

Data Visualization Literacy: Reading and Making Data Visualizations

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*10th annual Midwest Undergraduate Cognitive Science Conference
DeVault Alumni Center, Bloomington, IN*

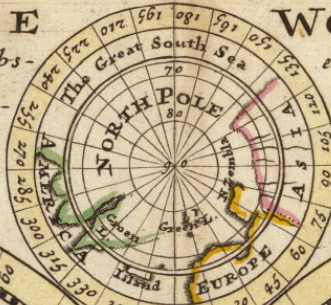
April 7, 2018



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: &c. Shew y^e Times of y^e Year when such Winds Blow.

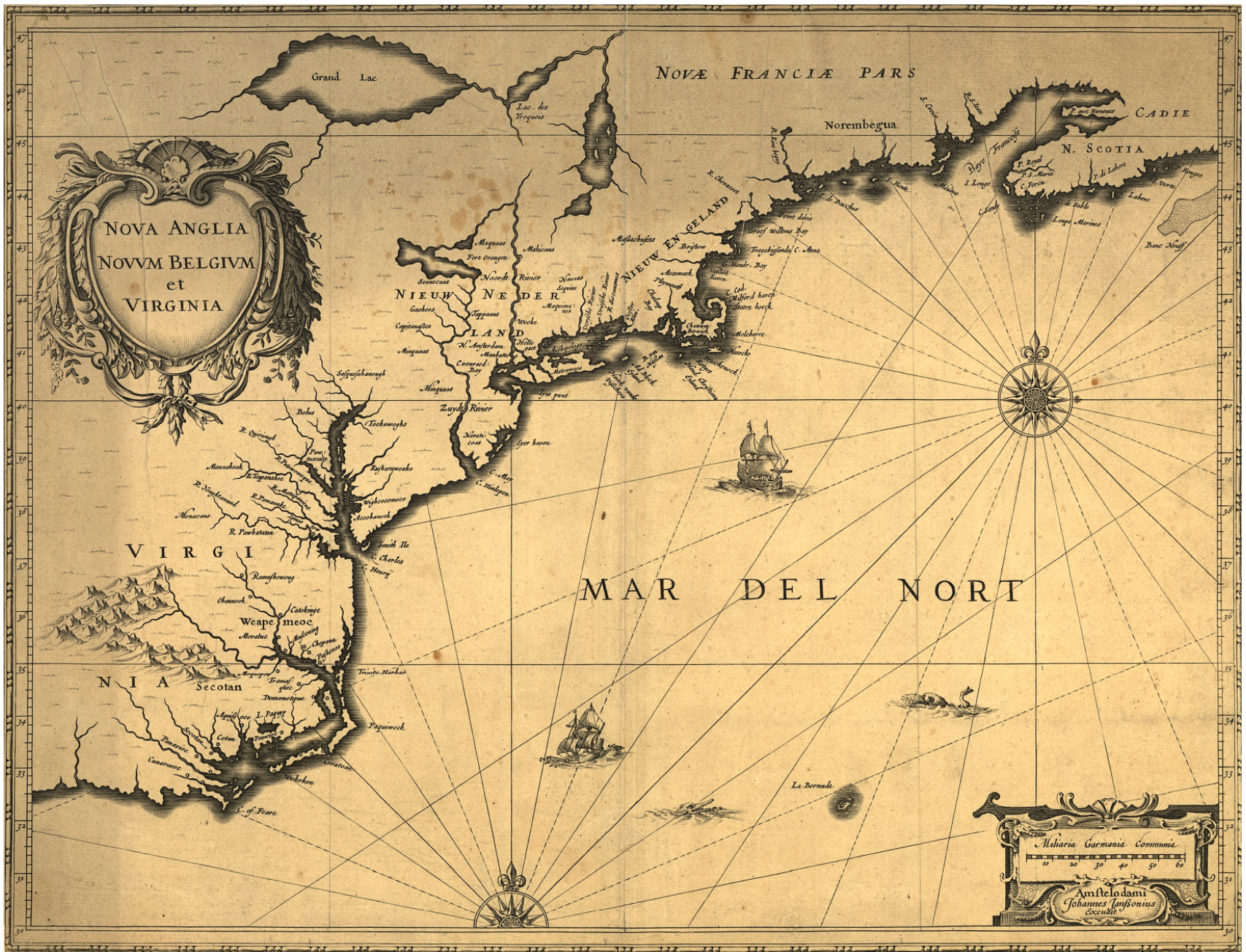


The Signs of the Zodiac. The First 6 are Northern, the other Southern Signs
 ♈ Aries . March
 ♉ Taurus . April
 ♊ Gemini . May
 ♋ Cancer . June
 ♌ Leo . July
 ♍ Virgo . August
 ♎ Libra . September
 ♏ Scorpio . October
 ♐ Sagittarius . November
 ♑ Capricornus . Decemb.
 ♒ Aquarius . January
 ♓ Pisces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



Printed for Tho: 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



1.2 Nova Anglia, Novvm Belgivm et Virginia – Johannes Janssonius - 1642

Map of Scientific Collaborations from 2005-2009



Computed Using Data from Elsevier's Scopus

DEATH & TAXES

A VISUAL GUIDE TO WHERE YOUR FEDERAL TAX DOLLARS GO



WHO PAYS?
For every \$1 billion of total federal government...

THE TOTAL BUDGET
The total \$1,182 billion federal budget is broken down...

The United States of America
2009 Federal Discretionary Budget
\$118.2 Billion Dollars

This graph reports the President's budget request for FY 2009. It will be debated, amended, and approved by Congress, likely by October 1st, to begin the fiscal year.

The center circle is the discretionary budget, amounting to what is approved by Congress every year. It is used for various types of federal income taxes and includes all departments within the federal government. Unlike Social Security, Medicare, and Medicaid, which are set by law and run on autopilot, the discretionary budget is a yearly working bill of the national government. It includes projects according to the whims of the President, at the power of the Congress, and the will of the people.

Why? National Security needed funding for the Iraq War (up to \$4.4 billion) for the goal. For the right side, it is devoted to a "6 or 70" ratio. The entire federal budget is in the same age group ratio to total.

General Notes: All figures are in US Dollars. There may not sum due to rounding, some figures are in millions or billions. Percentage change is the difference from the 2008 level. Spending and Revenue are shown in billions of dollars. The 2009 budget is a discretionary budget, meaning that it is subject to annual appropriations. It is not a permanent budget. The 2009 budget is a discretionary budget, meaning that it is subject to annual appropriations. It is not a permanent budget. The 2009 budget is a discretionary budget, meaning that it is subject to annual appropriations. It is not a permanent budget.

Footnote: While new spending or authority increases by more than 100%, it is not in the Department of Defense but military or national security related. Justifications and a full bill of military and national security spending are available at www.dod.gov. The \$1.182 billion includes the appropriations, appropriated by the House and the Senate, in the House of Representatives. It does not include the \$10.1 billion in debt held by the Treasury, which is used to fund the operations of the federal government. The \$1.182 billion is broken down into 118 categories of spending. The \$1.182 billion is broken down into 118 categories of spending. The \$1.182 billion is broken down into 118 categories of spending. The \$1.182 billion is broken down into 118 categories of spending.

V.5 Death and Taxes 2009 - Jess Bachman - 2009

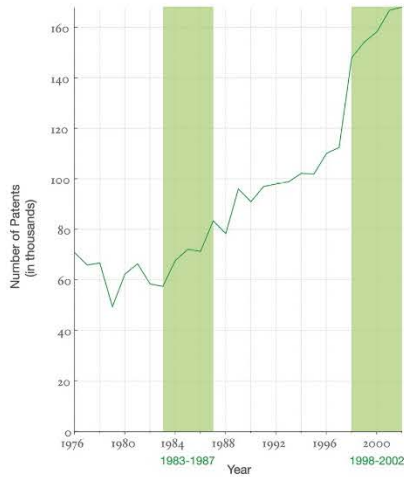
Examining the Evolution & Distribution of Patent Classifications

Managing Growing Patent Portfolios

Organizations, businesses, and individuals rely on patents to protect their intellectual property and business models. As market competition increases, patenting innovation and intellectual property rights becomes ever more important.

Managing the staggering number of patents demands new tools and methodologies. Grouping patents by their classifications offers an ideal resolution for better understanding how intellectual borders are established and change over time.

The charts below show the annual number of patents granted from January 1, 1976 to December 31, 2002 in the United States Patent and Trademark Office (USPTO) patent archive; slow and fast growing patent classes; the top 10 fast growing patent subclasses; and two evolving patent portfolios.



The Structure and Evolution of the Patent Space

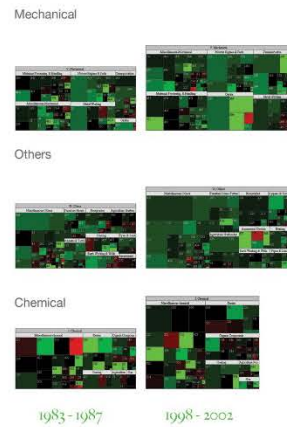
The United States Patent and Trademark Office assigns each patent to one of more than 450 classes covering broad application domains. For example, class 514 encompasses all patents dealing with 'Drug, Bio-Affecting and Body Treating Compositions.' Classes are further broken down by subclasses that have hierarchical associations. As one example, class 455 features subclass 99 entitled "with vehicle."

The top 10 fast growing patent classes for 1998–2002 are listed together with the number of patents granted. Most come from the 'Computer and Communications' and the 'Drugs and Medical' area.

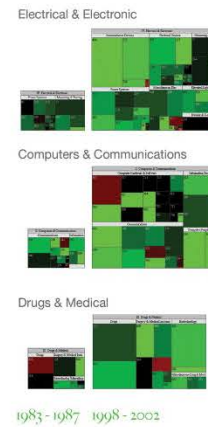
The evolving hierarchical structure of patent classes and their sizes is represented using treemaps, a space-filling visualization technique developed by Ben Shneiderman at the University of Maryland. A treemap presents a hierarchy as a collection of nested rectangles—demarkating a parent-child relationship between nodes by nesting the child within the parent rectangle. The size and color of each rectangle represent certain attributes of the nodes.

Here, each rectangle represents a class and the area size denotes the total number of patents in that class. The rectangle's color corresponds to percentage increase (green) or decrease (red) in the number of patents granted in that class from the previous interval.

Slow Growing Classes



Fast Growing Classes



Top-10 Subclasses

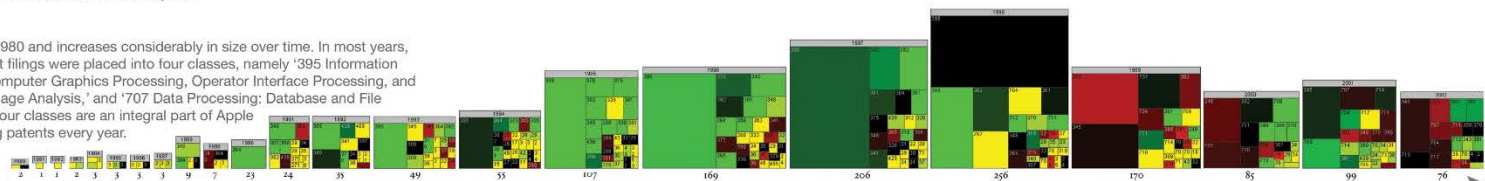
Class	Title	# of Patents
514	Drug, Bio-Affecting and Body Treating Compositions	18,778
438	Semiconductor Device Manufacturing:Process	17,775
435	Chemistry: Molecular Biology and Microbiology	17,474
424	Drug, Bio-Affecting and Body Treating Compositions	13,637
428	Stock Material or Miscellaneous Articles	13,314
257	Active Solid-State Devices (e.g., Transistors, Solid-State Diodes)	12,924
395	Information Processing System Organization	9,955
345	Computer Graphics Processing, Operator Interface Processing, and Selective Visual Display Systems	9,510
359	Optical: Systems and Elements	9,151
365	Static Information Storage and Retrieval	8,392
	Total	130,910

Patent Portfolio Analysis

A longitudinal analysis of portfolios reveals different patenting strategies. For each year (given in gray above each treemap), a treemap of all new patents granted to the assignee is shown. The number of patents is given below each treemap. The same size and color coding as above was used. In addition, yellow indicates that no patent has been granted in that class in the last 5 years.

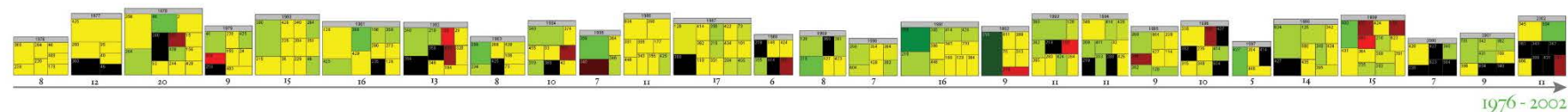
Apple Computer, Inc.

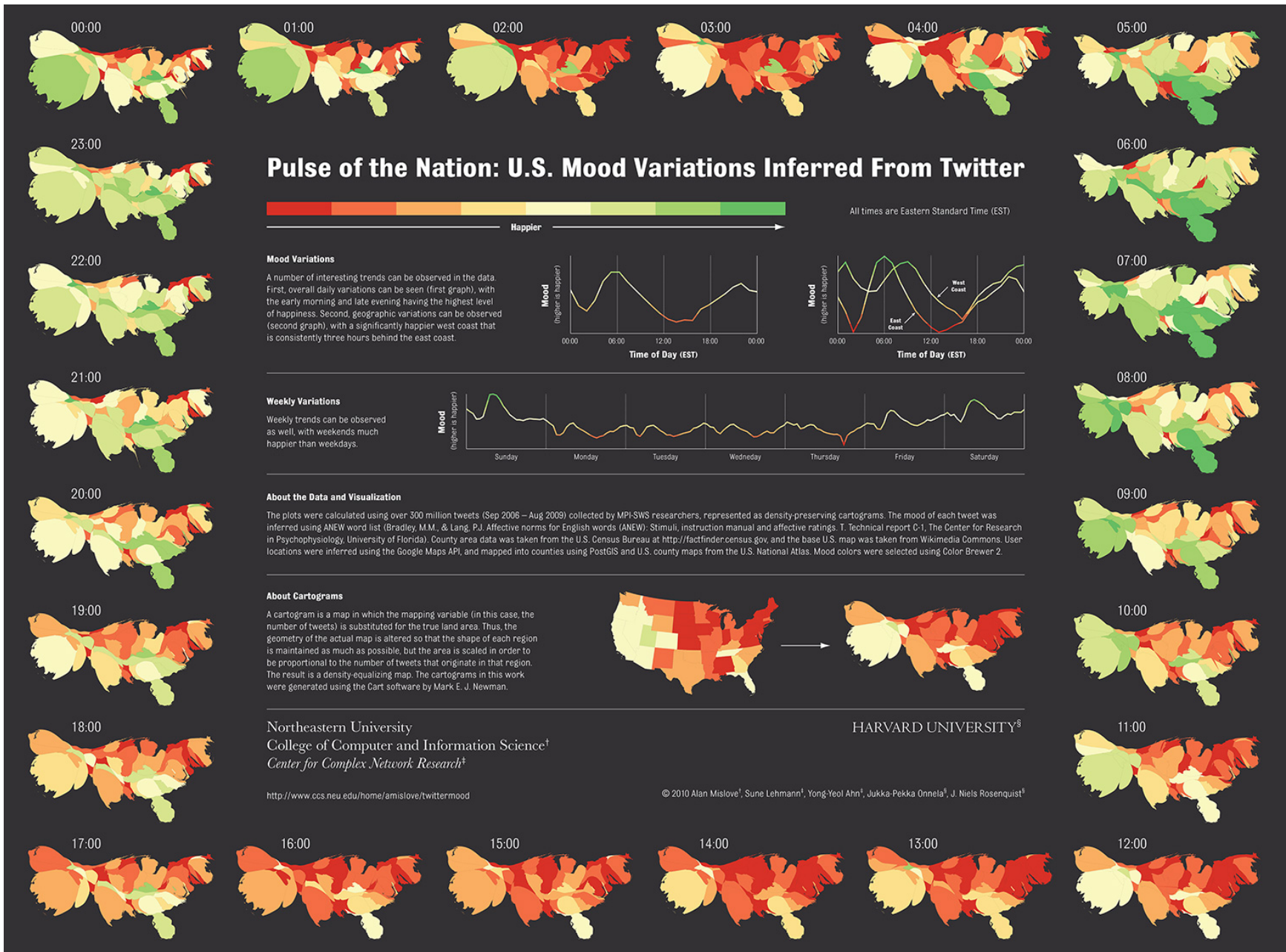
Apple Computer, Inc.'s portfolio starts in 1980 and increases considerably in size over time. In most years, more than half of Apple Computer's patent filings were placed into four classes, namely '395 Information Processing System Organization,' '345 Computer Graphics Processing, Operator Interface Processing, and Selective Visual Display Systems,' '382 Image Analysis,' and '707 Data Processing: Database and File Management or Data Structures.' These four classes are an integral part of Apple Computer, Inc.'s patent portfolio, receiving patents every year.

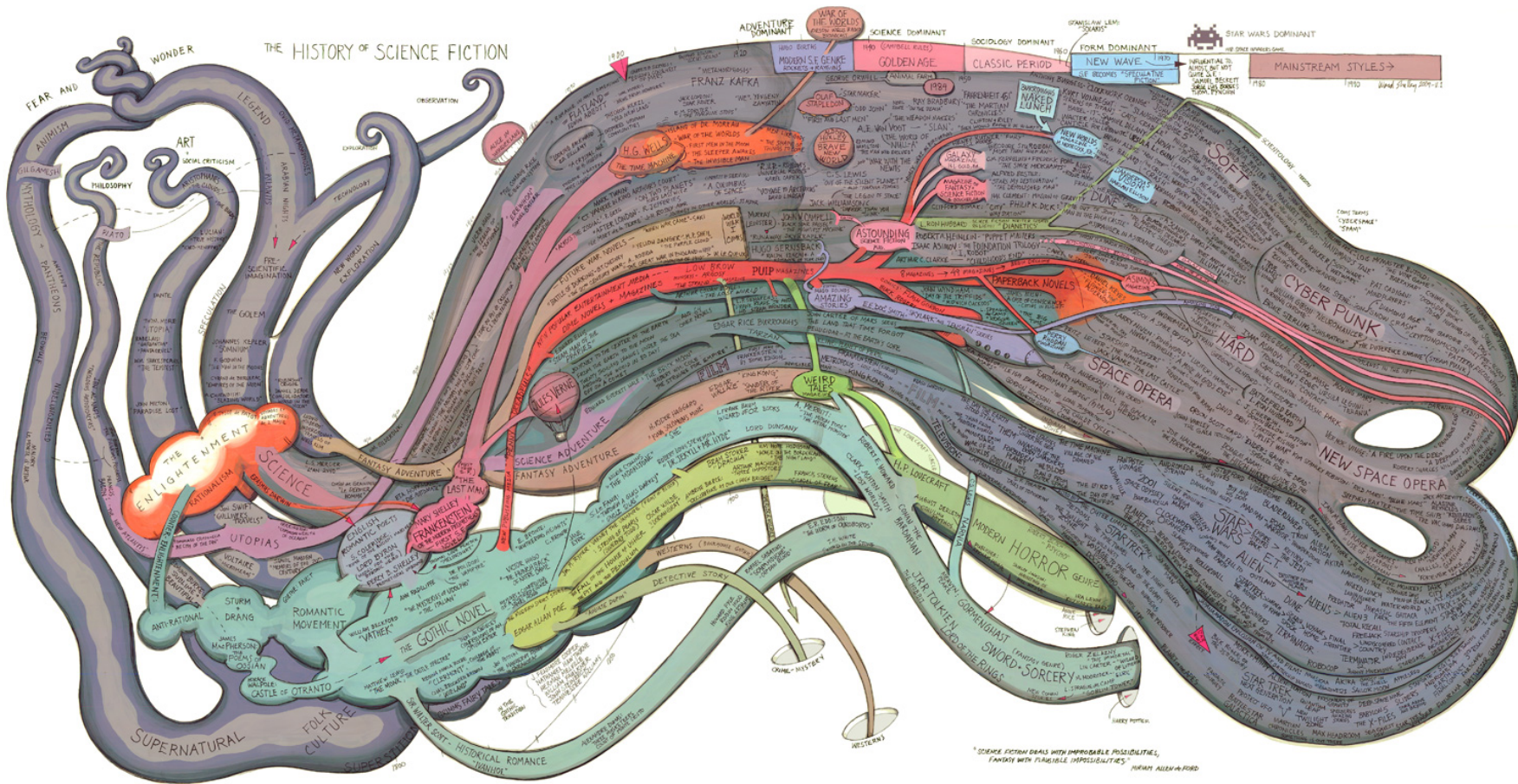


Jerome Lemelson

The patent portfolio of Jerome Lemelson shows a very different activity pattern. Starting in 1976, he publishes between 6–20 patents each year. However, the predominance of yellow shows that there is little continuity from previous years in regards to the classes into which patents are filed. No class dominates. Instead, more and more new intellectual space is claimed.







VII.10 History of Science Fiction - Ward Shelley - 2011

Check out our **Zoom Maps** online!

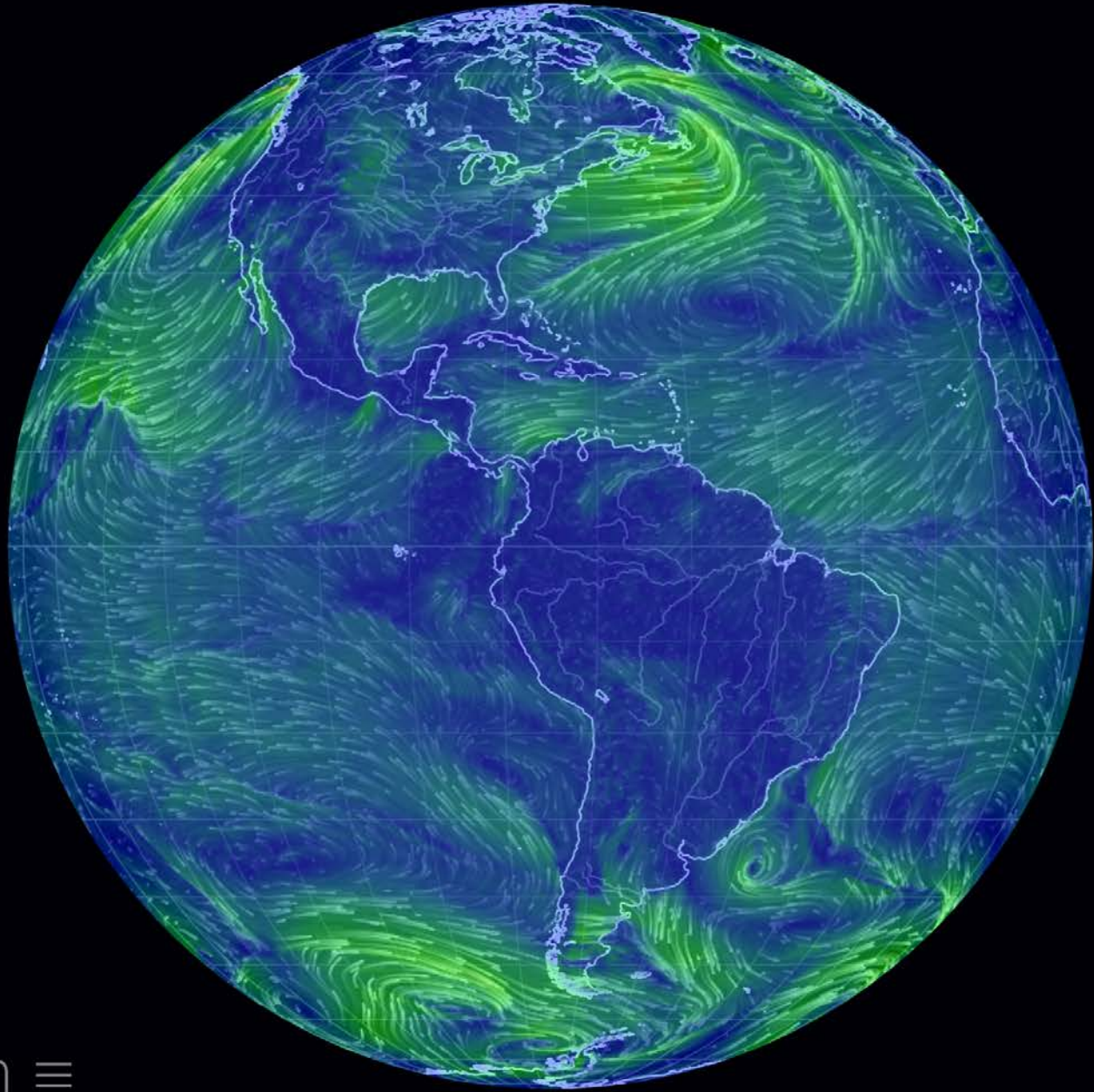
VII.10
History of Science Fiction, by Ward Shelley

BROOKLYN, NY 2011
Courtesy of Ward Shelley Studio

Ward Shelley is an artist identified with the Williamsburg scene in Brooklyn, New York. This map plots the science fiction literary genre from its nascent beginnings in the late 18th century, emerging out of the data, here the narrative structure precedes and organizes the data. The map's structure is like a tree whose tentacles are like trace roots to pre-historical sources and whose body is the genre itself. The map is a Romanticism, which birthed gothic fiction, source not only of Sci-Fi, but also of critical theory. The map progressed through a number of distinct periods, which are charted, citing hundreds of authors and works.

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earth ≡

Earth – Cameron Beccario

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- 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 navigation: 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

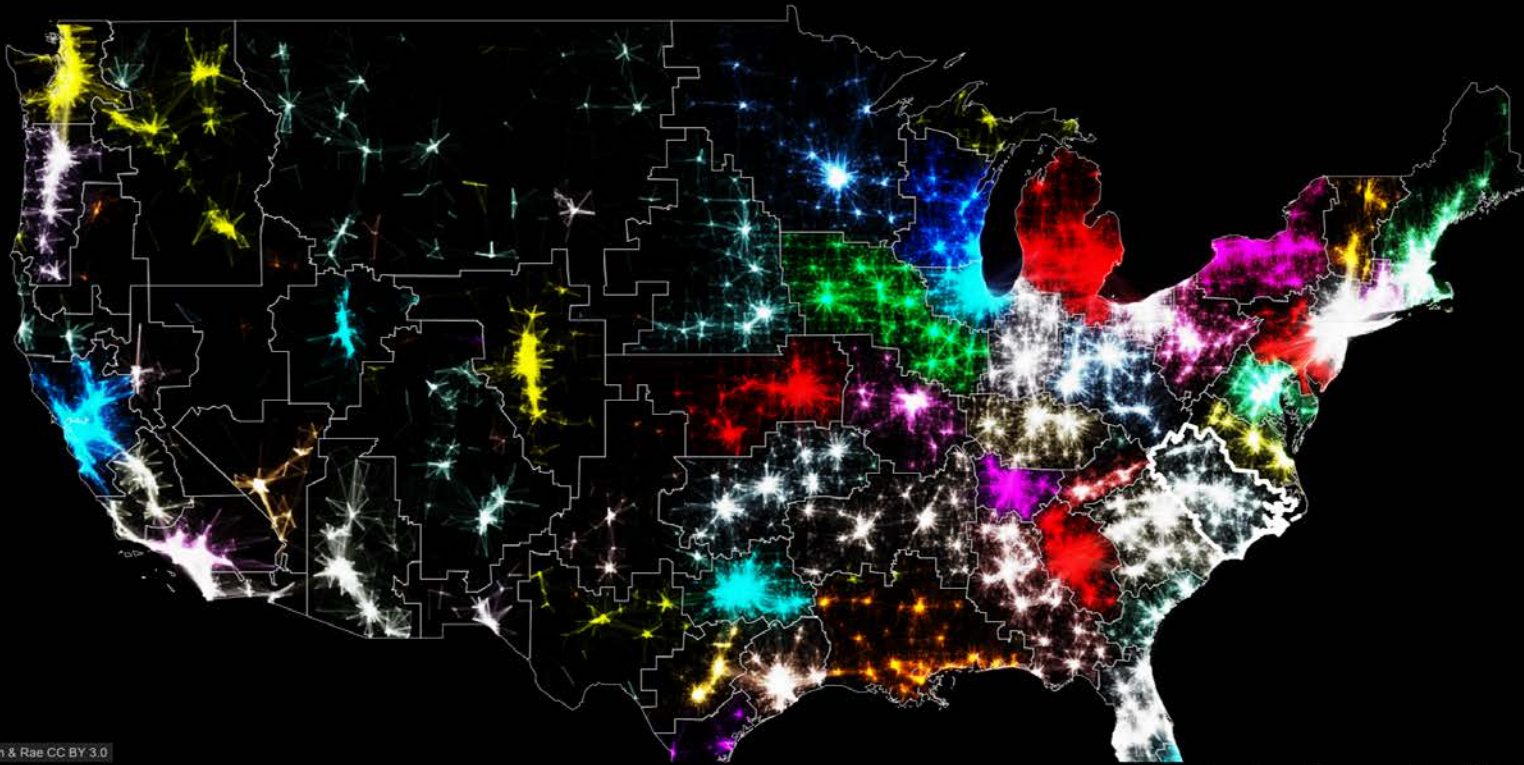
IN% OUT%



Smelly Maps – 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.

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

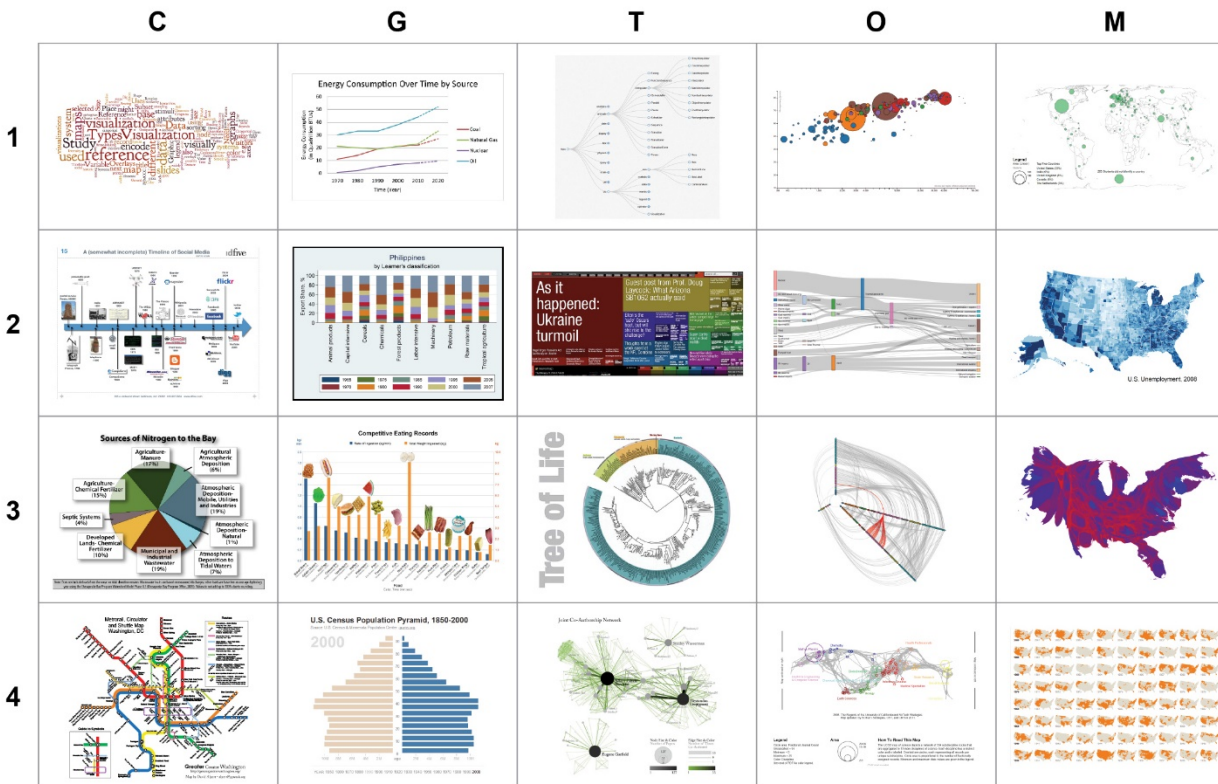


The David J. Sencer CDC Museum, Atlanta, GA.
January 25 - June 17, 2016.

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

Problem: Data Visualization Literacy is Low

Most science museum visitors in the US cannot name, read, or interpret common data visualizations.



Börner, Katy, Joe E. Heimlich, Russell Balliet, and Adam V. Maltese. 2015. Investigating aspects of data visualization literacy using 20 information visualizations and 273 science museum visitors. *Information Visualization* 1-16. <http://cns.iu.edu/docs/publications/2015-borner-investigating.pdf>

**Data Visualization Literacy:
Research and Tools that Advance Public Understanding of
Scientific Data**



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Data Visualization Literacy

Data visualization literacy (ability to read, make, and explain data visualizations) requires

- *literacy* (ability to read and write text, e.g., in titles, axis labels, legend),
- *visual literacy* (ability to find, interpret, evaluate, use, and create images and visual media), and
- *data literacy* (ability to read, create, and communicate data).

Being able to “read and write” data visualizations is becoming as important as being able to read and write text. Understanding, measuring, and improving data and visualization literacy is important for understanding STEAM developments and to strategically approach global issues.

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 ?

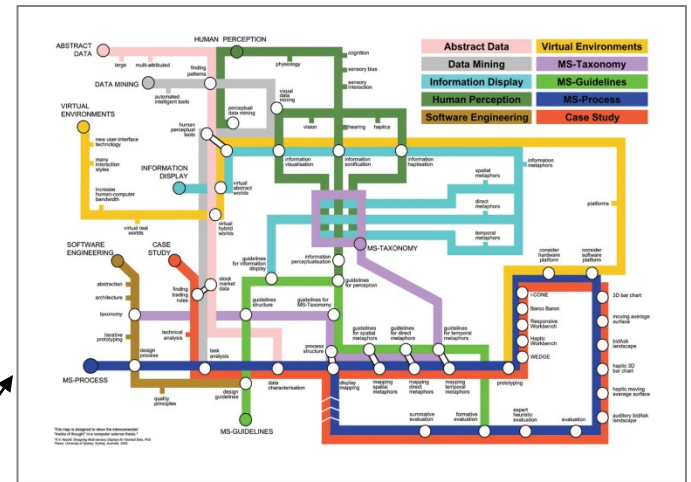


Different Question Types



Terabytes of data

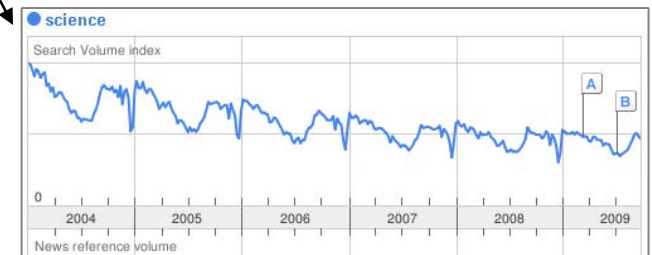
Descriptive & Predictive Models



Find your way



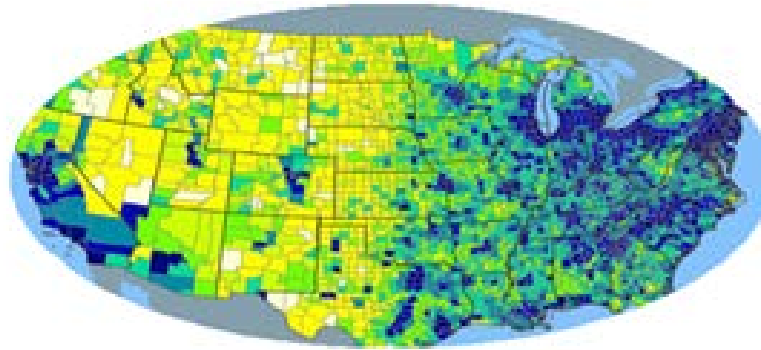
Find collaborators, friends



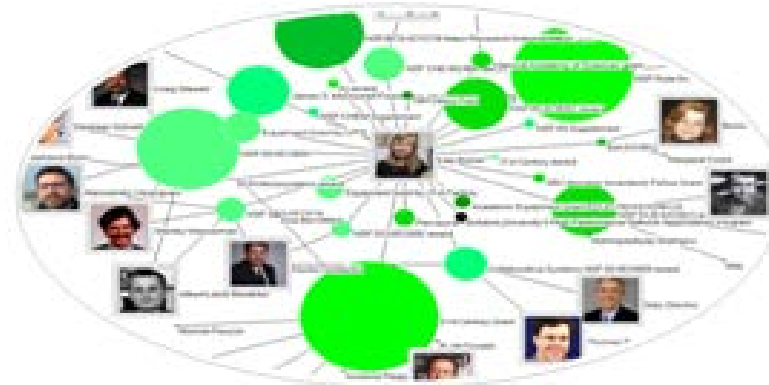
Identify trends

Different Levels of Abstraction/Analysis

Macro/Global
Population Level



Meso/Local
Group Level

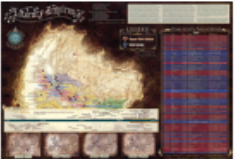


Micro
Individual Level



Tasks

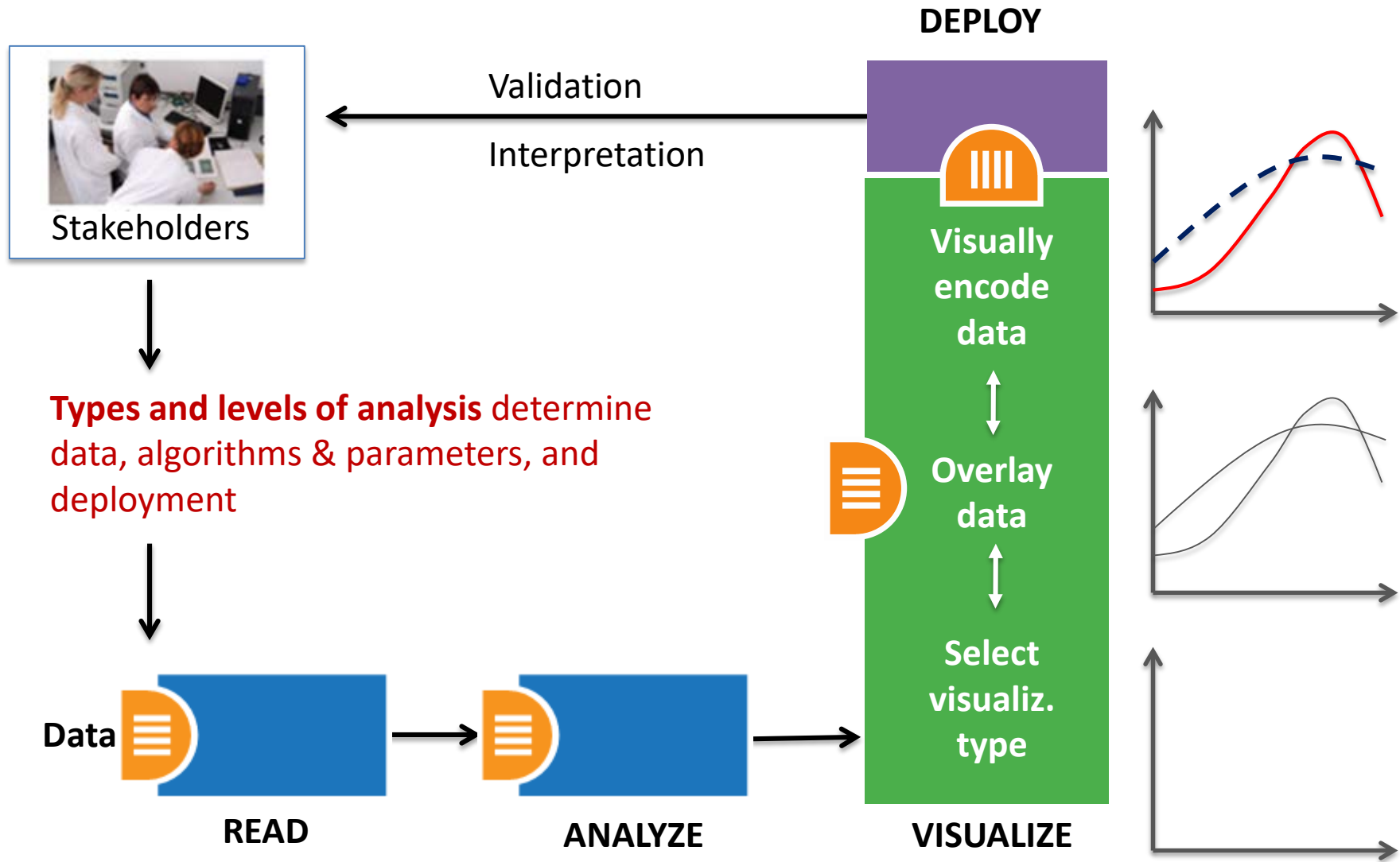
LEVELS

	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	 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 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

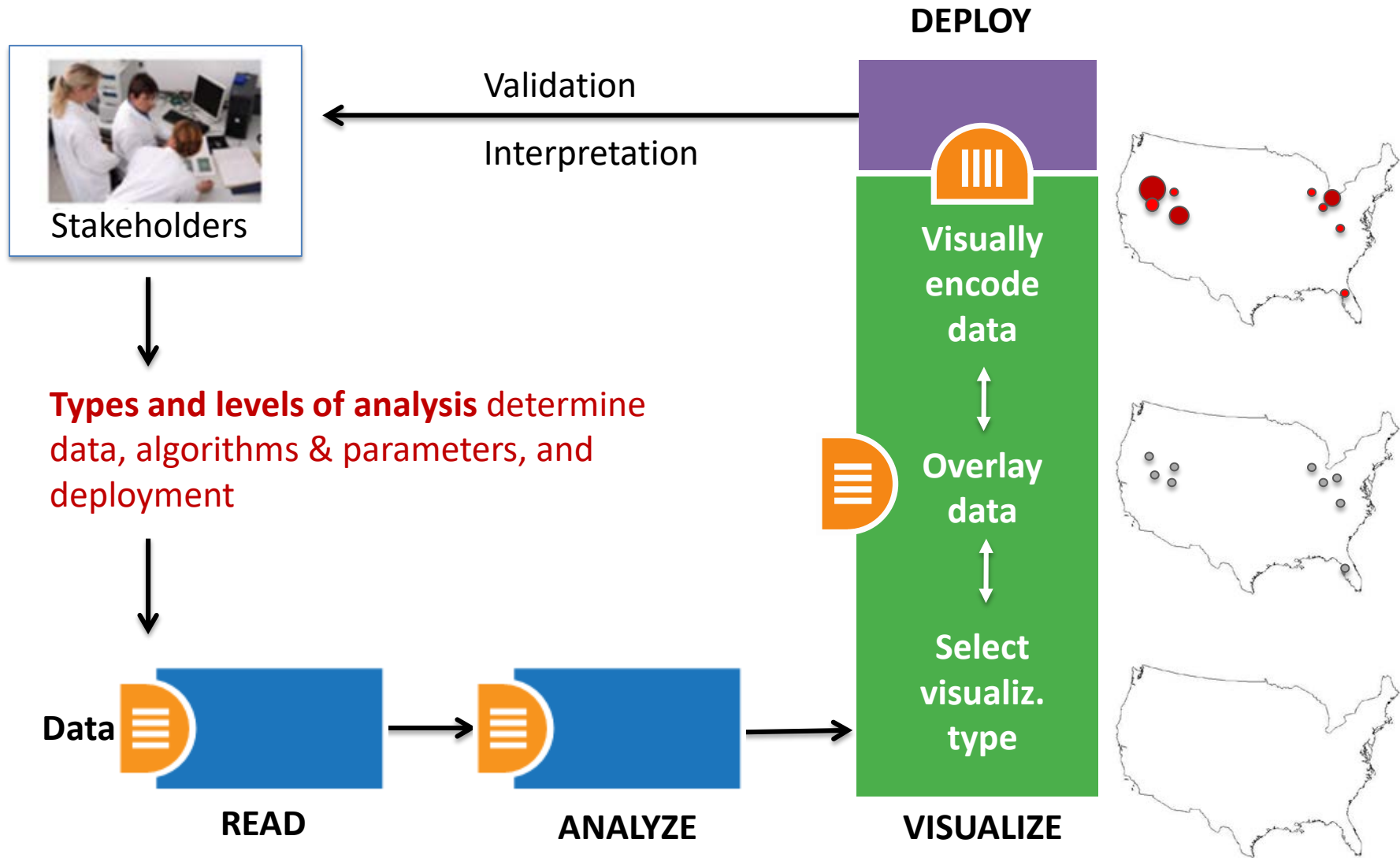


See *Atlas of Science: Anyone Can Map*, page 5

Needs-Driven Workflow Design

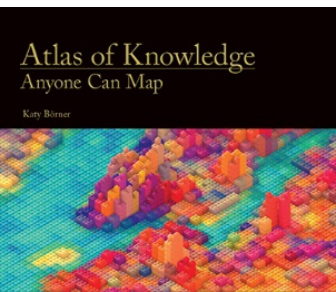


Needs-Driven Workflow Design



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"> 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



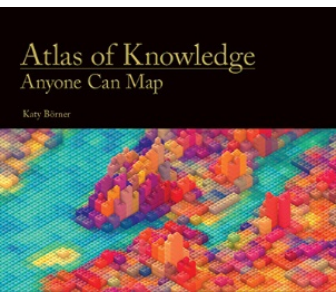
See *Atlas of Science: Anyone Can Map*, page 24

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
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See *Atlas of Science: Anyone Can Map*, 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				Some table cells are left blank to encourage future exploration of combinations.		
	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							
	Transparency	quantitative							
Optics	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
	Speed	quantitative							
Motion	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

**Data Visualization Literacy:
Research and **Tools** that Advance Public Understanding of
Scientific Data
+ **Methods****



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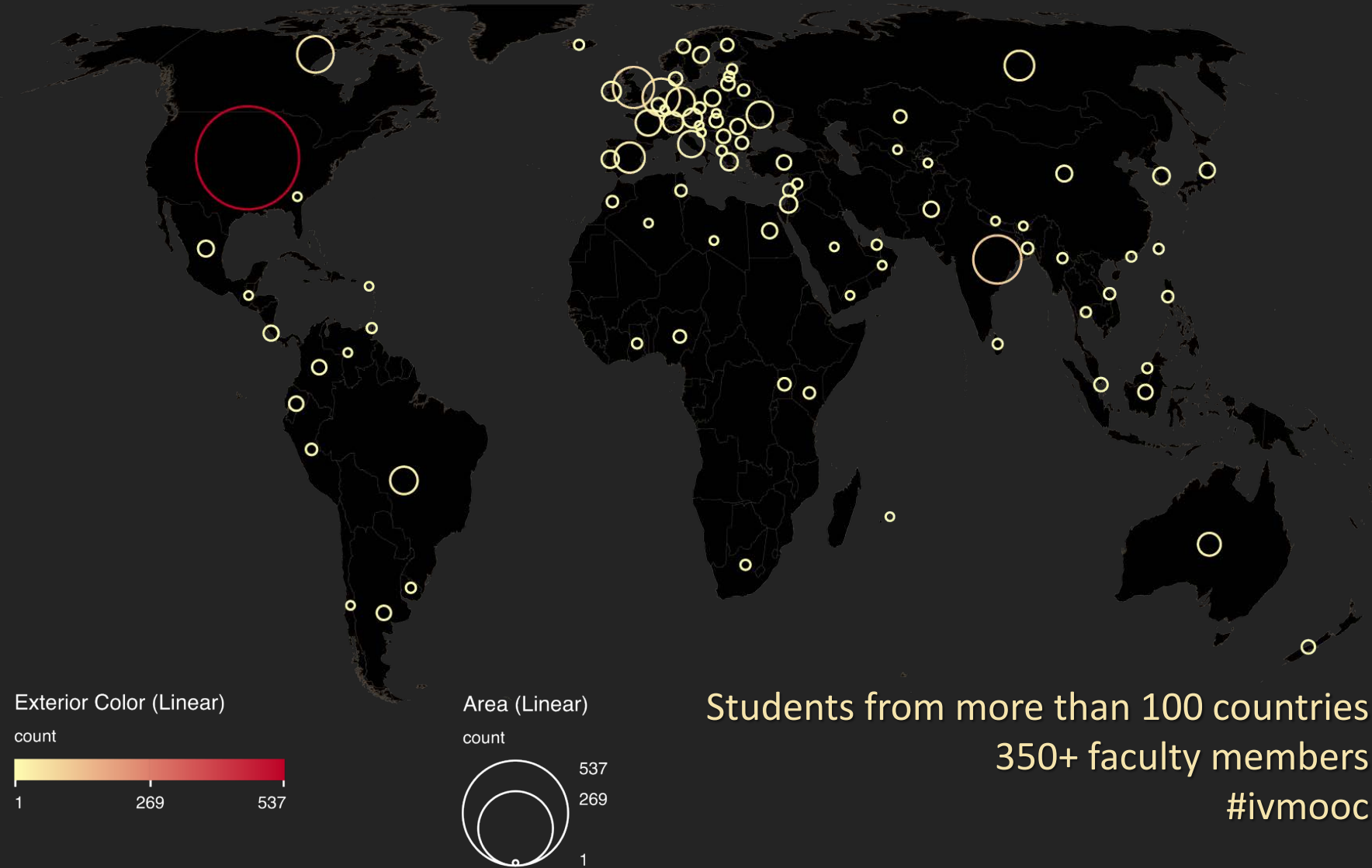
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The Information Visualization MOOC

ivmooc.cns.iu.edu



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

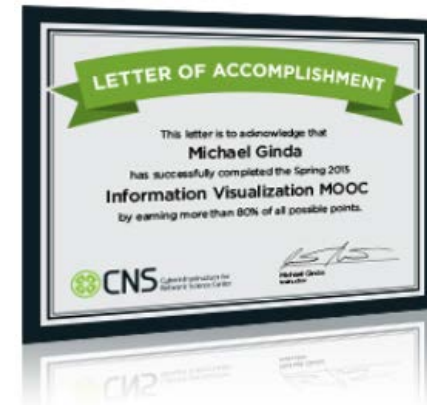
Mid-Term

- **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%**).



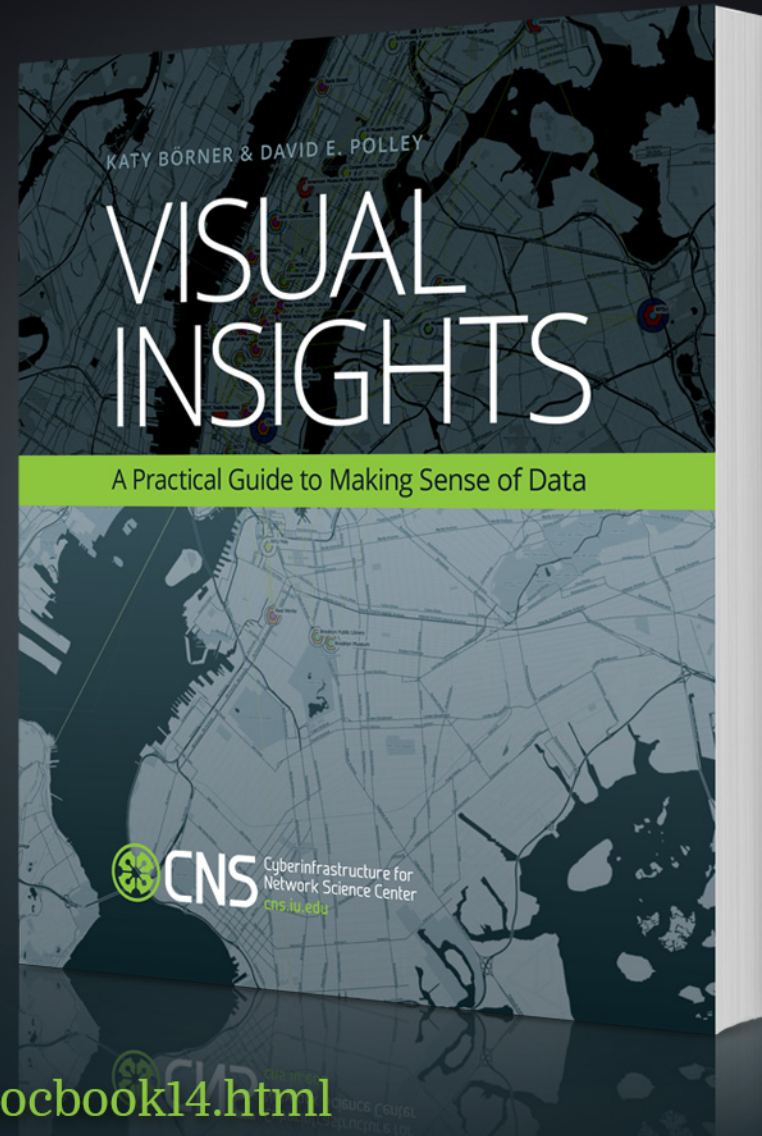
The IVMOOC Companion Textbook

This textbook offers a gentle introduction to the design of insightful visualizations. It seamlessly blends theory and practice, giving readers both the theoretical foundation and the practical skills necessary to render data into insights.

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

<http://ivmooc.cns.iu.edu>


cns.iu.edu/ivmoocbook14.html




IVMOOC App

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


Google Play





IVMOOC Flashcards
Studio Cypher Education
Everyone
This app is compatible with all of your devices.
Installed

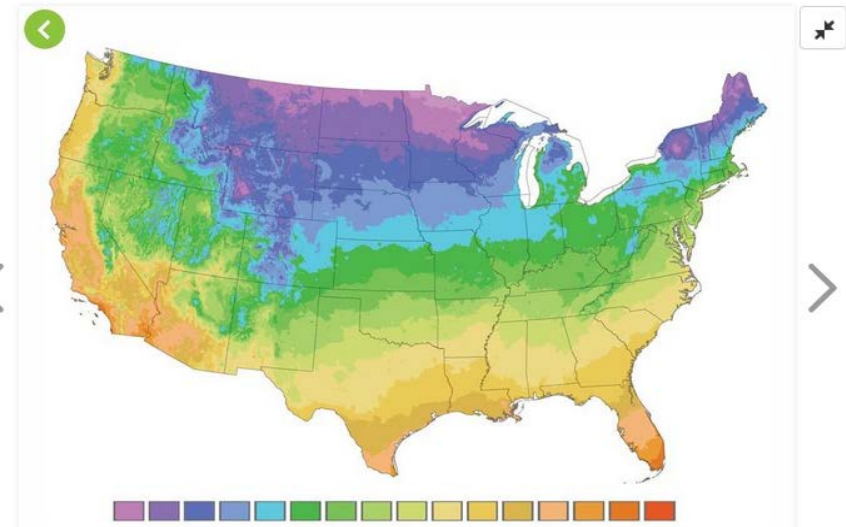


IVMOOC Flashcards
Studio Cypher Education
Everyone
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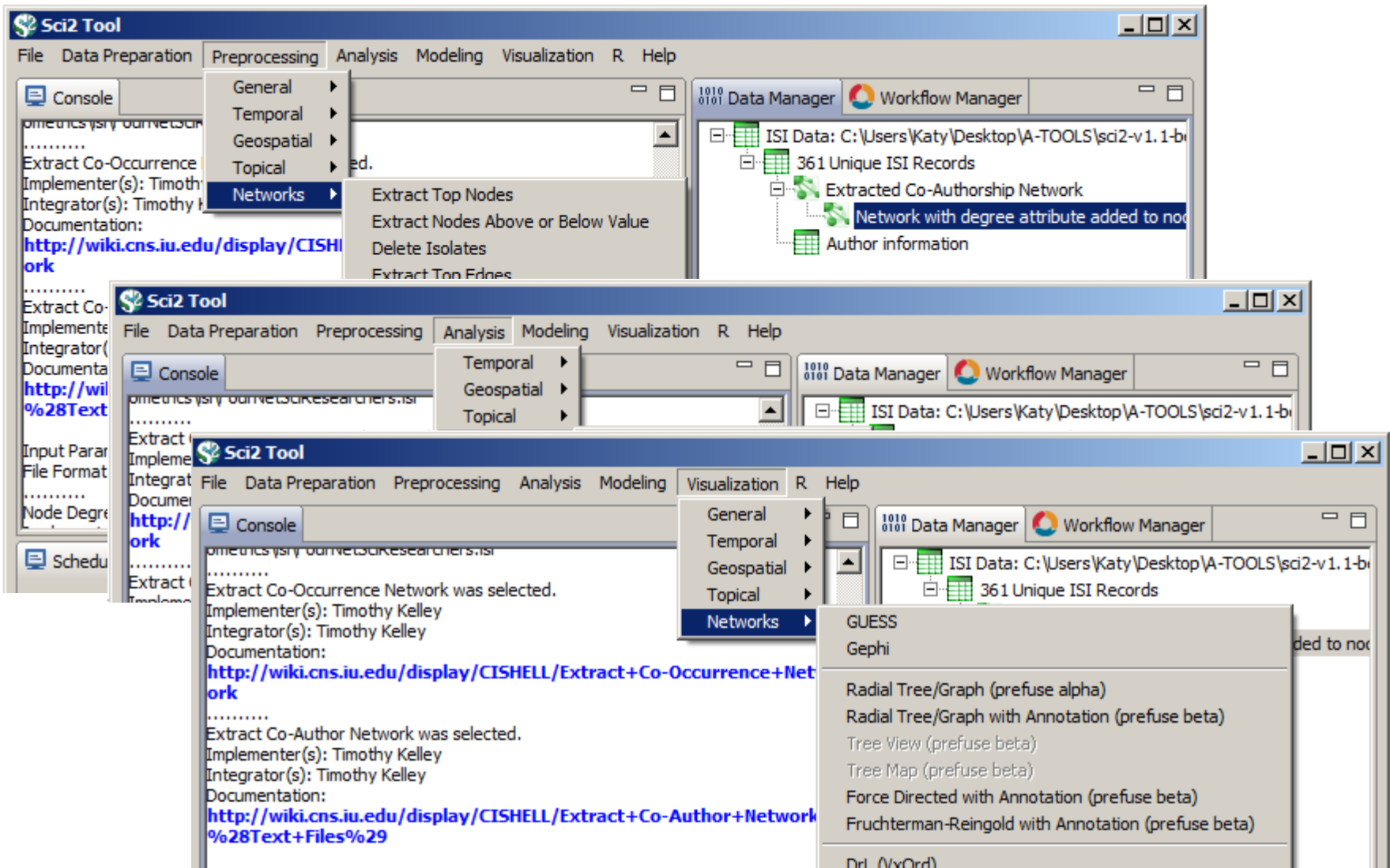
Information Visualization MOOC Flashcards
ivmooc.cns.iu.edu

 **CNS** Cyberinfrastructure for Network Science Center
cns.iu.edu  **Studio Cyph-r**



Sci2 Tool Interface Components Implement Vis Framework

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



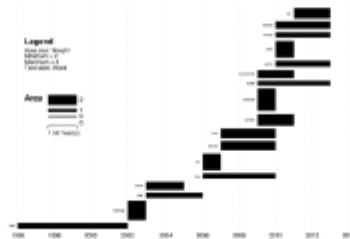
Load **One** File and Run **Many** Analyses and Visualizations

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

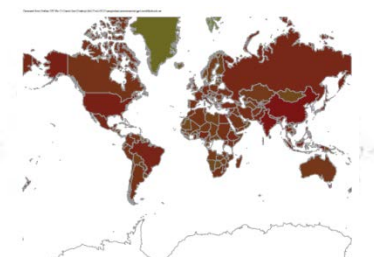
Temporal Burst Analysis—p. 48



Geospatial Analysis—p. 52



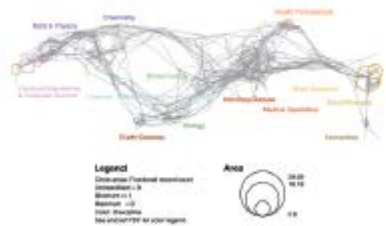
Geospatial Analysis—p. 52



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
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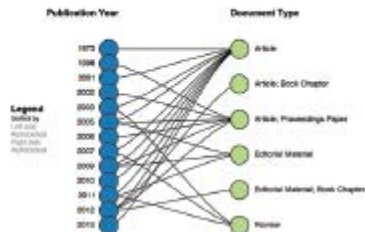
Topical Analysis—p. 56



Paper Citation Network—p. 60



Bi-Modal Network—p. 60

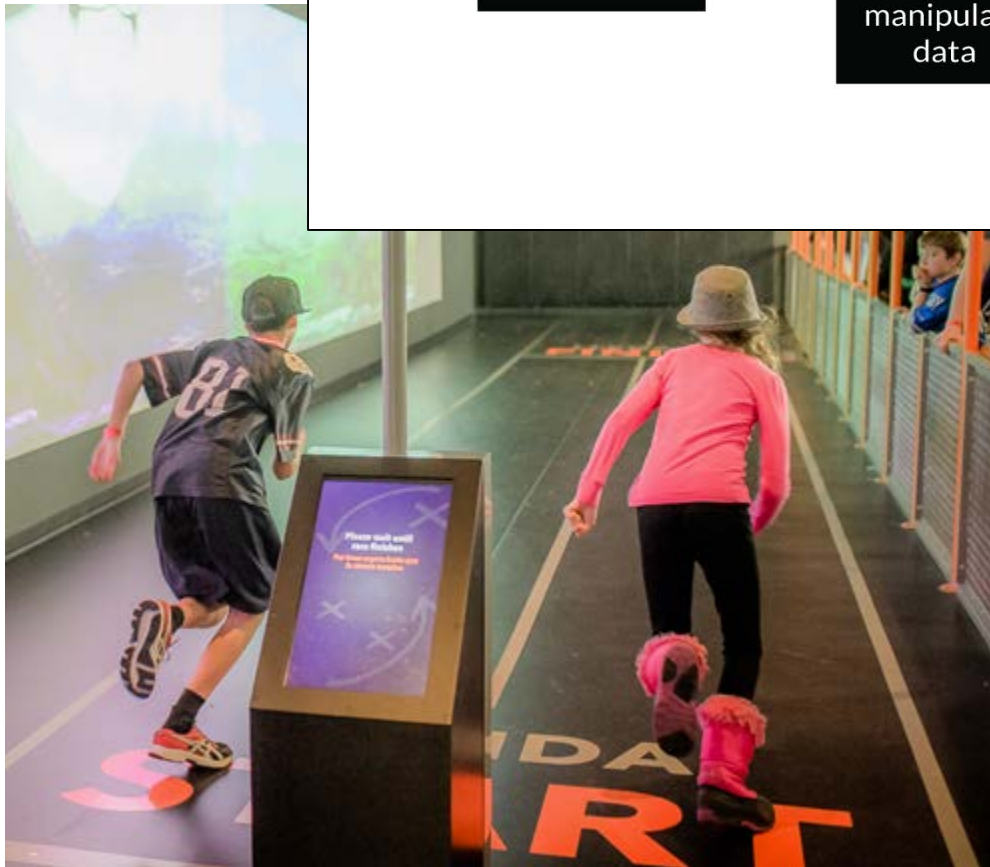
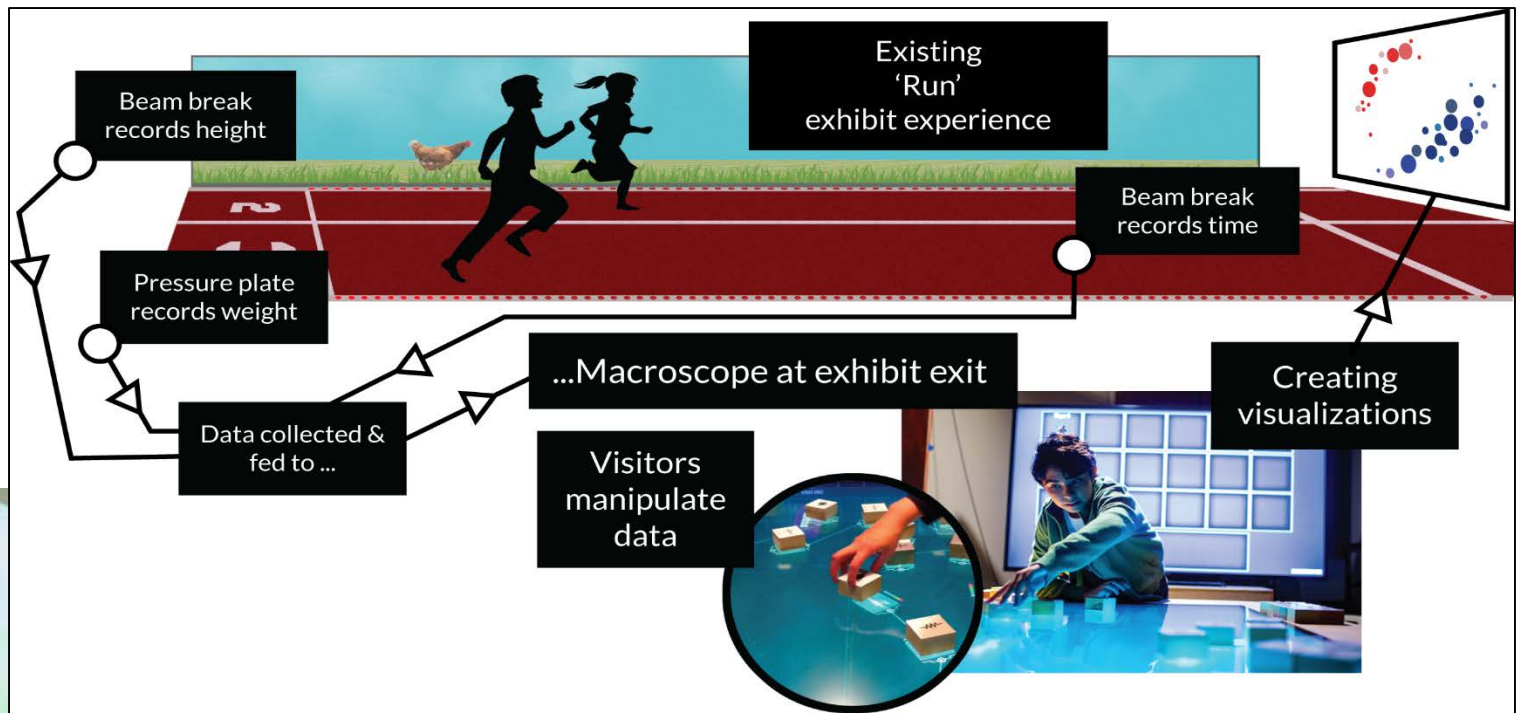


Co-author and many other bi-modal networks.

Data Visualization Literacy: Research and Tools that Advance **Public** Understanding of Scientific Data



Data Visualization Literacy: Research and Tools that Advance Public Understanding of Scientific Data.
Katy Borner & Kylie Pepler (IU), Bryan Kennedy (SMM), Stephen Uzzo (NYSCI), Joe Heimlich (COSI).
NSF AISL award #1713567.

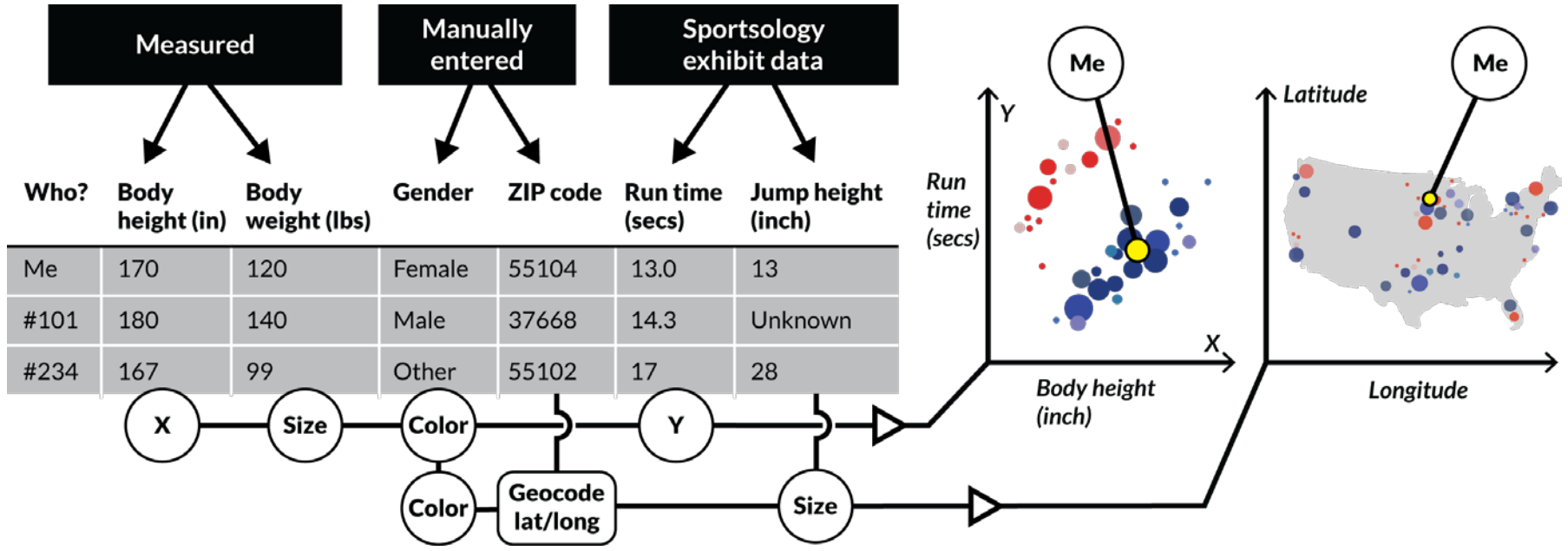


Sketch of the *Run* exhibit including data collection (top) and macroscope add-on that lets interested visitors explore more complex data visualizations using table-top displays.

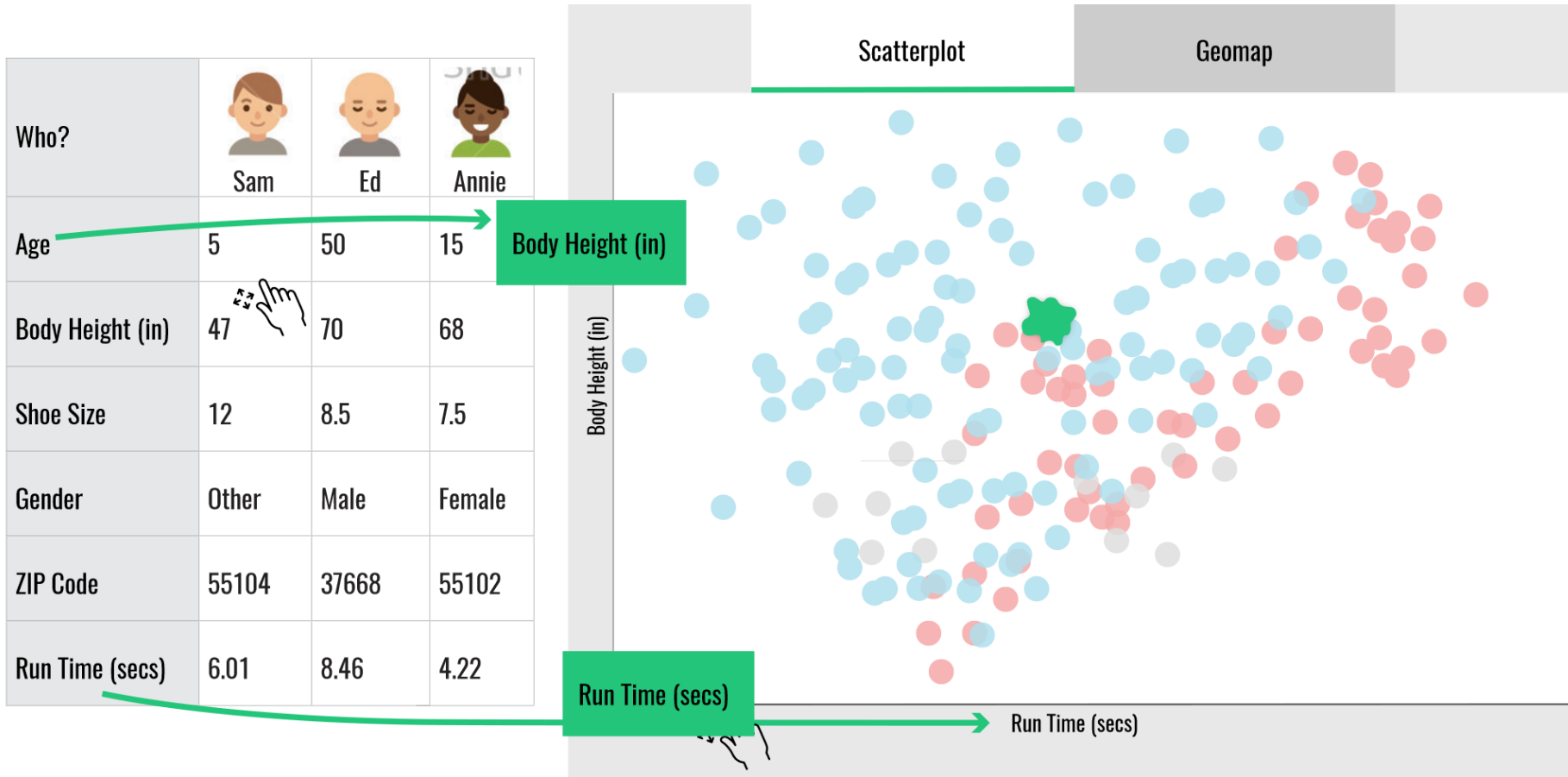
Sportsology @ Science Museum of Minnesota



<https://www.youtube.com/watch?v=oy34R45EfBg>



xMacroscopic general setup and activity—Raw data on left is converted to visualization on right by dragging and dropping (or connecting) column headers to axes, paint buckets, size, and shape.



xMacroscope general setup and activity—Raw data on left is converted to visualization on right by dragging and dropping (or connecting) column headers to axes, paint buckets, size, and shape.

**Data Visualization Literacy:
Research and Tools that Advance Public Understanding of
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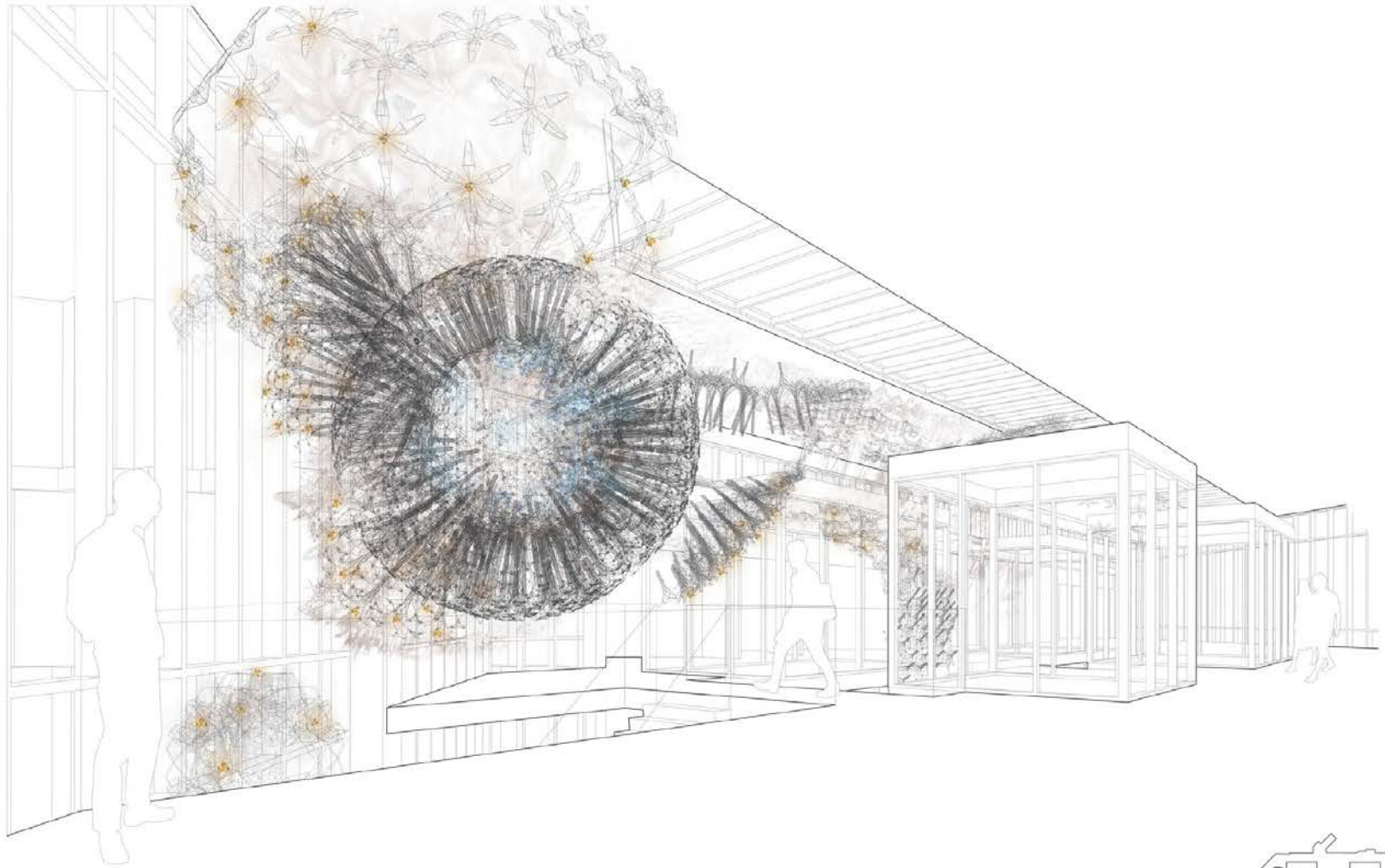
Visualizing the Internet of Things (IoT)

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



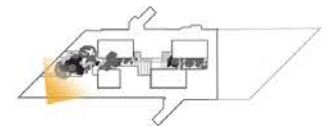
Work by Philip Beesley | www.philipbeesley.ca | www.lasg.ca



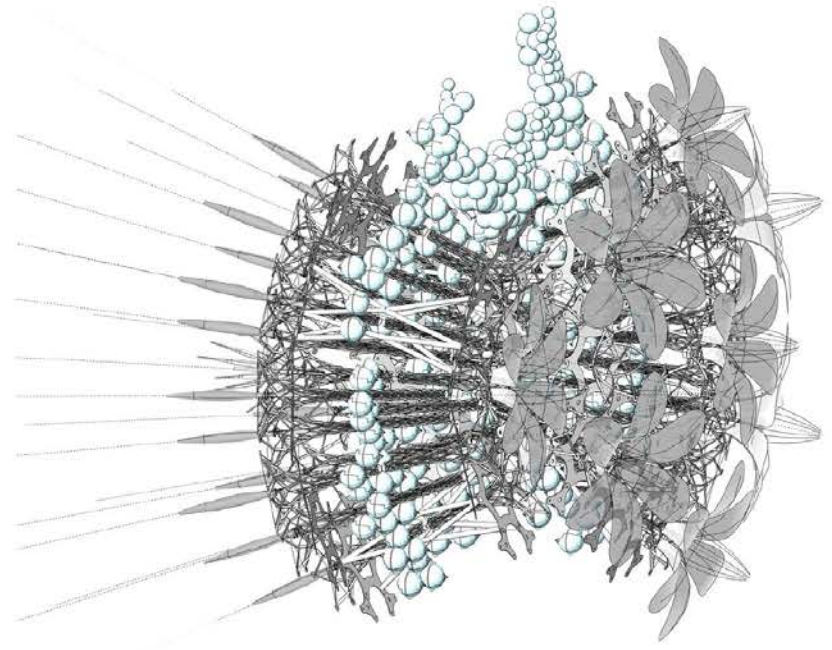
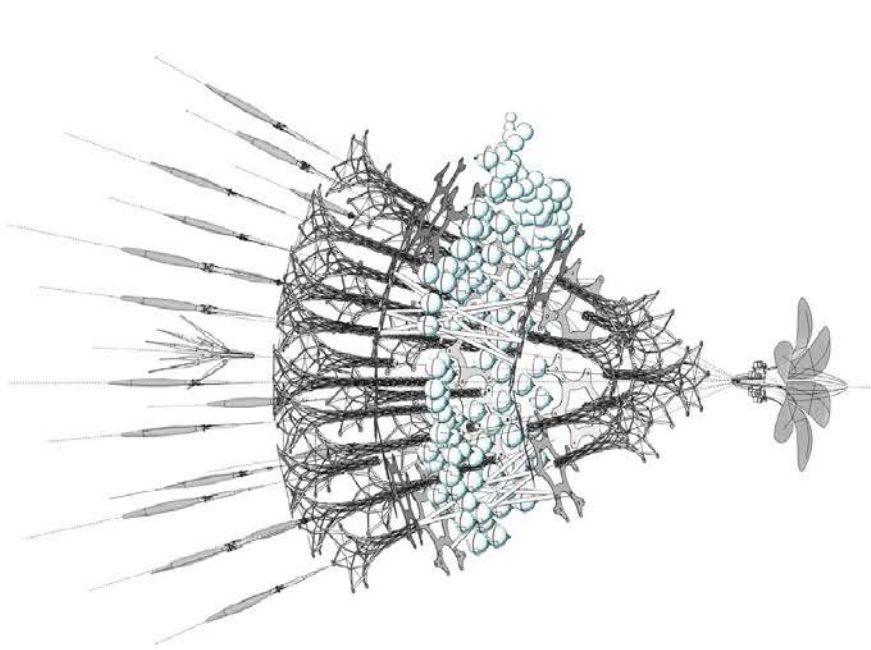


Luddy Hall Installation
Indiana University Bloomington
April 29 2017

UPPER ATRIUM



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Luddy Hall Installation
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April 29 2017

ASSEMBLY SAMPLE

Philip Beesley • Living Architecture Systems

Photo shared by Bruce Shei





Photo by Tracey Theriault



Amatria Unveiled by Andreas Bueckle et al. Data visualizations of sensor/actuator positions and types, energy and communication flows, and emergent behavior of smart environments.

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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.

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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

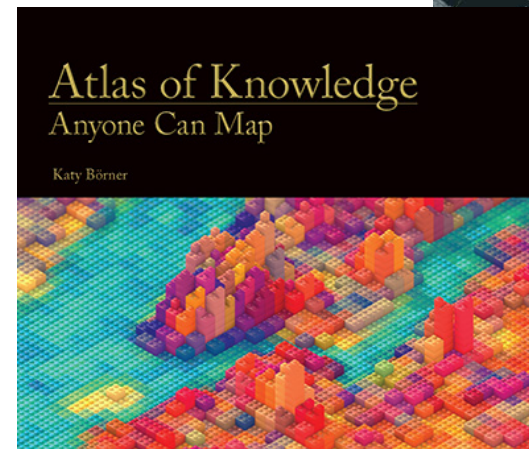
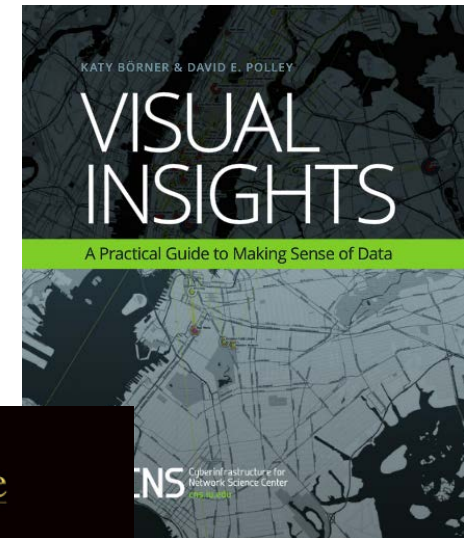
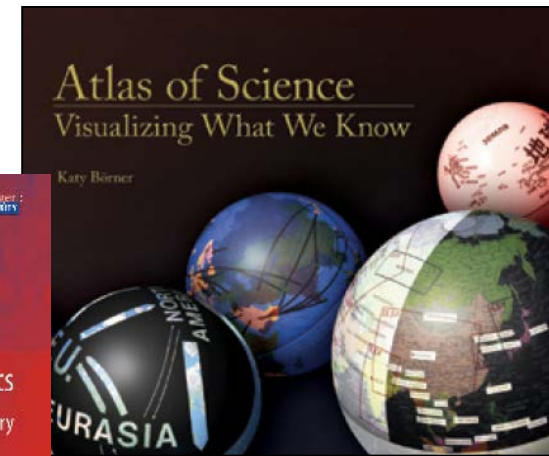
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Scharnhorst, Andrea, Börner, Katy, van den Besselaar, Peter (2012) **Models of Science Dynamics**. Springer Verlag.

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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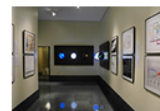
Upcoming Events

- 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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