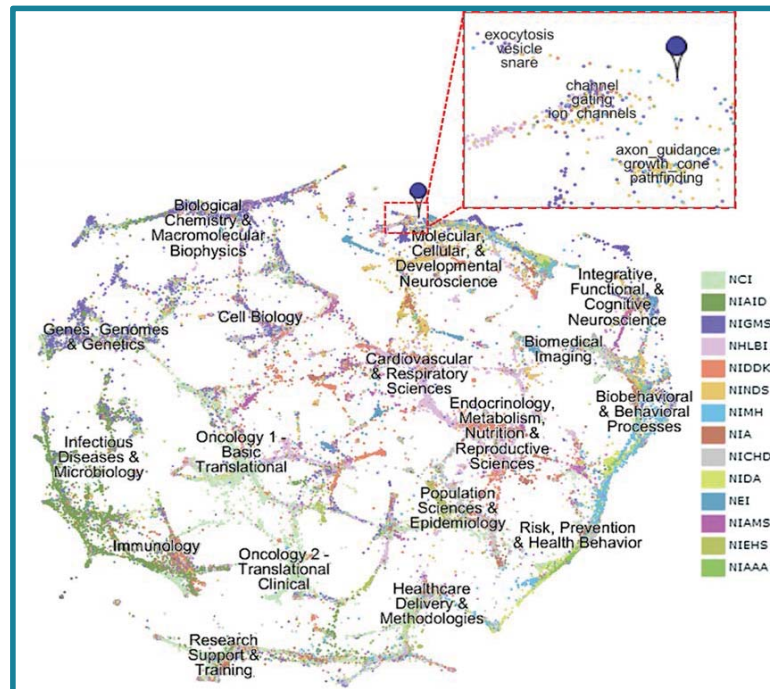
CIShell/Sci2 World and Science Visualizations of NIH RePORTER Data



Sci2 Desktop

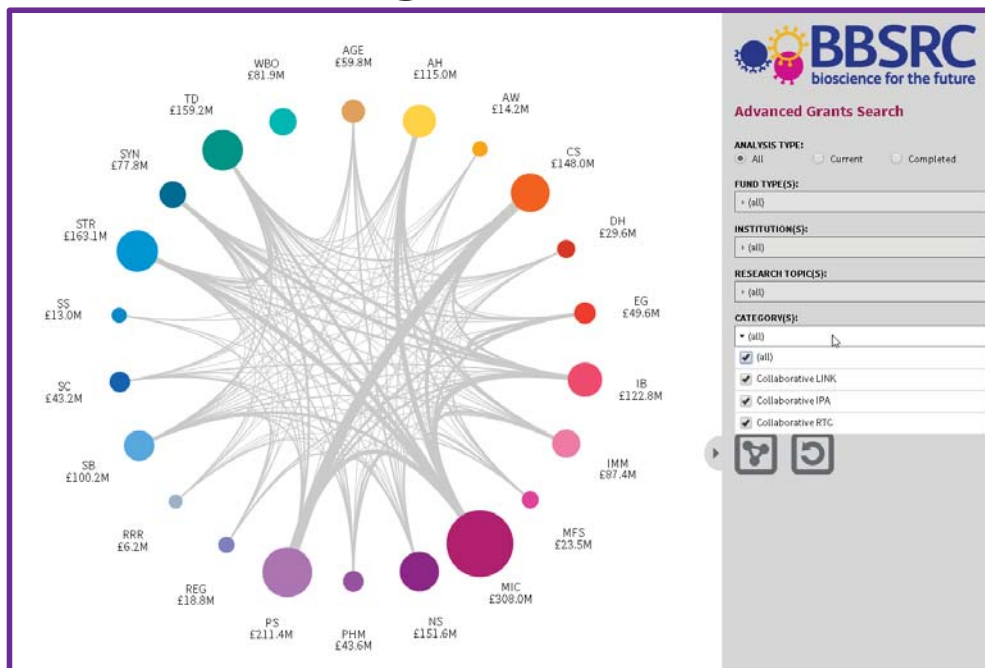


NIH RePORTER: NIH Map



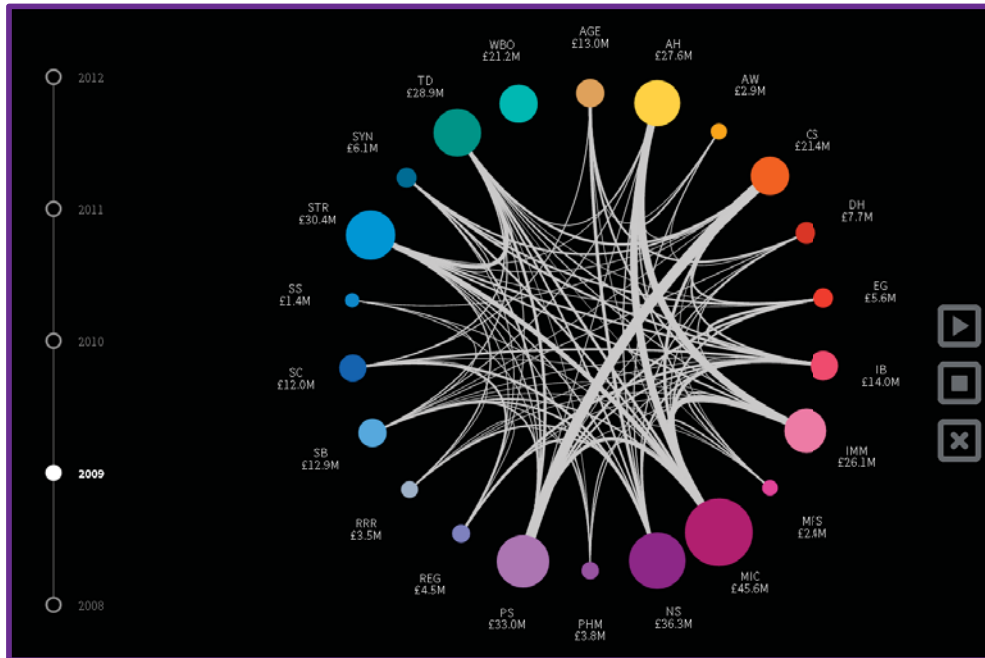
<http://nihmaps.org/>

BBSRC: Visual Interface to Biomedical Funding Data in UK

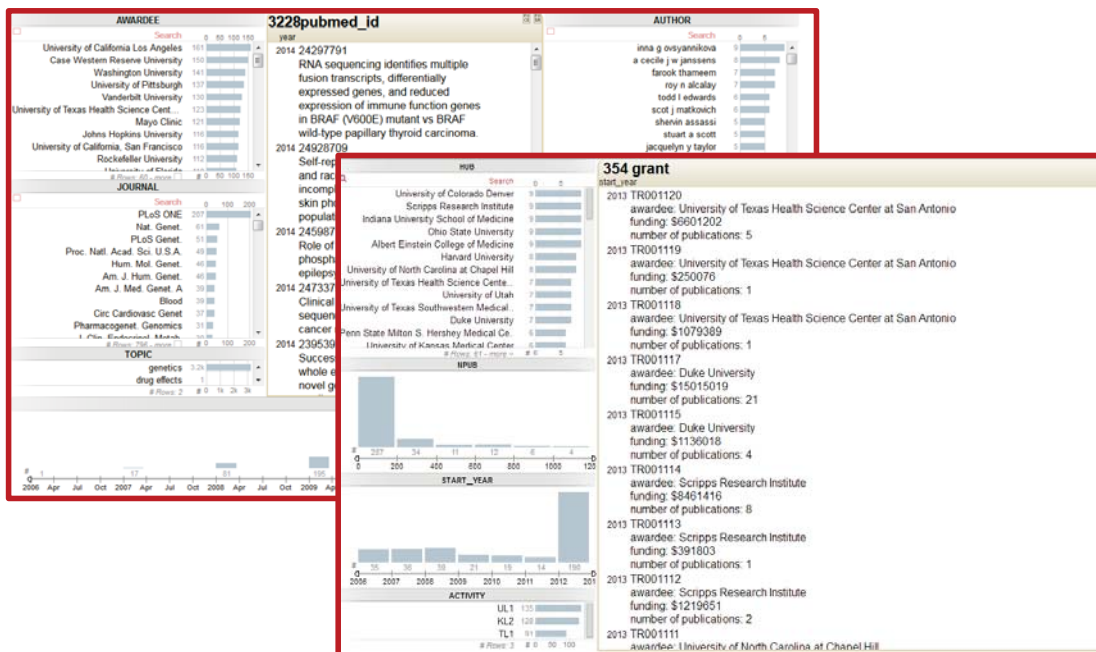


<http://www.bbsrc.ac.uk/>

BBSRC: Temporal animation



IAI Multidimensional Analysis



Scraawl: Twitter Analysis

Edit Report
Report Name: NIH-NCATS Test - Search Terms: @NIH, #ncats

Search terms: @NIH, #ncats

Separate your search terms with a comma to search for multiple terms (e.g. twitter, social, twitter socialmedia).

Rollover report
When the report is completed, automatically create a new report and continue collecting data.

Name (optional)
NIH-NCATS Test

Optional name for the report

Data sources
 Twitter (Coming soon) Instagram Tumblr LinkedIn Flickr

Your Scraawl searches will time out in 1 hours, or when the search returns the number of privileges.

A product of Intelligent Analysis
Beta release version 0.9.4. Please report any bugs.

Top Users	Top Words	Top Hashtags	Top Mentions
@francescmiley 4	Cancer 43	#cancerfilm 74	@nih 100
@4ooglalmrphdhd 2	Research 37	#nih 27	@condandrennes 6
@lioxespi_s21 2	Medical 26	#cancer 27	@ucsfccancer 5
@qprovesearch 2	May 25	#clinicaltrials 5	@listm_malaria 3
@medsci_news 2	Lasker 25	#precisionmedicine 4	@wahamsadamy 3
90 total users	197 total words	23 total hashtags	29 total mentions

Top URLs	Top Retweets	Top Languages	Top Locations
http://profiles.nlm.nih.gov/ps... 24	RT @NIH: Mary Lasker, som... 20	English 99%	España 1
http://dtp.nci.nih.gov/tmle/... 9	RT @NIH: Largely thanks to... 9	French 0%	
http://www.nlm.nih.gov/medli... 9	RT @NIH: President Naom st... 6		
http://seer.cancer.gov/statfa... 7	RT @NIH: Cancer is a gene... 6		
http://www.nih.gov/health/d... 5	RT @NIH: #Canceroccurs w... 5		
26 total URLs	28 retweeted tweets	2 total languages	0 geocoded tweets

Tweet Timeline

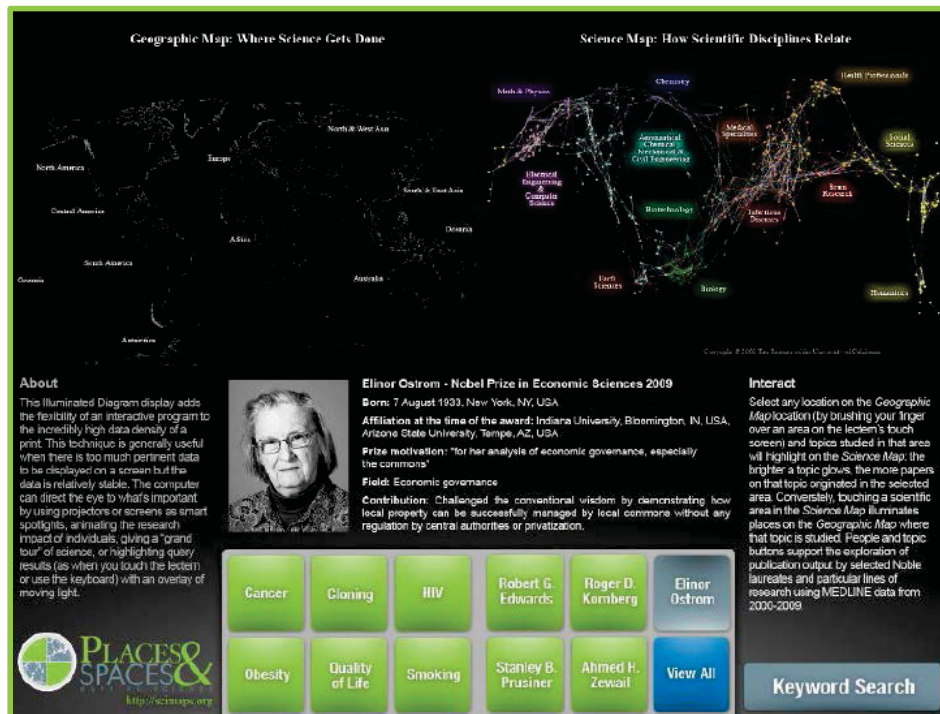
<https://www.scraawl.com/>

Illuminated Diagram: Searchable World and Science Maps



http://cns.iu.edu/interactive_displays.html

Illuminated Diagram: Search detail



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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/

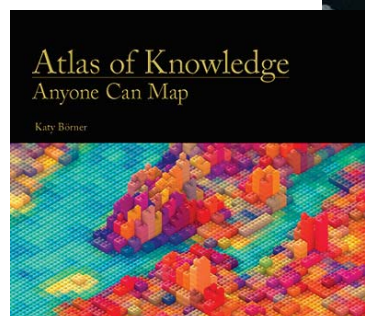
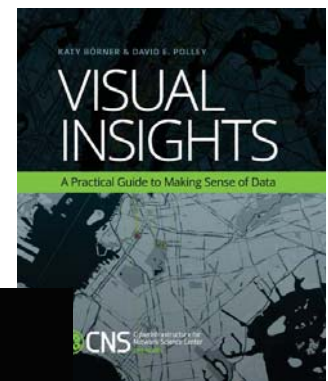
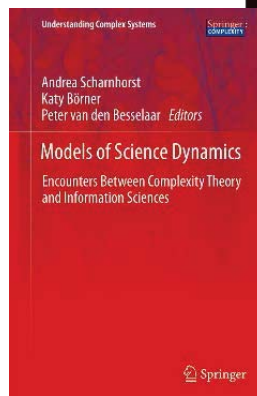
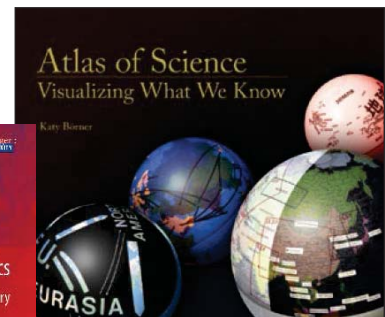
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10.13 Katy Börner presents Mapping Science Exhibit at WSSF
10.15 Ted Polley & Google Team present IVMOOC at EDUCAUSE
10.22 Katy Börner presents at the SciELO 15 Years Conference

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