

Actionable Data Visualizations

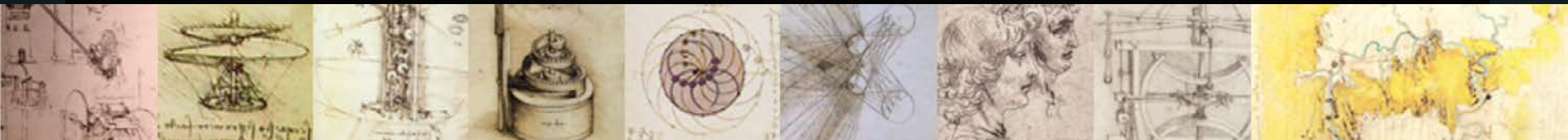
Katy Börner @katycns

Victor H. Yngve Distinguished Professor of
Intelligent Systems Engineering & Information Science
Director, Cyberinfrastructure for Network Science Center
School of Informatics, Computing, and Engineering
Indiana University Network Science Institute (IUNI)
Indiana University, Bloomington, IN, USA
+ 2018 Humboldt Fellow, TU Dresden, Germany



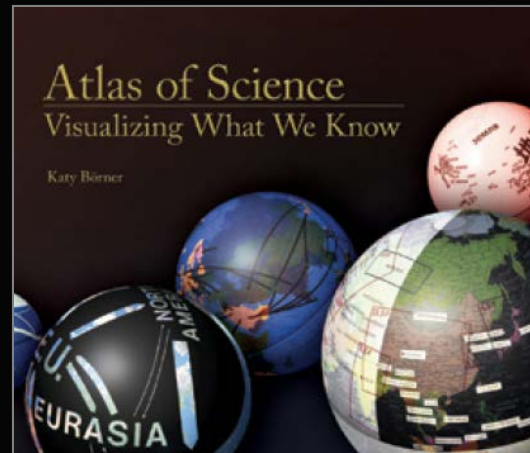
*The European Summer University in Digital Humanities
Leipzig, Germany*

July 17, 2018



Maps of Science & Technology

Using large scale datasets, advanced data mining and visualization techniques, and substantial computing resources.



Maps of Science & Technology

<http://scimaps.org>



101st Annual Meeting of the Association of American Geographers, Denver, CO.
April 5th - 9th, 2005 (First showing of Places & Spaces)



University of Miami, Miami, FL.
September 4 - December 11, 2014.



Duke University, Durham, NC.
January 12 - April 10, 2015



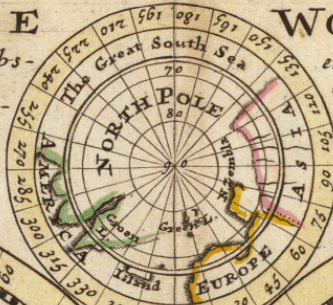
The David J. Sencer CDC Museum, Atlanta, GA.
January 25 - June 17, 2016.

100 maps and 12 macrosopes by 215 experts on display at 354 venues in 28 countries.

A New Map of the **WHOLE**
According to y^e latest and most Exact Obs-

WORLD with the Trade winds
ervations By H. Moll Geographer

In this Maps is inserted A View of y^e General & Coasting Trade Winds, Monsoons or y^e Shifting Trade winds Note that y^e Arrows among y^e Lines shew y^e Course of those General & Coasting Winds. and y^e Arrows in y^e void Spaces shew y^e Course of y^e Shifting Trade winds, and y^e Abbreviation Sep^r & c. Shew y^e Times of y^e Year when such Winds Blow.

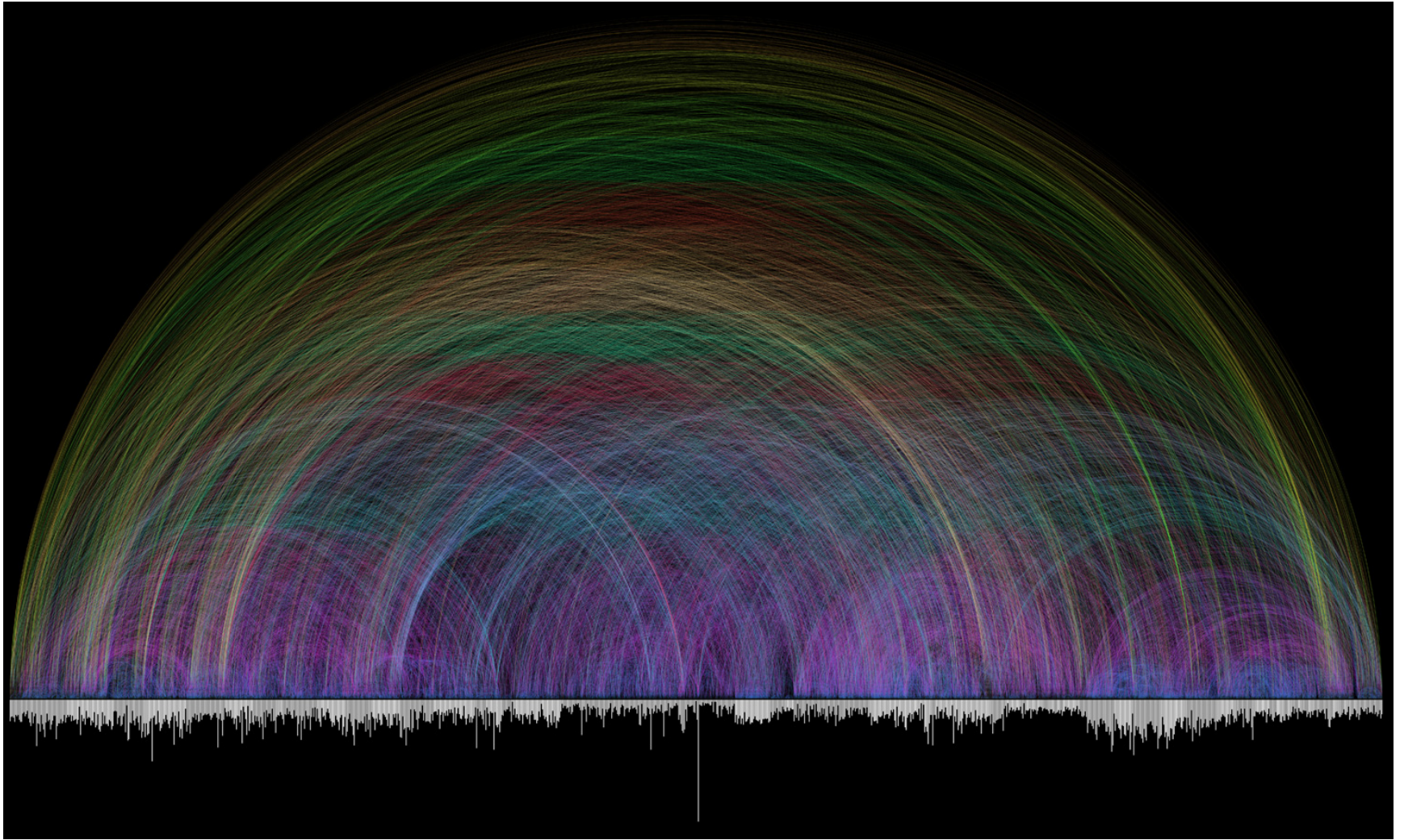


The Signs of the Zodiac. The First 6 are Northern, the other Southern Signs
♈ Aries . March
♉ Taurus . April
♊ Gemini . May
♋ Cancer . June
♌ Leo . July
♍ Virgo . August
♎ Libra . September
♏ Scorpio . October
♐ Sagittarius . November
♑ Capricornus . Decemb.
♒ Aquarius . January
♓ Pisces . February



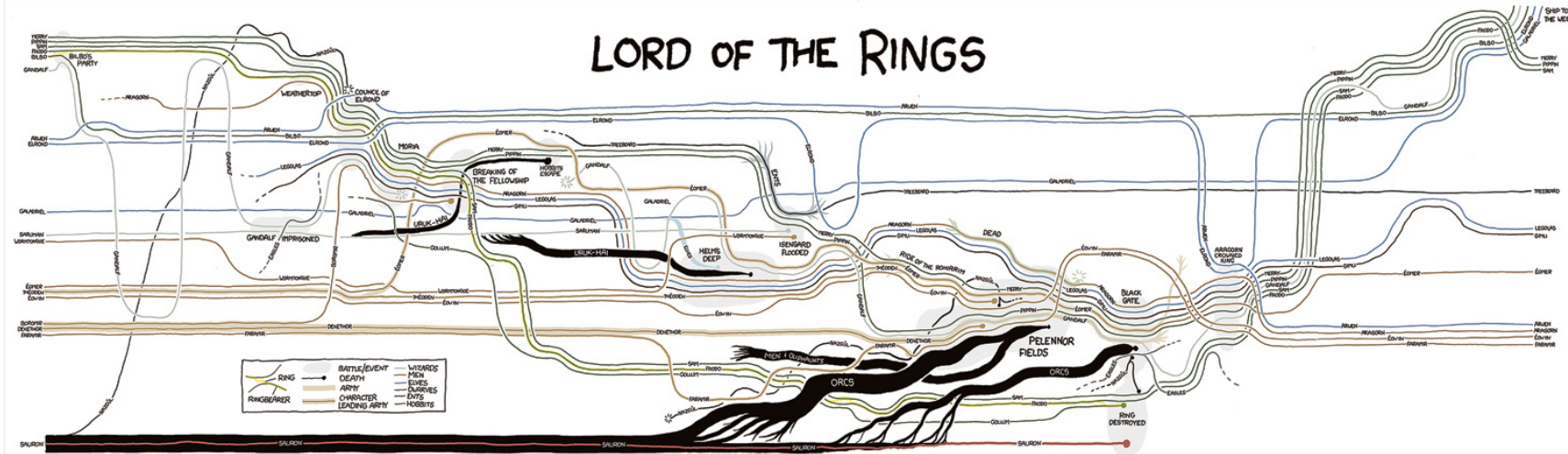
Printed for Tho^s Bowles Print and Map Seller next y^e Charter House in S^t. Pauls Church yard; and John Bowles Print and Map Seller at the Black Horse in Cornhill London.

1.3 A New Map of the Whole World with Trade Winds According to the Latest and Most Exact Observations - Herman Moll - 1736

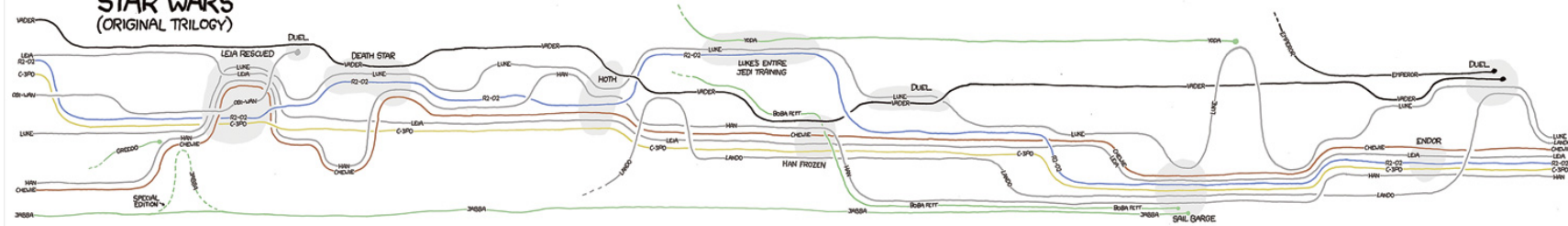


THESE CHARTS SHOW MOVIE CHARACTER INTERACTIONS.
 THE HORIZONTAL AXIS IS TIME. THE VERTICAL GROUPING OF THE
 LINES INDICATES WHICH CHARACTERS ARE TOGETHER AT A GIVEN TIME.

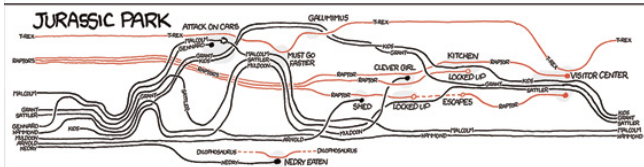
LORD OF THE RINGS



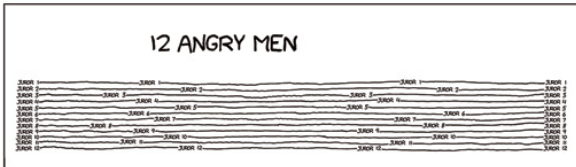
STAR WARS (ORIGINAL TRILOGY)



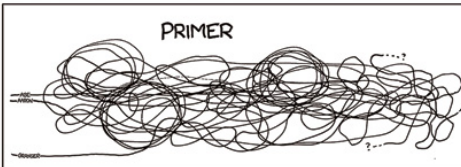
JURASSIC PARK



12 ANGRY MEN



PRIMER

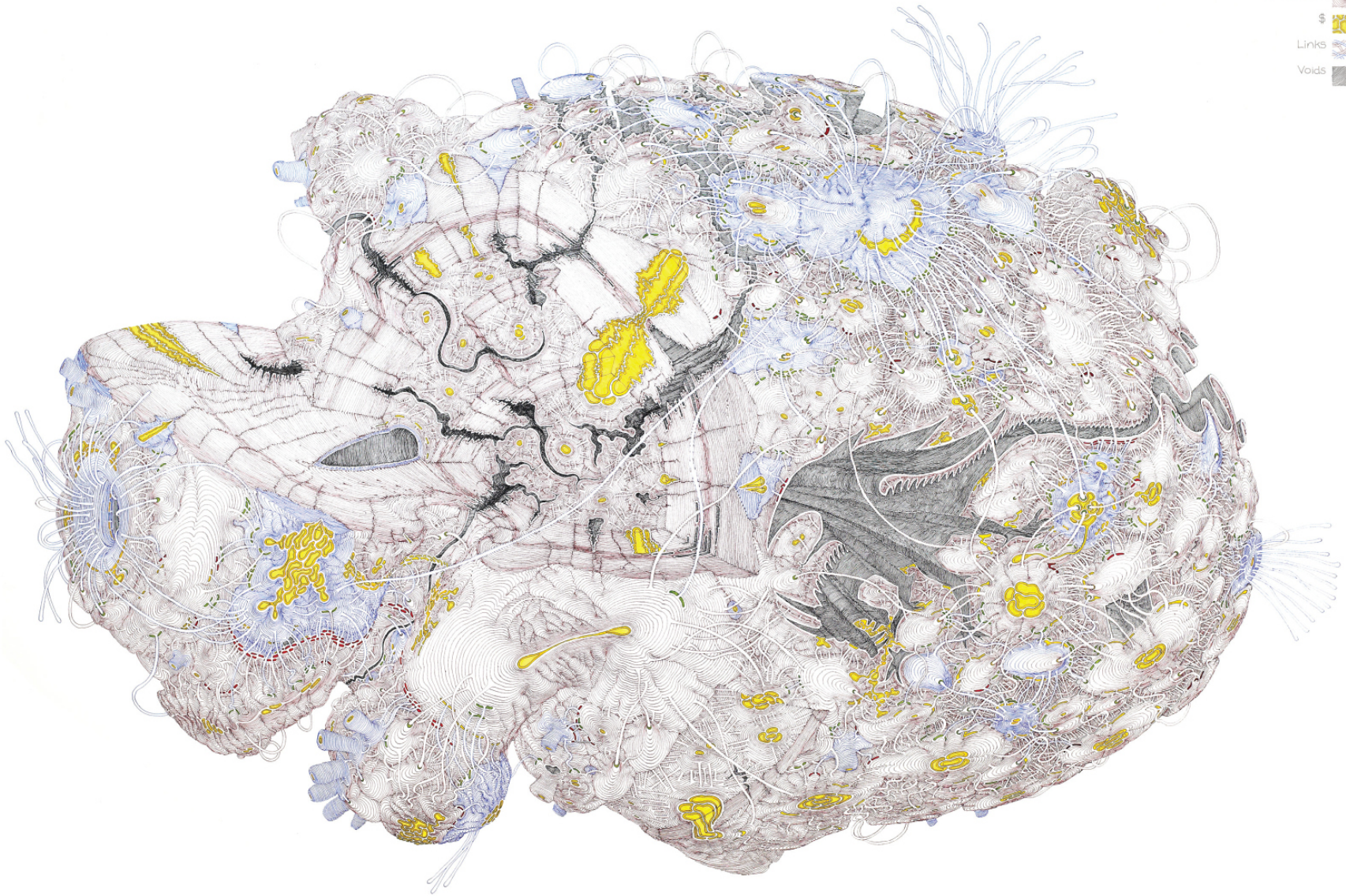


Map of Scientific Collaborations from 2005-2009



Computed Using Data from Elsevier's Scopus

- Emerging
- Established
- Links
- Voids

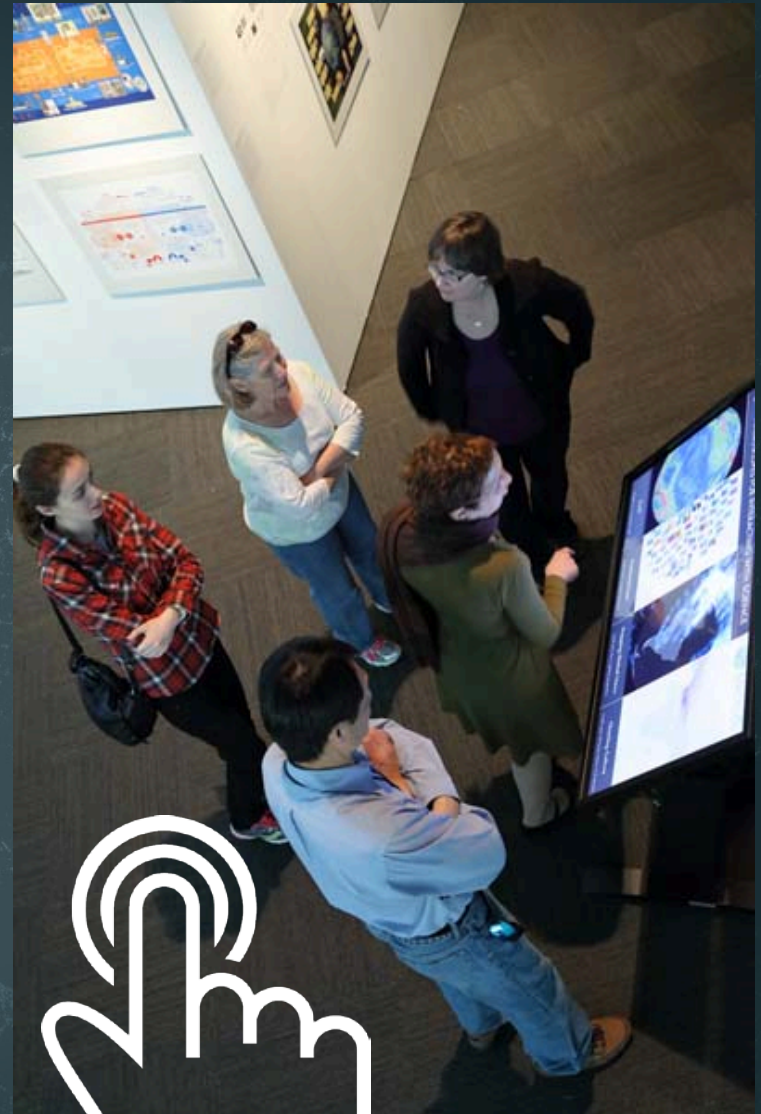


One of Many Possible Interpretations

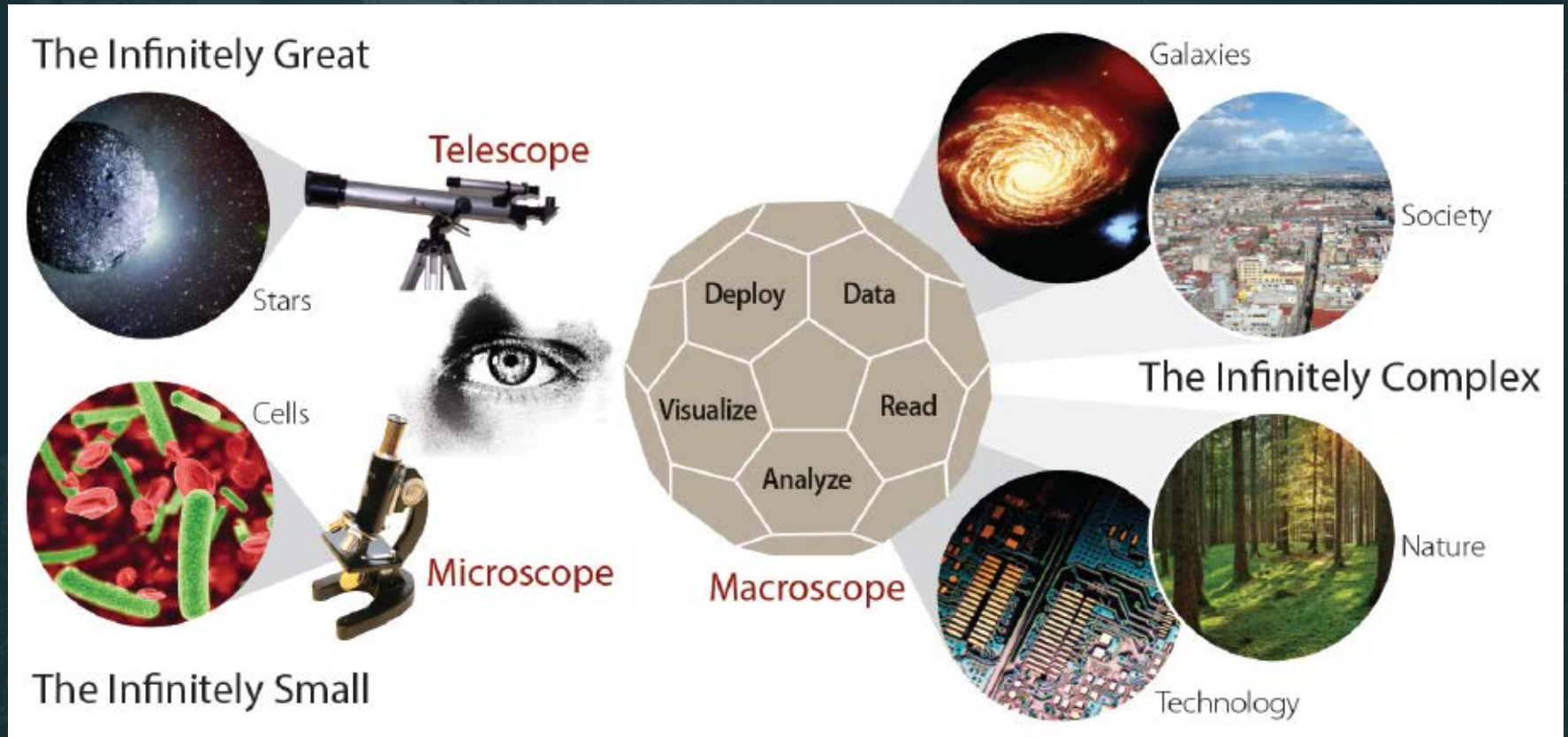
Daniel Zeller 2007



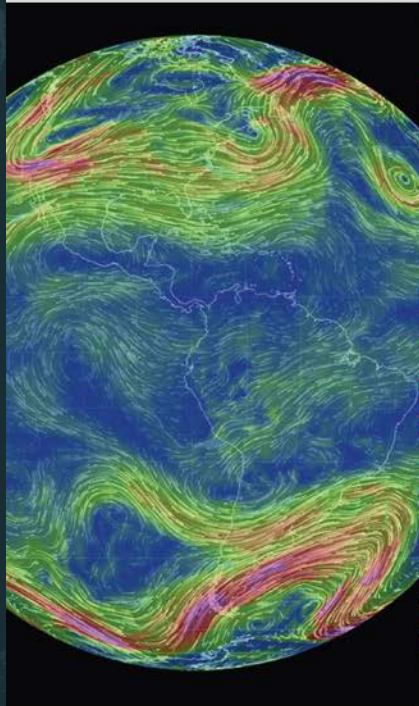
MAPS vs. MACROSCOPES



Microscopes & Telescopes vs. MACROSCOPES



i **MACROSCOPES FOR INTERACTING WITH SCIENCE**



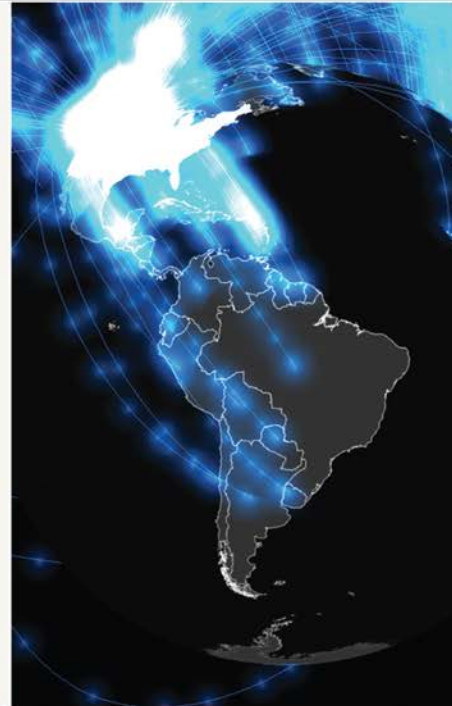
Earth

Weather on a worldwide scale



AcademyScope

Exploring the scientific landscape



Mapping Global Society

Local news from a global perspective

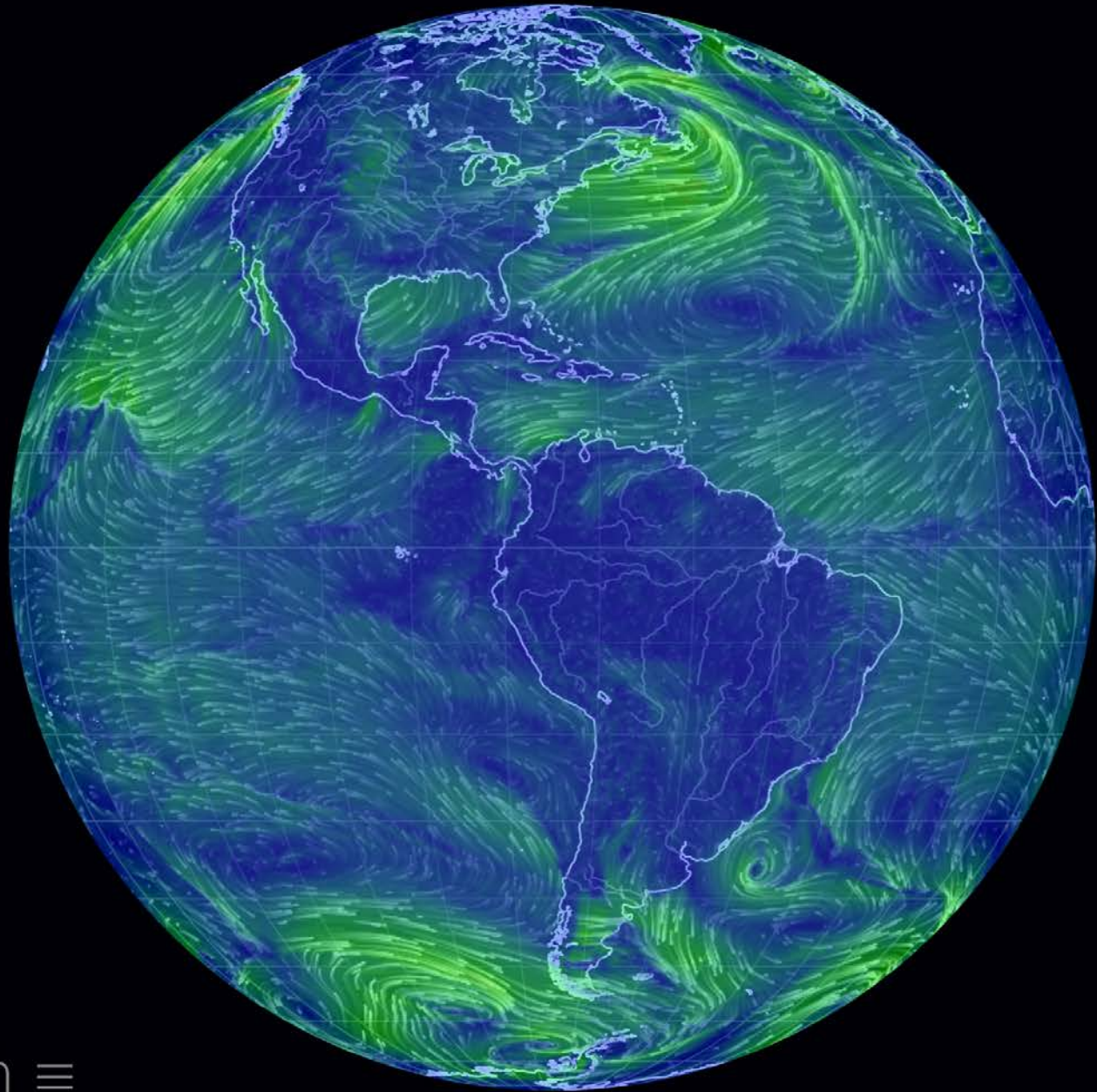


Charting Culture

2,600 years of human history in 5 minutes

Iteration XI (2015): Macroscopes for Interacting with Science

<http://scimaps.org/iteration/11>



earth ≡

Earth – Cameron Beccario

Top downloads



- +

- Agriculture
- Behavioral and Social Sciences
- Biography and Autobiography
- Biology and Life Sciences
- Computers and Information Technology
- Conflict and Security Issues
- Earth Sciences
- Education
- Energy and Energy Conservation
- Engineering and Technology
- Environment and Environmental Studies
- Explore Science
- Food and Nutrition
- Health and Medicine
- Industry and Labor
- Math, Chemistry and Physics
- Policy for Science and Technology
- Space and Aeronautics
- Transportation

opic=282

The News Co-occurrence Globe

An interactive visualization of how countries are mentioned together in the world's news media

+ - UNITED KINGDOM SEARCH ABOUT



2.92K
COOCCUR%

UNITED KINGDOM cooccurrences in: 2,922%
cooccurrences out: 80%

Timeline: Feb 22, Mar 1, Mar 8, Mar 15, Mar 22, Mar 29, Apr 5, Apr 12, Apr 19, Apr 26, May 3, May 10, May 17, May 24



COOCCUR

IN%

OUT%



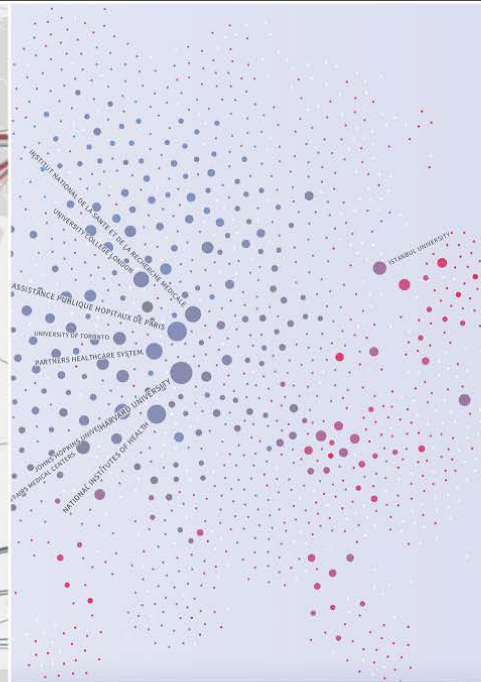
Smelly Maps

Charting urban smellscapes



HathiTrust

Storehouse of knowledge



Excellence Networks

Publish or perish together



FleetMon Explorer

Tracking the seven seas

Iteration XII (2016): Macrosopes for Making Sense of Science

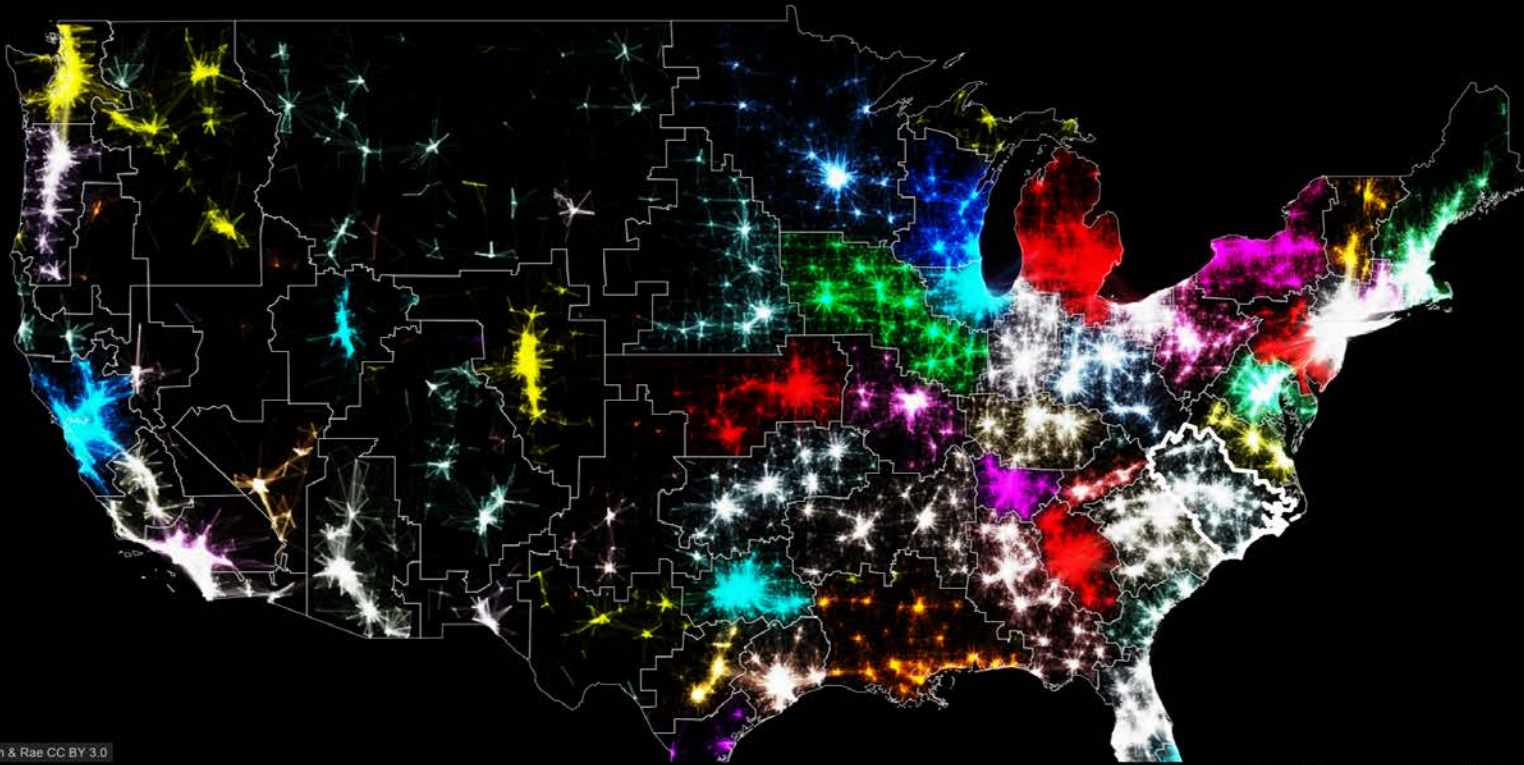
<http://scimaps.org/iteration/12>



Smelly Maps – Daniele Quercia, Rossano Schifanella, and Luca Maria Aiello – 2015

THE MEGAREGIONS OF THE US

Explore the new geography of commuter connections in the US.
Tap to identify regions. Tap and hold to see a single location's commuted.



Leaflet | Nelson & Rae CC BY 3.0

This is the Roanoke (Raleigh) megaregion.

 **FleetMon**
Tracking the Seven Seas



00:08

01:31

FleetMon Explorer – FleetMon – 2012

Models of Science & Technology

Using large scale datasets, advanced data mining, modeling, and visualization techniques, and substantial computing resources.





Modeling Science, Technology & Innovation Conference

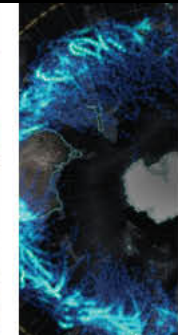
WASHINGTON D.C. | MAY 17-18, 2016

[View Agenda](#)

Government, academic, and industry leaders discussed challenges and opportunities associated with using big data, visual analytics, and computational models in STI decision-making.

Conference slides, recordings, and report are available via <http://modsti.cns.iu.edu/report>





Modeling and Visualizing Science and Technology Developments

National Academy of Sciences Sackler Colloquium, December 4-5, 2017, Irvine, CA

Rankings and the Efficiency of Institutions

H. Eugene Stanley | Albert-László Barabási | Lada Adamic | Marta González | Kaye Husbands Fealing | Brian Uzzi | John V. Lombardi

Higher Education and the Science & Technology Job Market

Katy Börner | Wendy L. Martinez | Michael Richey | William Rouse | Stasa Milojevic | Rob Rubin | David Krakauer

Innovation Diffusion and Technology Adoption

William Rouse | Donna Cox | Jeff Alstott | Ben Shneiderman | Rahul C. Basole | Scott Stern | Cesar Hidalgo

Modeling Needs, Infrastructures, Standards

Paul Trunfio | Sallie Keller | Andrew L. Russell | Guru Madhavan | Azer Bestavros | Jason Owen-Smith



PROGRAMS

Sackler Colloquia

- » About Sackler Colloquia
- » Upcoming Colloquia
- » Completed Colloquia
- » Sackler Lectures
- » Video Gallery
- » Connect with Sackler Colloquia
- » Give to Sackler Colloquia

Cultural Programs

Distinctive Voices

Kavli Frontiers of Science

Keck Futures Initiative

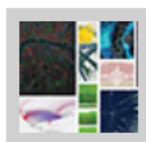
LabX

Sackler Forum

Science & Entertainment Exchange



Modeling and Visualizing Science and Technology Developments



December 4-5, 2017; Irvine, CA

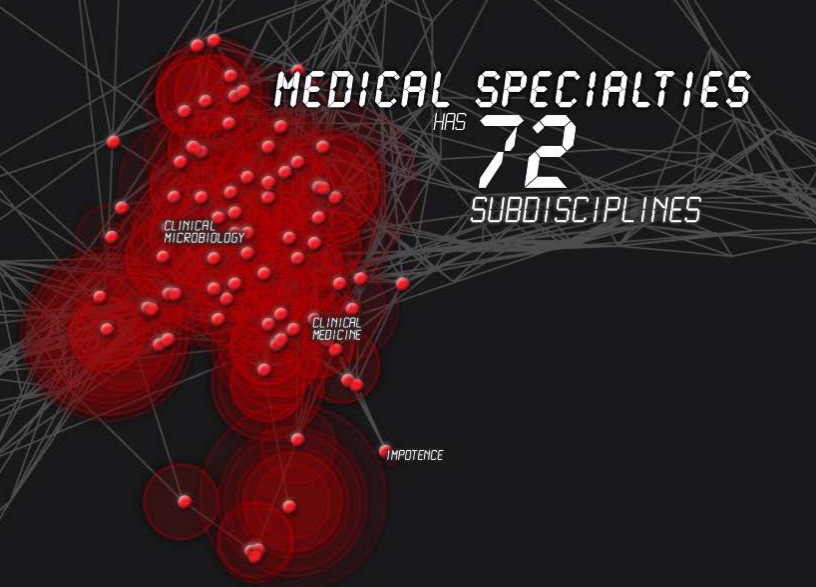
Organized by Katy Börner, H. Eugene Stanley, William Rouse and Paul Trunfio

Overview

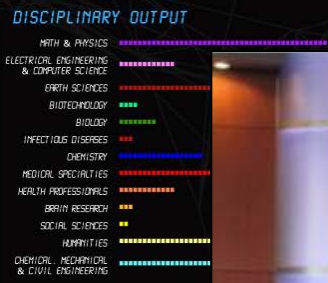
This colloquium was held in Irvine, CA on December 4-5, 2017.

This colloquium brought together researchers and practitioners from multiple disciplines to present, discuss, and advance computational models and visualizations of science and technology (S&T). Existing computational models are being applied by academia, government, and industry to explore questions such as: What jobs will exist in ten years and what career paths lead to success? Which types of institutions will likely be most innovative in the future? How will the higher education cost bubble burst affect these institutions? What funding strategies have the highest return on investment? How will changing demographics, alternative economic growth trajectories, and relationships among nations impact answers to these and other questions? Large-scale datasets (e.g., publications, patents, funding, clinical trials, stock market, social media data) can now be utilized to simulate the structure and evolution of S&T. Advances in computational power have created the possibility of implementing scalable, empirically validated computational models. However, because the databases are massive and multidimensional, both the data and the models tend to exceed human comprehension. How can advances in data visualizations be effectively employed to communicate the data, the models, and the model results to diverse stakeholder groups? Who will be the users of next generation models and visualizations and what decisions will they be addressing.

Videos of the talks are available on the [Sackler YouTube Channel](#).



**MAP OF SCIENCE: FORECASTING
LARGE TRENDS IN SCIENCE**



**Science Forecast
S1:E1**



Science Forecast

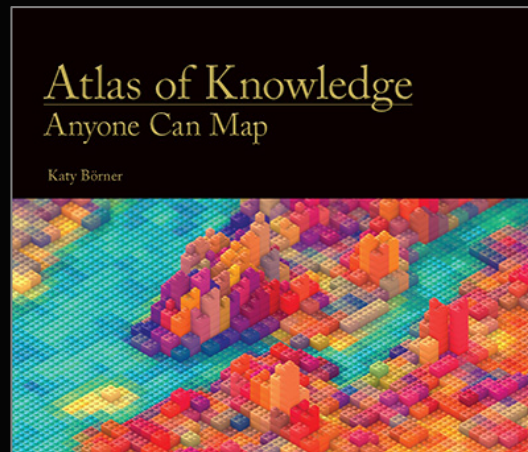
S1:E1

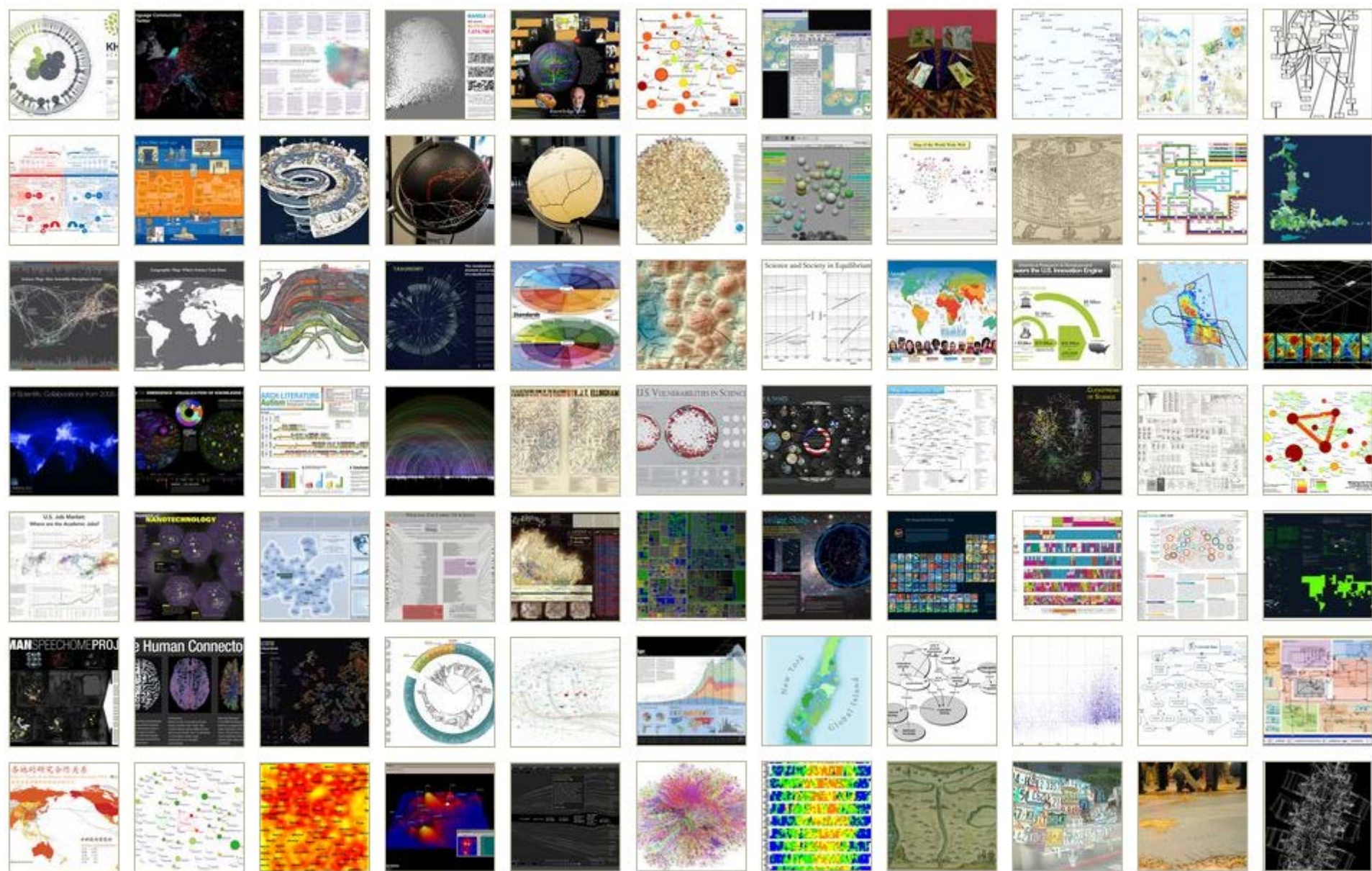


https://www.youtube.com/watch?v=lByX2_eb_QQ

Making Science & Technology Visualizations

Using a theoretically grounded visualization framework that defines key terminology and processes together with valid workflows and data mappings.





Places & Spaces: Mapping Science Exhibit, online at <http://scimaps.org>

How to Classify (Name & Make) Different Visualizations?

By

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

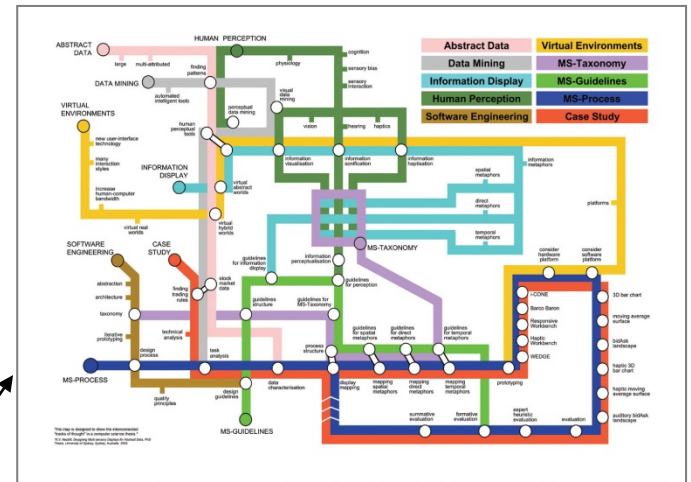


Different Question Types



Terabytes of data

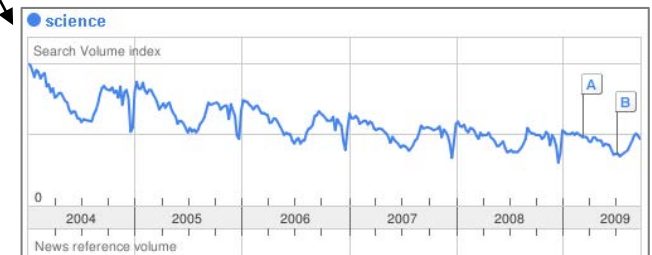
Descriptive & Predictive Models



Find your way



Find collaborators, friends



Identify trends

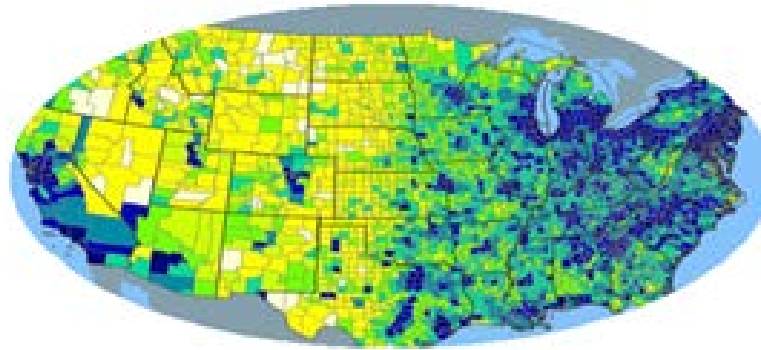
Different Question Types

- Monitor Data Quality
- Customer Complaints
- Customer/Supplier/Learner Churn
- Optimizing Supplier Chains
- Improving (Traffic/Communication) Network Resilience
- Optimizing Traffic/Communication Flows
- Optimizing Work Cells/Built Process
- Workforce Development

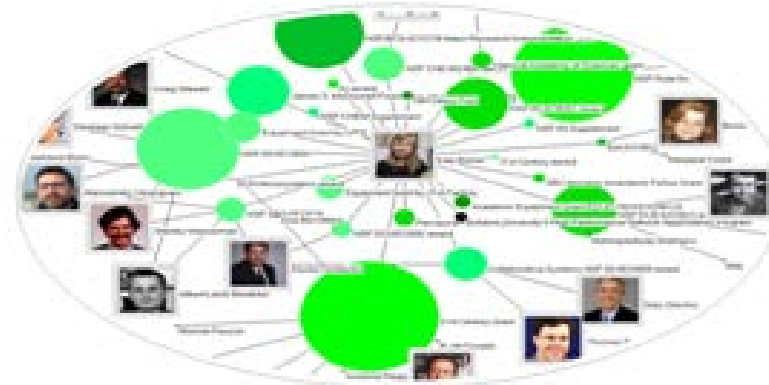
And other **WHEN, WHERE, WHAT, WITH WHOM** questions.

Different Levels of Abstraction/Analysis

Macro/Global
Population Level



Meso/Local
Group Level



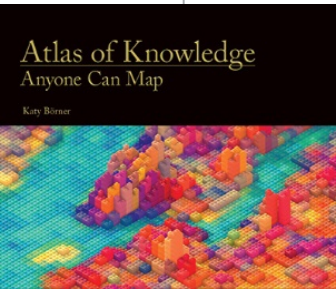
Micro
Individual Level



Tasks

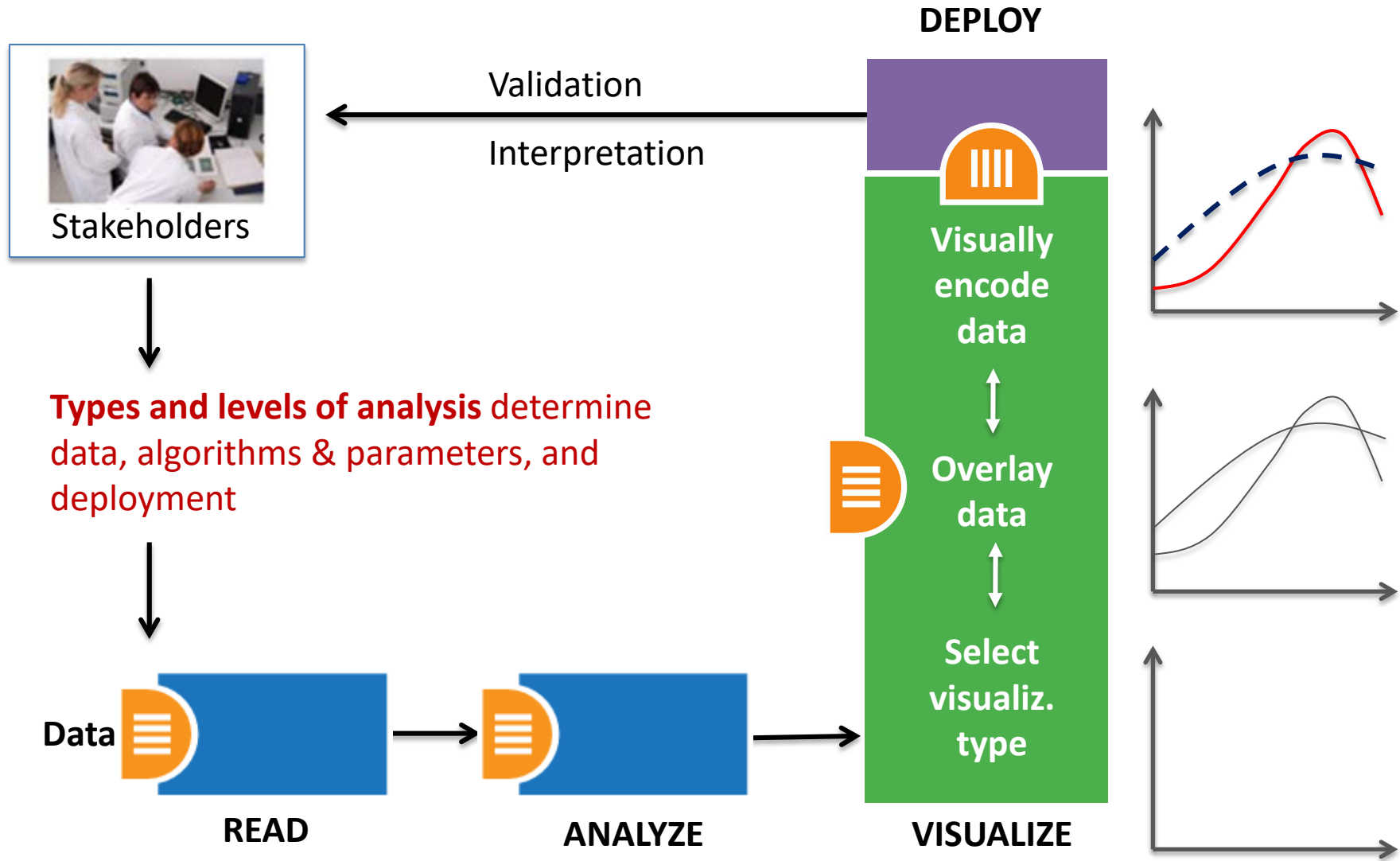
LEVELS

	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	 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 139	 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

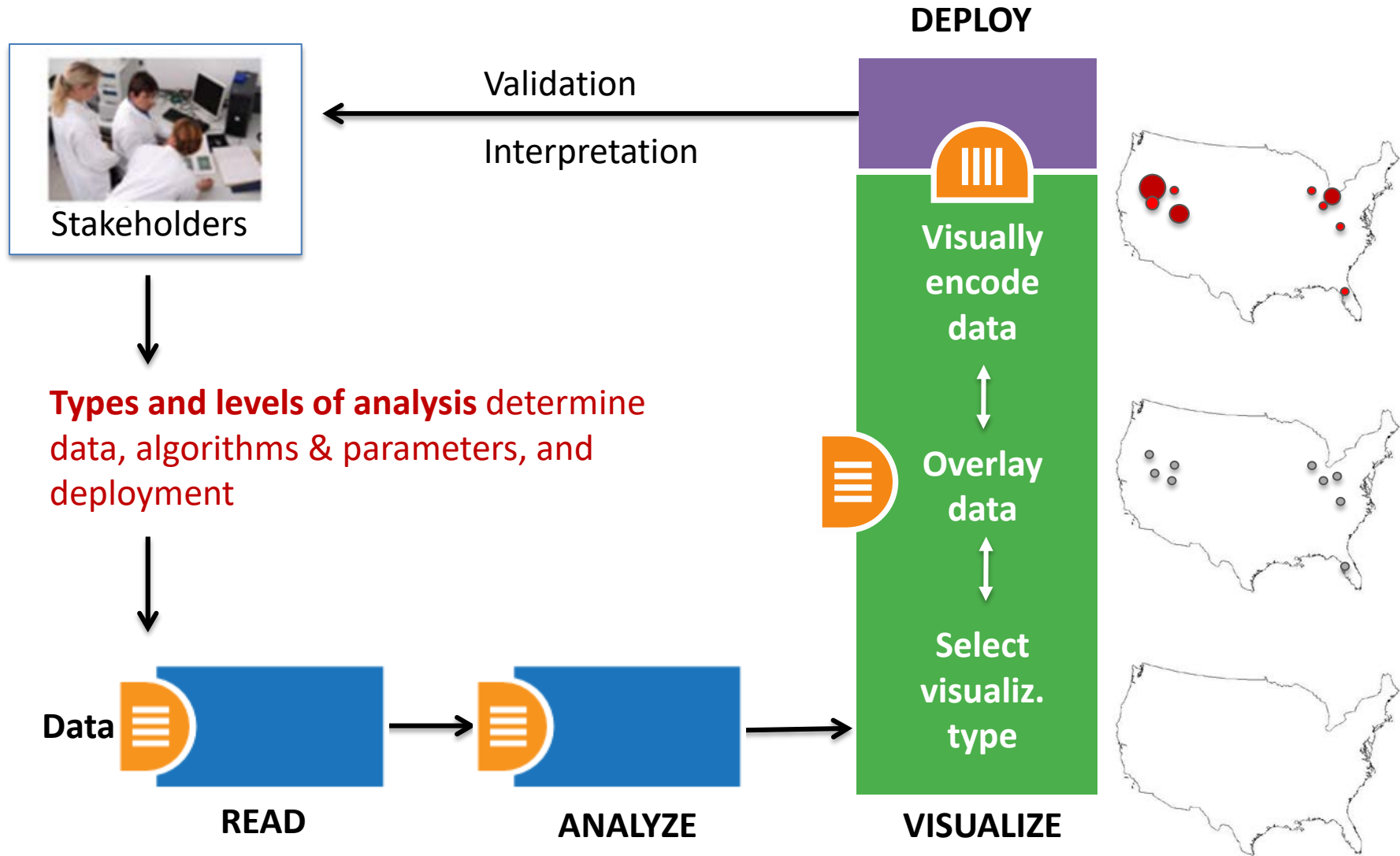


See *Atlas of Science: Anyone Can Map*, page 5

Needs-Driven Workflow Design

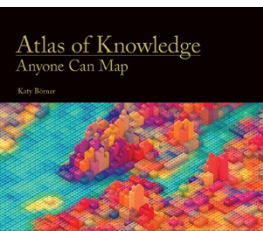


Needs-Driven Workflow Design



Visualization Framework

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">pointlineareasurfacevolume• linguistic symbols<ul style="list-style-type: none">textnumeralspunctuation marks• pictorial symbols<ul style="list-style-type: none">imagesiconsstatistical glyphs	<ul style="list-style-type: none">• spatial<ul style="list-style-type: none">position• retinal<ul style="list-style-type: none">formcoloropticsmotion	<ul style="list-style-type: none">• overview• zoom• search and locate• filter• details-on-demand• history• extract• link and brush• projection• distortion



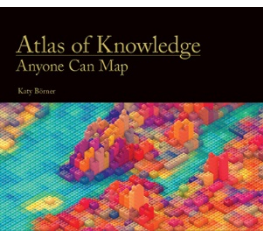
See page 24

Visualization Framework

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

Visualization Framework

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

Graphic Variable Types Versus Graphic Symbol Types

			Geometric Symbols					
			Point		Line		Area	
Spatial	x	quantitative						
	y	quantitative						
	z	quantitative						
Retinal	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						

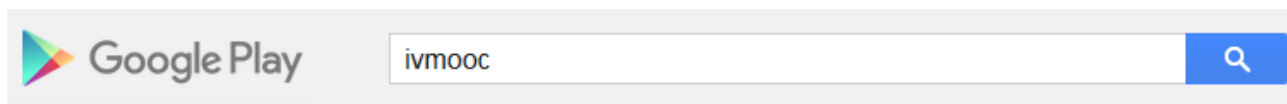
Graphic Variable Types Versus Graphic Symbol Types

			Geometric Symbols			Linguistic Symbols Text, Numerals, Punctuation Marks		Pictorial Symbols Images, Icons, Statistical Glyphs	
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						
	Value	quantitative							
Color	Hue	qualitative							
	Saturation	quantitative							

			Geometric Symbols			Linguistic Symbols Text, Numerals, Punctuation Marks		Pictorial Symbols Images, Icons, Statistical Glyphs	
Texture	Spacing	quantitative							
	Granularity	quantitative							
	Pattern	qualitative							
	Orientation	quantitative	NA						
	Gradient	quantitative							
	Blur	quantitative							
	Optics	Transparency	quantitative						
Shading		quantitative							
Stereoscopic Depth		quantitative	Point in foreground -- background	Line in foreground -- background	Area in foreground -- background	Surface in foreground -- background	Volume in foreground -- background	Text in foreground -- background	Icons in foreground -- background
Motion	Speed	quantitative							
	Velocity	quantitative							
	Rhythm	quantitative	Blinking point slow -- fast	Blinking line slow -- fast	Blinking area slow -- fast	Blinking surface slow -- fast	Blinking volume slow -- fast	Blinking text slow -- fast	Blinking icons slow -- fast

IVMOOC App

The “IVMOOC Flashcards” app can be downloaded from Google Play and Apple iOS stores.



IVMOOC Flashcards

Studio Cypher Education

Everyone

This app is compatible with all of your devices.

★★★★★ 0

Installed



IVMOOC Flashcards

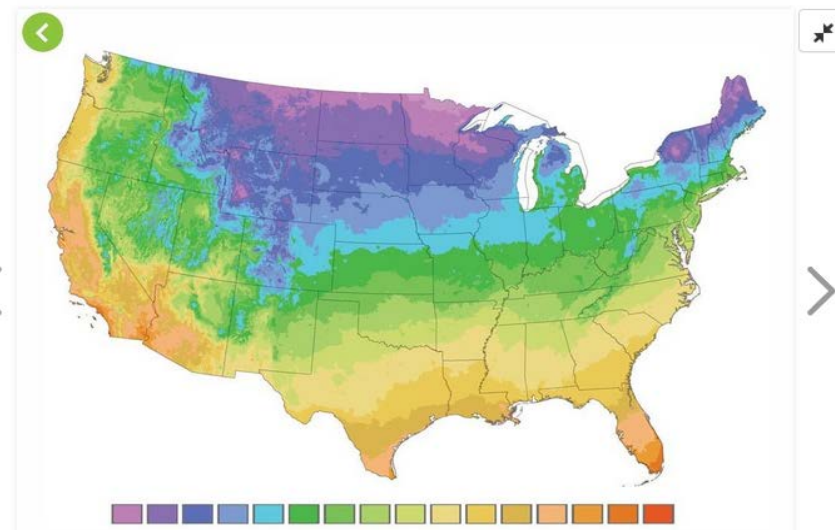
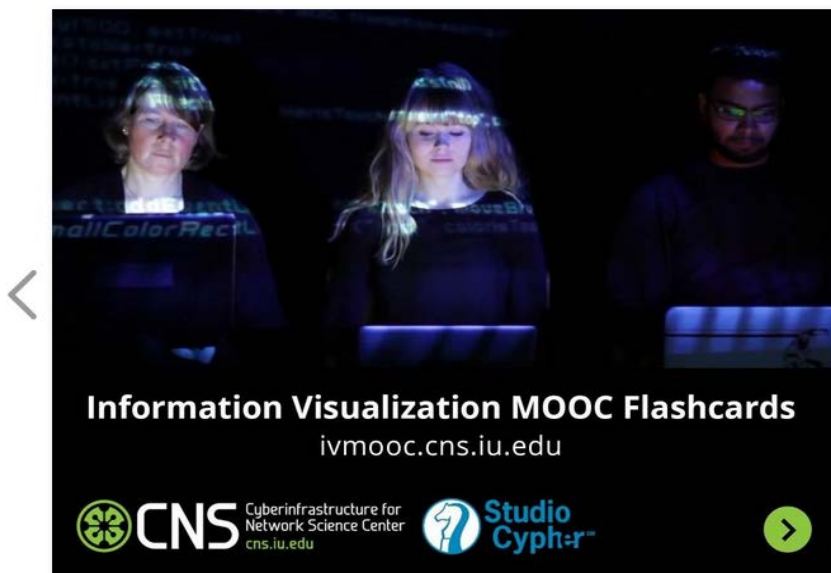
Studio Cypher Education

Everyone

This app is compatible with all of your devices.

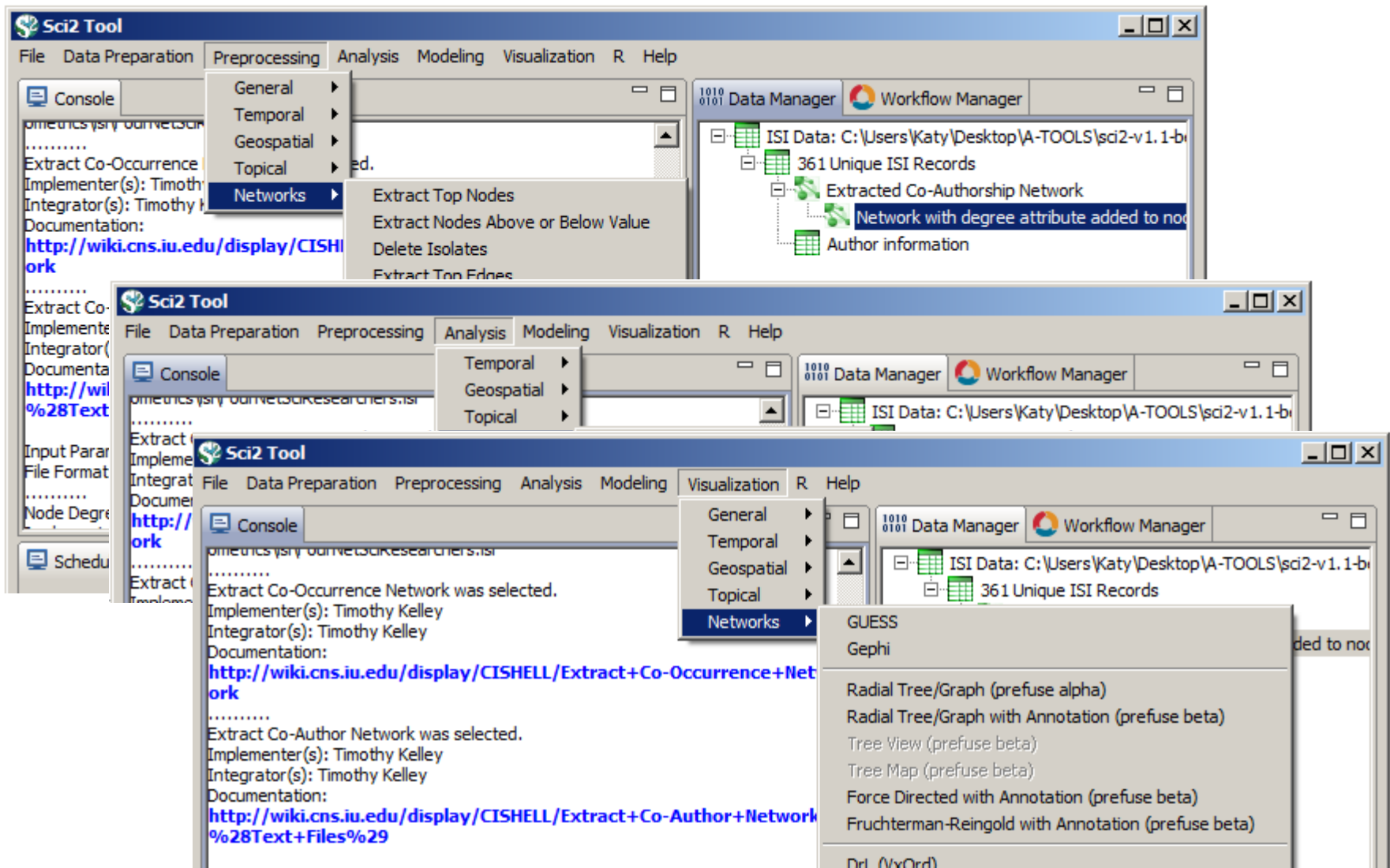
★★★★★ 0

Installed



Sci2 Tool Interface Components Implement Vis Framework

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



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 Microscopes	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, N 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, N 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

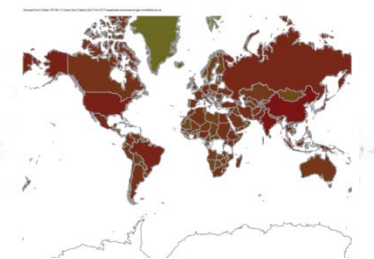
Temporal Burst Analysis—p. 48



Geospatial Analysis—p. 52



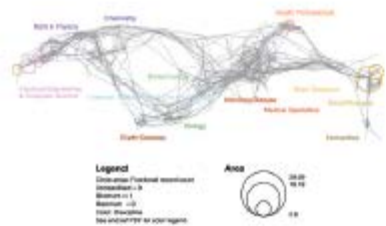
Geospatial Analysis—p. 52



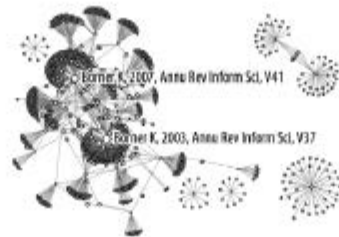
Load **One** File and Run **Many** Analyses and Visualizations

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, N 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, N Falk-Krzesinski, HJ Fiore, SM Hall, KL Keyton, J Spring, B Stokols, D Trochim, W Uzzi, B

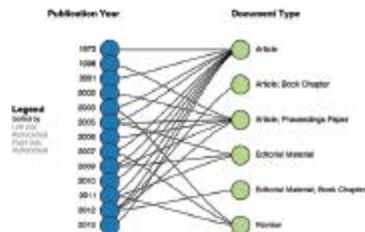
Topical Analysis—p. 56



Paper Citation Network—p. 60



Bi-Modal Network—p. 60



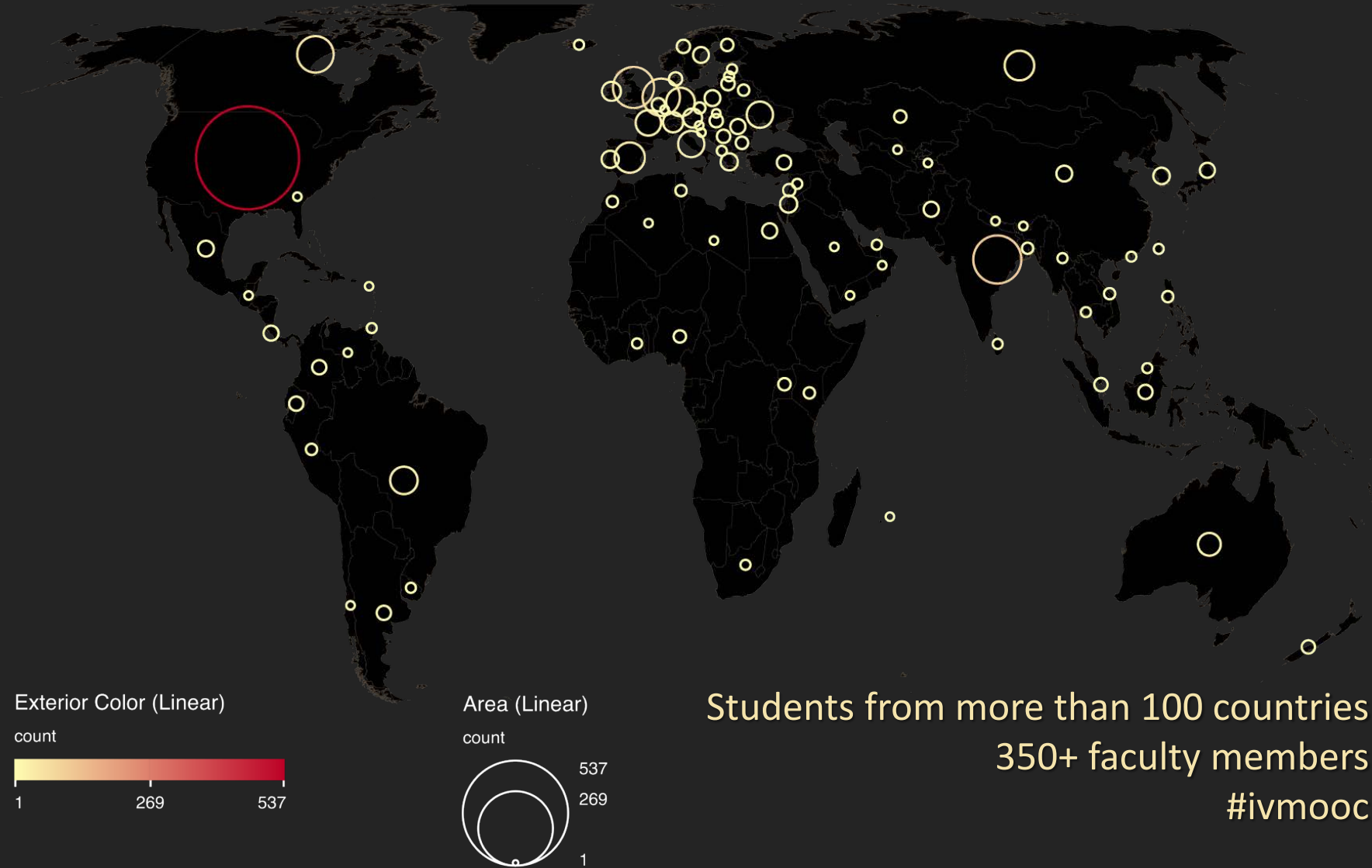
Co-author and many other bi-modal networks.



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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.

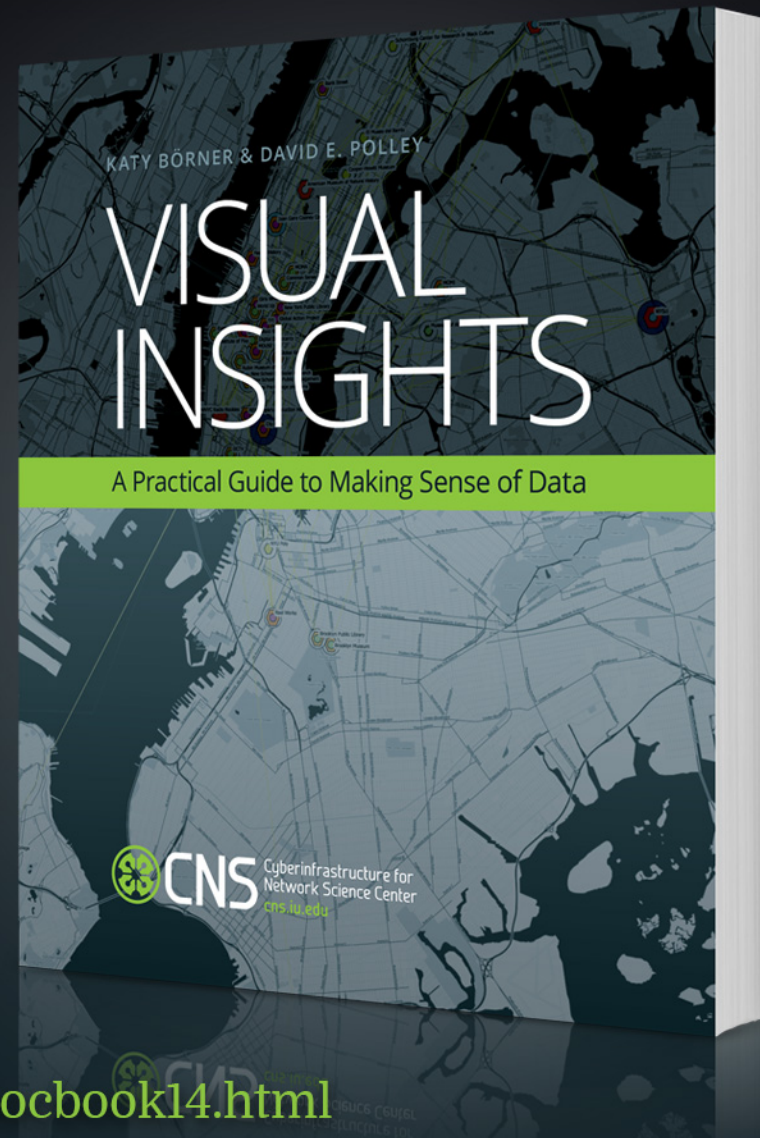
Final grade is based on Homework and Quizzes (**10%**), Midterm (**20%**), Final (**30%**), Client Project (**30%**), and Class Participation (**10%**).



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The book accompanies the Information Visualization MOOC that attracted students, scholars, and practitioners from many fields of science and more than 100 different countries.



cns.iu.edu/ivmooobook14.html

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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

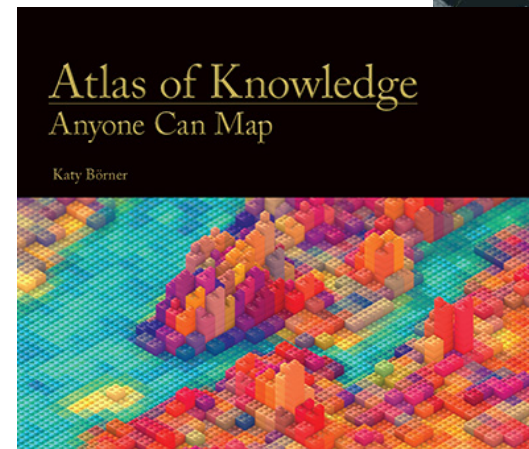
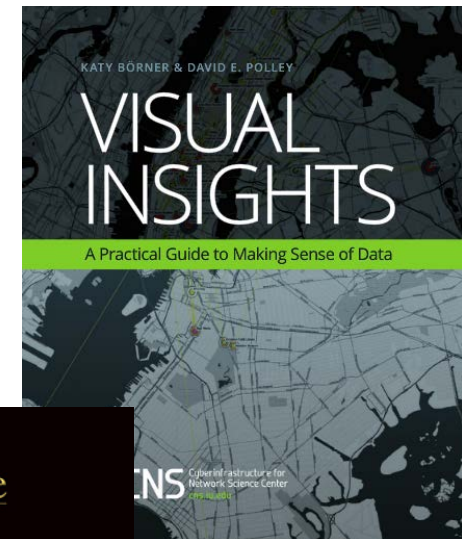
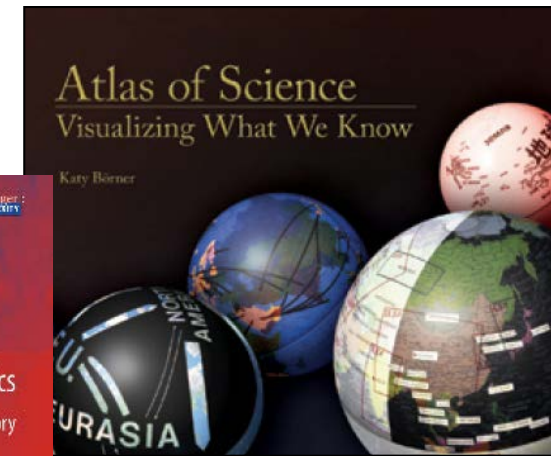
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Scharnhorst, Andrea, Börner, Katy, van den Besselaar, Peter (2012) **Models of Science Dynamics**. Springer Verlag.

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.

Börner, Katy (2015) **Atlas of Knowledge: Anyone Can Map**. The MIT Press. <http://scimaps.org/atlas2>






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- OCT 1** Katy Börner attends PIUG 2013 Northeast Conference
- 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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