

## Data Visualization Literacy

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*Hypertext Conference*

*Halifax, Canada  
July 10-13, 2016*

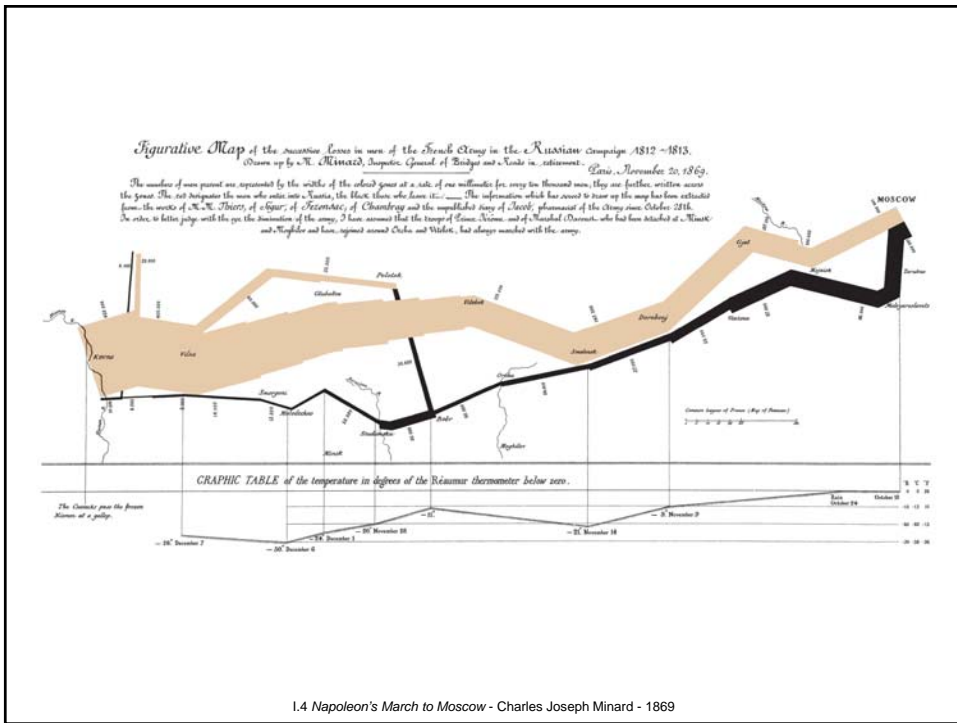
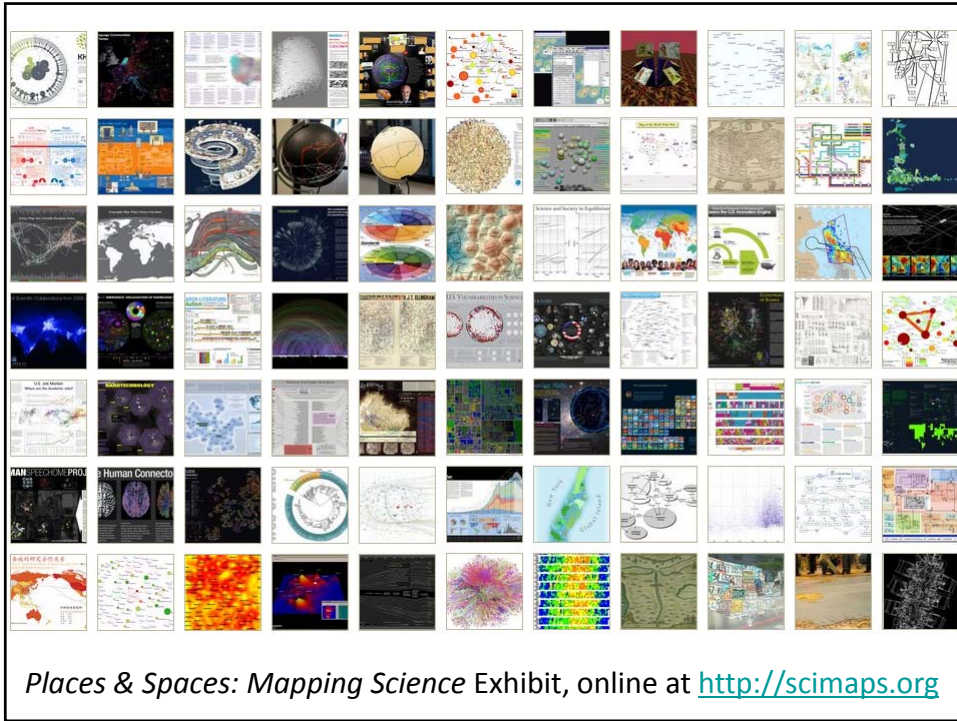
@katycns #acmht16

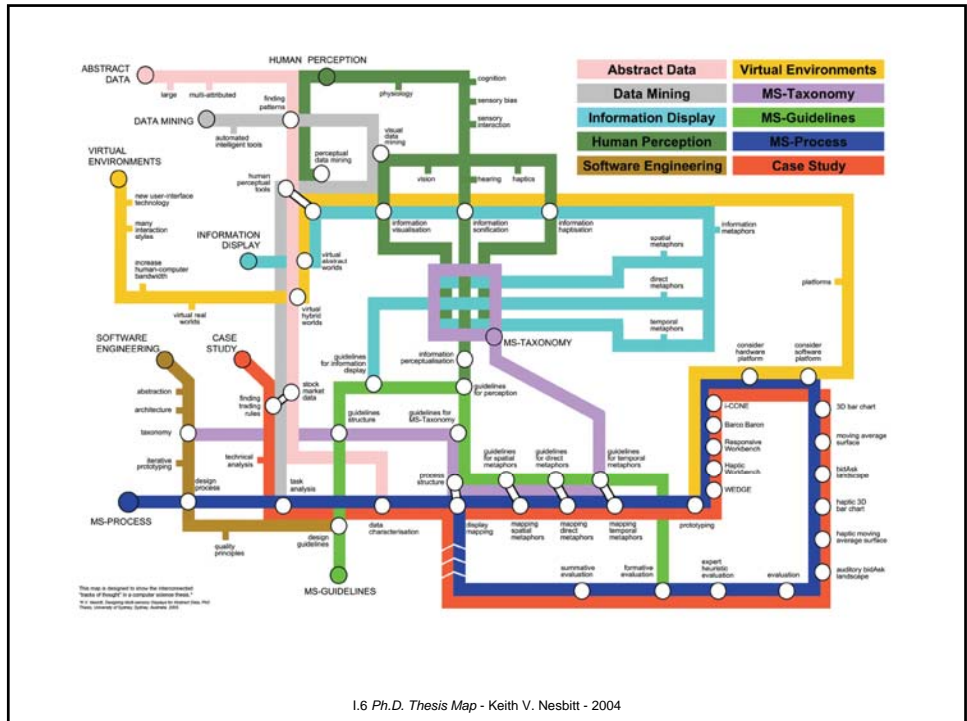


## *Places & Spaces: Mapping Science Exhibit*

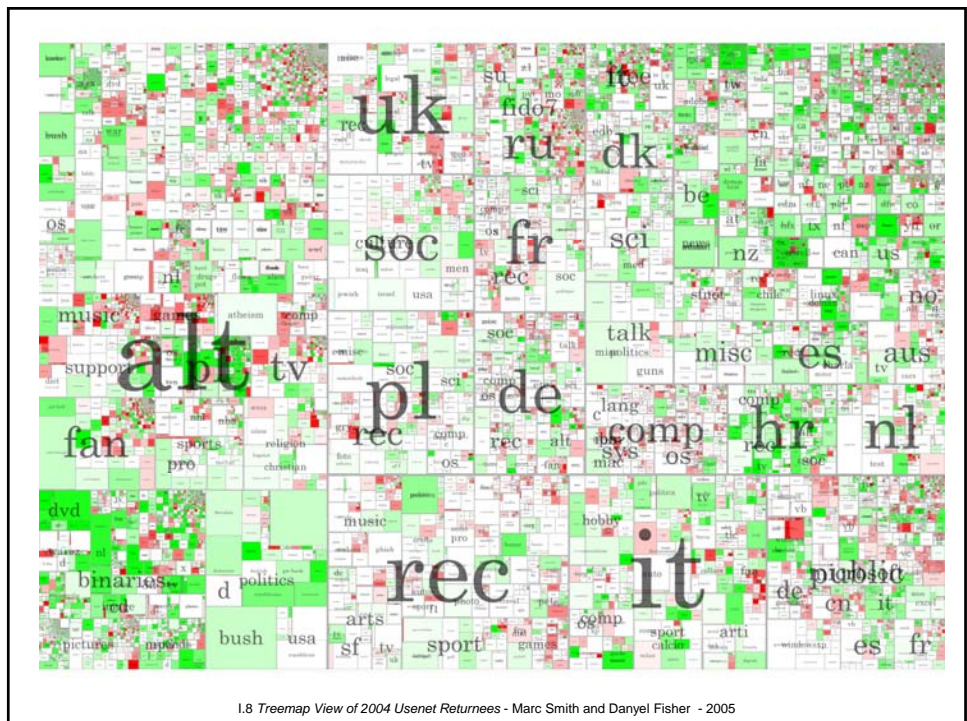
<http://scimaps.org>







I.6 Ph.D. Thesis Map - Keith V. Nesbitt - 2004



I.8 Treemap View of 2004 Usenet Returnees - Marc Smith and Danyel Fisher - 2005





# Literary Empires

Mapping Temporal & Spatial Settings of Victorian Poetry

**LEGEND**

- Approx. Order of Publication
- Poet's Country

**7 Poems Sorted by Temporal Settings**

Year	Poet	Poem	Poem's Country
1802	William Wordsworth	Michael	England
1805	William Wordsworth	Sonnet	England
1807	William Wordsworth	Michael	England
1810	William Wordsworth	Sonnet	England
1811	William Wordsworth	Sonnet	England
1812	William Wordsworth	Sonnet	England
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1898	William Wordsworth	Sonnet	England
1899	William Wordsworth	Sonnet	England
1900	William Wordsworth	Sonnet	England

VI.7 Literary Empires: Mapping Temporal and Spatial Settings of Victorian Poetry  
John A. Walsh, Devin Becker, Bradford Demarest, Jonathan Tweedy, Theodora Michaelidou, and Laura Pence - 2010

# MONDOTHÈQUE

A MULTIMEDIA DESK IN A GLOBAL INTERNET

Paul Otlet (1868-1944), visionary Belgian lawyer fascinated by the problems of access to global knowledge, is often acknowledged as a pioneer of the Internet. His design of 1936 for a multimedia desk for home use, the Mondothèque, integrated access to new documentary formats including multimedia substitutes for traditional books involving all available communications technologies such as microfilm, gramophone, radio and TV. A major resource was a new form of visual encyclopedia, the Encyclopedia Universalis Mundaneum. Connected by the Mondothèque to a network of global collections (Species Mundaneum), the user could access and engage in the international production and dissemination of knowledge.

**Paul Otlet**  
Mondothèque  
June 8, 1936 | 144 x 107 cm  
Pen and ink on transparent paper  
© Mundaneum, Mons, Belgium

The Mondothèque is a multimedia desk with spaces for essential books, with shelves in the form of visual encyclopedias, for small personal objects and with drawers for bibliographical cards, and microfilm cabinets according to the rules of his Universal Decimal Classification system. On the shelves of communication and broadcasting instruments, such as radio, telephone, television and film equipment.

"Otlet's original drawing is on light grey tracing paper. It has been reproduced here for legibility and printing purposes."

**Paul Otlet**  
Species Mundaneum  
January 16, 1937 | 21 x 28 cm  
Pen and ink on transparent paper  
© Mundaneum, Mons, Belgium

**MUNDOTECA** [Documentatio-Universalis-Mundaneum]

BRINGING TOGETHER OF ALL KINDS OF DOCUMENTATION - (THE 16 KINDS) IN A SINGLE ORDERED GROUPING

An agency for - conservation, - preservation, - use (specific or general) - systematic development in furniture, furnishings, galleries.

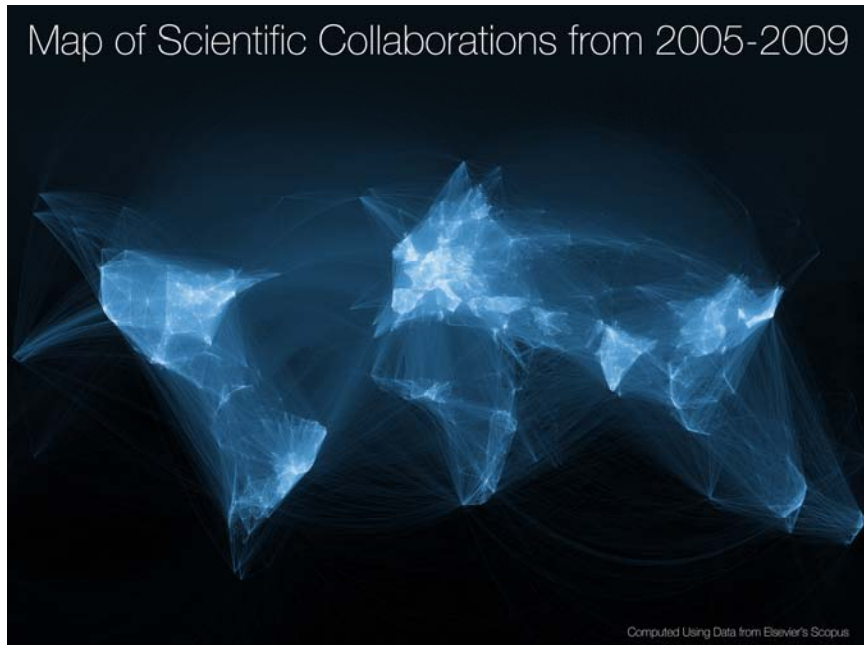
**COMPONENTS:**

- 1. Microfilm
- 2. Gramophone
- 3. Library
- 4. Encyclopedia
- 5. Photograph
- 6. Radio
- 7. TV
- 8. Microfilm
- 9. Encyclopedia
- 10. Radio
- 11. TV
- 12. Microfilm
- 13. Encyclopedia
- 14. Radio
- 15. TV
- 16. Microfilm

VII.1 Mondothèque. Multimedia Desk in a Global Internet - Paul Otlet - 1936/37

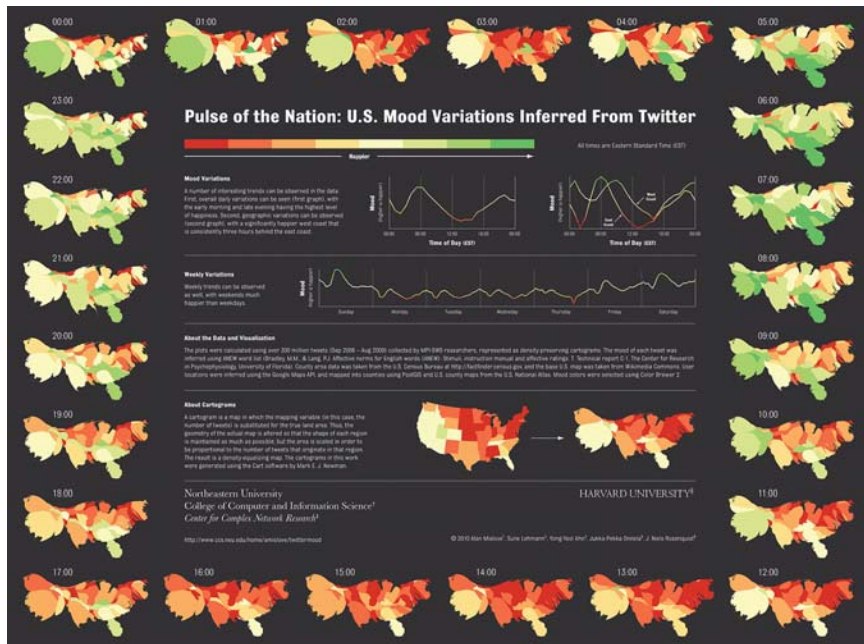


# Map of Scientific Collaborations from 2005-2009

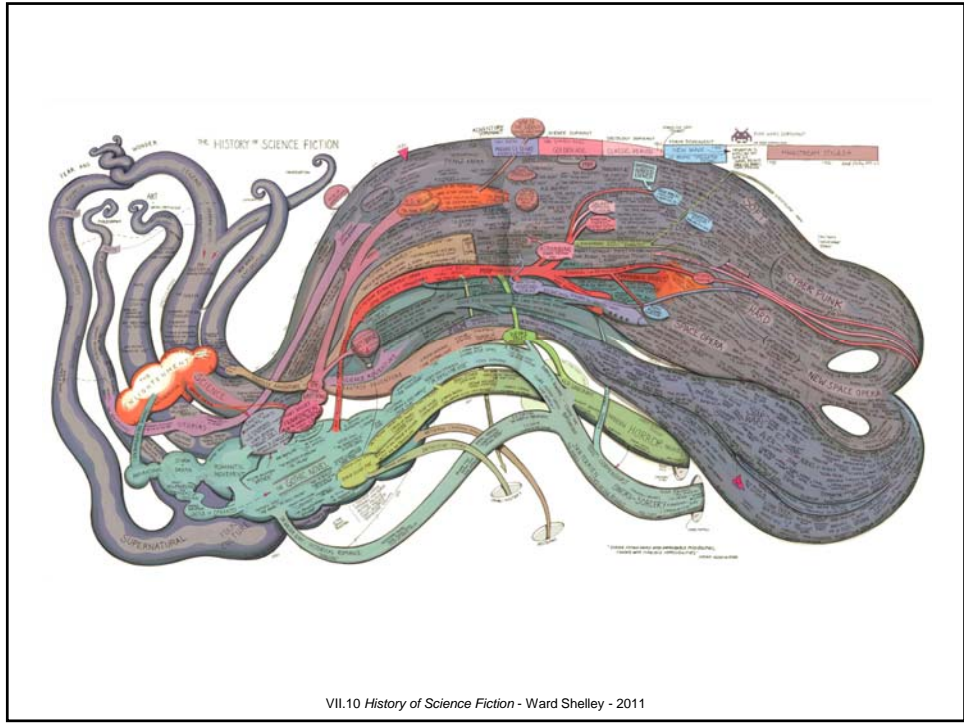


Computed Using Data from Elsevier's Scopus

VII.6 Map of Scientific Collaborations from 2005-2009 - Olivier H. Beauchesne - 2012

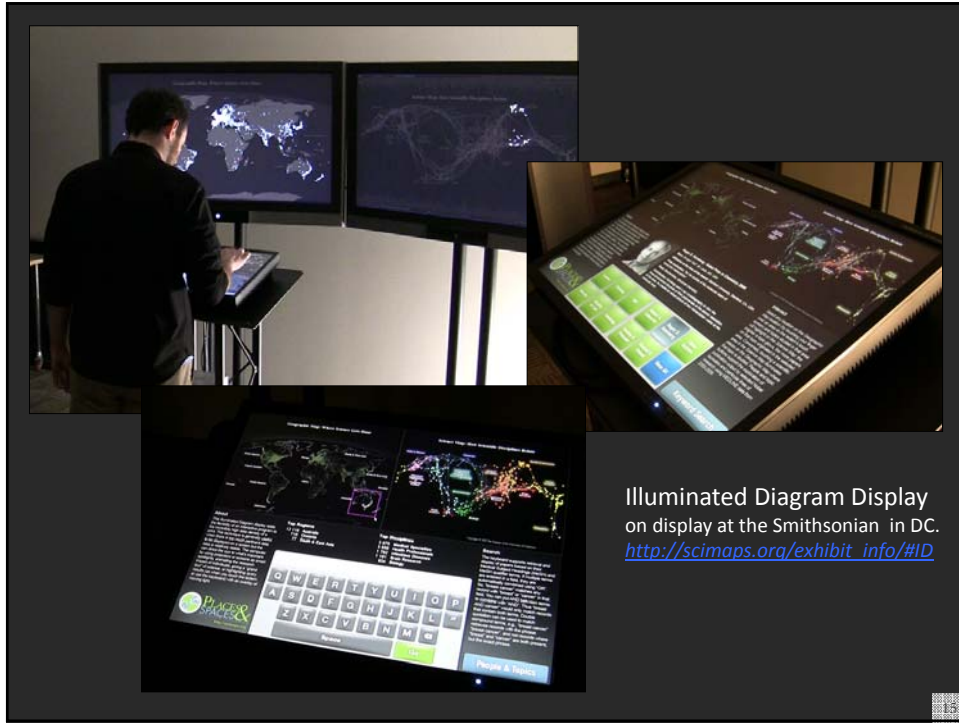


IX.4 Pulse of the Nation - Alan Mislove, Sune Lehmann, Yong-Yeol Ahn, Jukka-Pekka Onnela, and James Niels Rosenquist - 2010



 **Kristi Holmes** @kristiholmes · Apr 30  
Excited for @cnscenter Places&Spaces at @galterlibrary! @katycns  
@NUCATsinstitute #unpackingcrates #viz

Places & Spaces at Northwestern University  
May 14 - September 23, 2015



### Geographic Map: Where Science Gets Done

### Science Map: How Scientific Disciplines Relate

**About**

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

<http://scimaps.org>

**Top Five Continents**

- North America - 4,000 records
- South & East Asia - 3,589
- Australia - 2,421
- Africa - 2,208
- South America - 1,562

**Top Five Scientific Disciplines**

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

Input your search query here

**Go**

**Search**

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

**People & Topics**



### Geographic Map: Where Science Gets Done

### Science Map: How Scientific Disciplines Relate

**About**

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

**Elinor Ostrom - Nobel Prize in Economic Sciences 2009**

**Born:** 7 August 1933, New York, NY, USA

**Affiliation at the time of the award:** Indiana University, Bloomington, IN, USA, Arizona State University, Tempe, AZ, USA

**Prize motivation:** "for her analysis of economic governance, especially the commons"

**Field:** Economic governance

**Contribution:** Challenged the conventional wisdom by demonstrating how local property can be successfully managed by local commons without any regulation by central authorities or privatization.

**Interact**

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

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

**Keyword Search**

<http://scimaps.org>

Science Maps in "Expedition Zukunft" science train visited 62 cities in 7 months.  
 Opening on April 23<sup>rd</sup>, 2009 by German Chancellor Merkel



*Places & Spaces Exhibit at the David J. Sencer CDC Museum, Atlanta, GA  
January 25-June 17, 2016*

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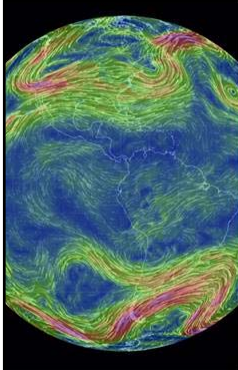
**Seeing for  
Action - Using  
Maps and  
Graphs  
to Protect the  
Public's Health.**

**CDC Opening Event: Maps of Health  
Tutorial and Symposium  
February 4-5, 2016**


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① **MACROSCOPES FOR INTERACTING WITH SCIENCE**







Earth



AcademyScope



Mapping Global Society




Charting Culture


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

### Microscopes, Telescopes, Macroscopes Plug-and-Play Macroscopes


**The Infinitely Great**




Telescope




Stars



Macroscope




Galaxies

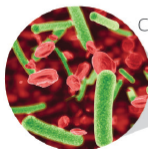


Society

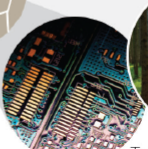
**The Infinitely Small**



Microscope




Cells



Technology

**The Infinitely Complex**



Nature

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Curated by the Cyberinfrastructure for Network Science Center

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

## Call for Macroscope Tools for the *Places & Spaces: Mapping Science* Exhibit (2016) <http://scimaps.org/call>

**Background and Goals**

The *Places & Spaces: Mapping Science* exhibit was created to in communicate human activity and scientific progress on a glol that enable the close inspection of large-scale maps in public conferences; (2) novel, interactive macroscope tools that let!

Themes for the upcoming iterations/years are:

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

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## Macroscope Standard Setting

**Plug-and-play system architectures**—supporting workflow design.

- ASTC Panel on “Plug-and-Play Macroscopes: Modular Hardware and Software Platforms that Render Data into Insights” in Montreal, Canada
- See other workshops and slides at <http://cns.iu.edu/workshops>

**Data-code-vis-expertise marketplaces**—easy access to relevant datasets and tools.


- OSGI+CIShell, D3, ESRI, Plotly, many others

**Visualization hardware**—support existing de-facto display standards, envision novel interfaces.

- Science on a Sphere, Beesley’s Living Architectures, augmented realities, IoT



Science on a Sphere by NOAA

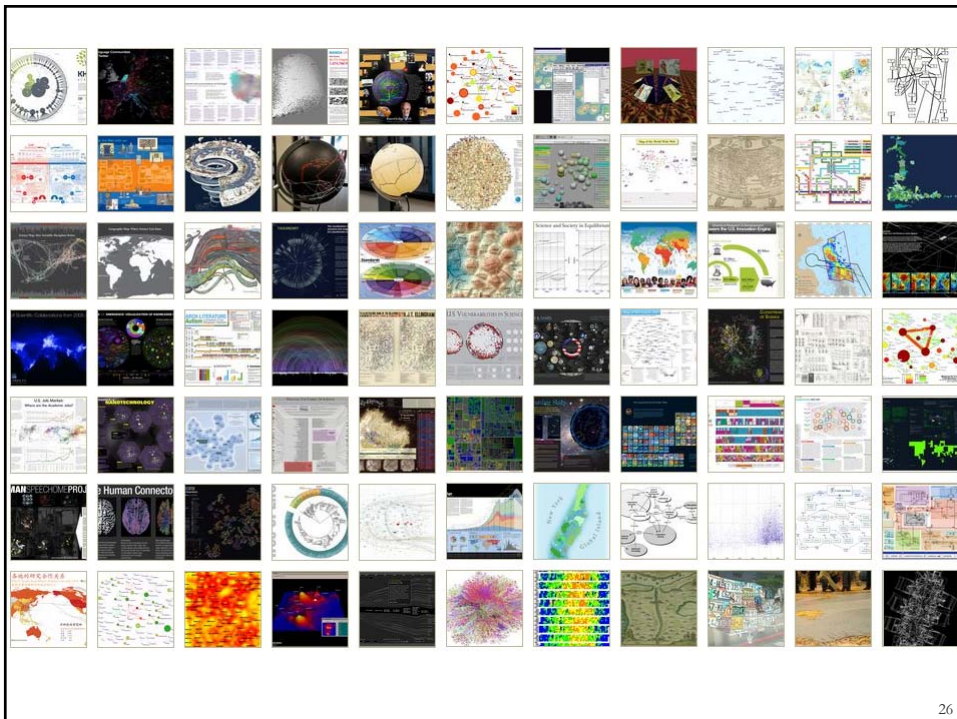


Beesley’s Living Architectures

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# Improving Data Visualization Literacy

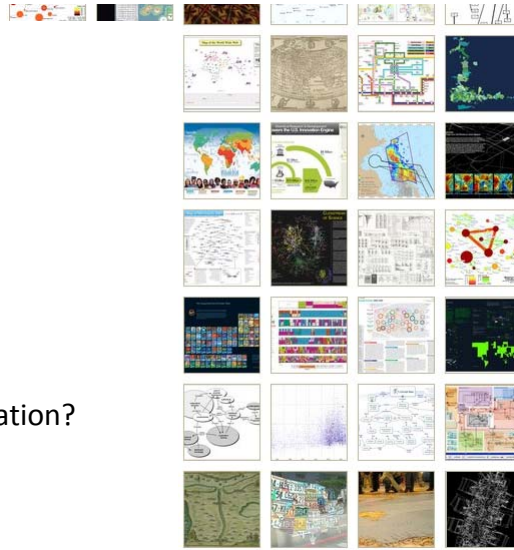
*Visualization Framework*  
IVMOOC



## 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 ?



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## Different Question Types



Terabytes of data

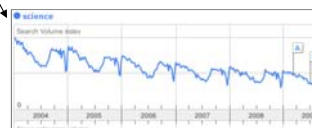
Descriptive & Predictive Models



Find your way



Find collaborators, friends



Identify trends

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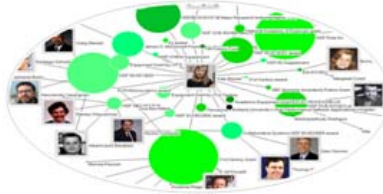


## Different Levels of Abstraction/Analysis

Macro/Global  
Population Level



Meso/Local  
Group Level



Micro  
Individual Level



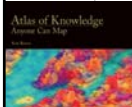
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## Tasks

### LEVELS

### TYPES

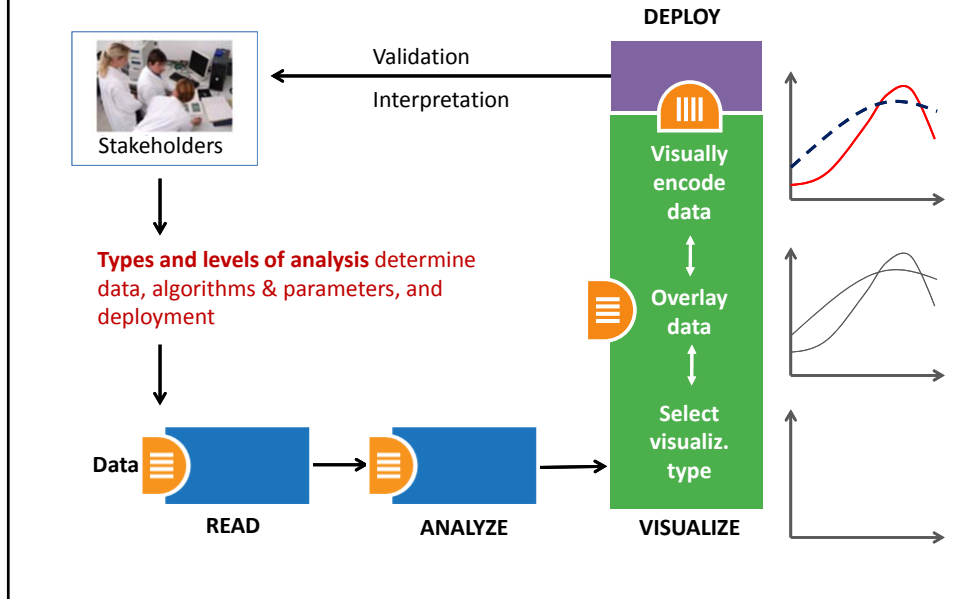
	MICRO: Individual Level about 1-1,000 records page 6	MESO: Local Level about 1,001-100,000 records page 8	MACRO: Global Level more than 100,000 records page 10
<b>Statistical Analysis</b> page 44			
<b>WHEN: Temporal Analysis</b> page 48			
<b>WHERE: Geospatial Analysis</b> page 52			
<b>WHAT: Topical Analysis</b> page 56			
<b>WITH WHOM: Network Analysis</b> page 60			



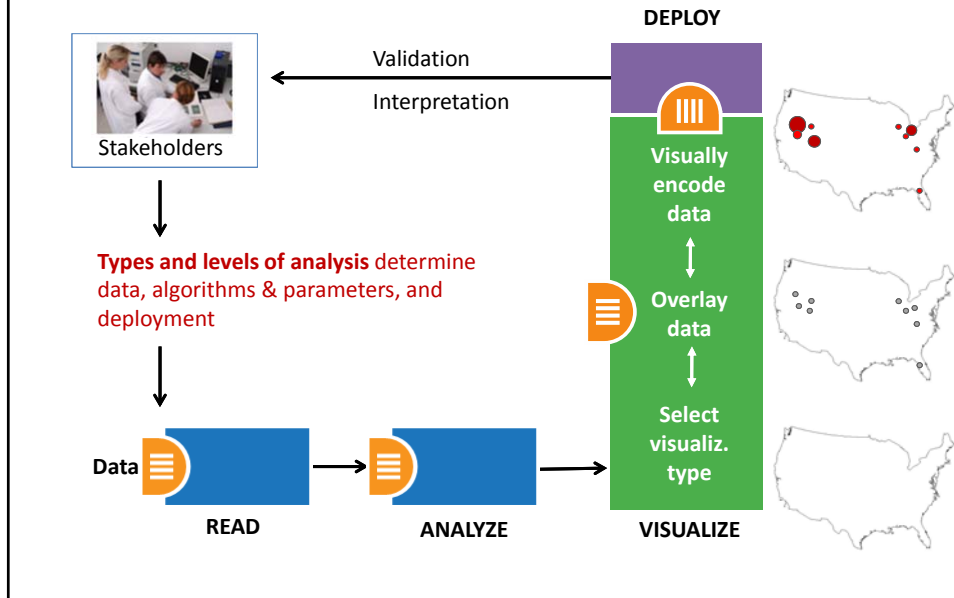
See page 5

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## Needs-Driven Workflow Design

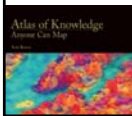


## Needs-Driven Workflow Design



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



See page 24

## Visualization Framework

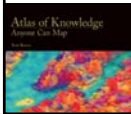
Basic Task Types								
Bertin, 1967	Wehrend & Lewis, 1996	Few, 2004	Yau, 2011	Rendgen & Wiedemann, 2012	Frankel, 2012	Tool: Many Eyes	Tool: Chart Chooser	Börner, 2014
selection	categorize			category				categorize/cluster
order	rank	ranking					table	order/rank/sort
	distribution	distribution					distribution	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

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



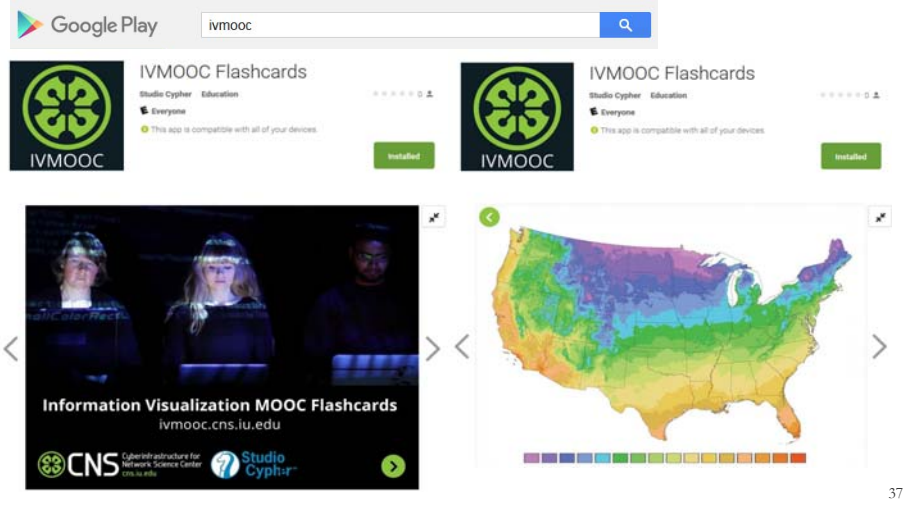
See page 24

## 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 graphs:** Node position might depend on node attributes or node similarity. **Tree graphs:** hierarchies, taxonomies, genealogies. **Networks:** social networks, migration flows.

## IVMOOC App – More than 60 visualizations

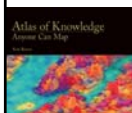
The “IVMOOC Flashcards” app can be downloaded from Google Play and Apple iOS stores.



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



See page 24

## 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		
	Value	quantitative			
Color	Hue	qualitative			
	Saturation	quantitative			

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## Graphic Variable Types Versus Graphic Symbol Types

		Geometric Symbols				Linguistic Symbols				Pictorial Symbols			
		Point	Line	Area	Color	Value	Text, Markers, Punctuation Marks	Images, Icons, Symbolic Objects					
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											

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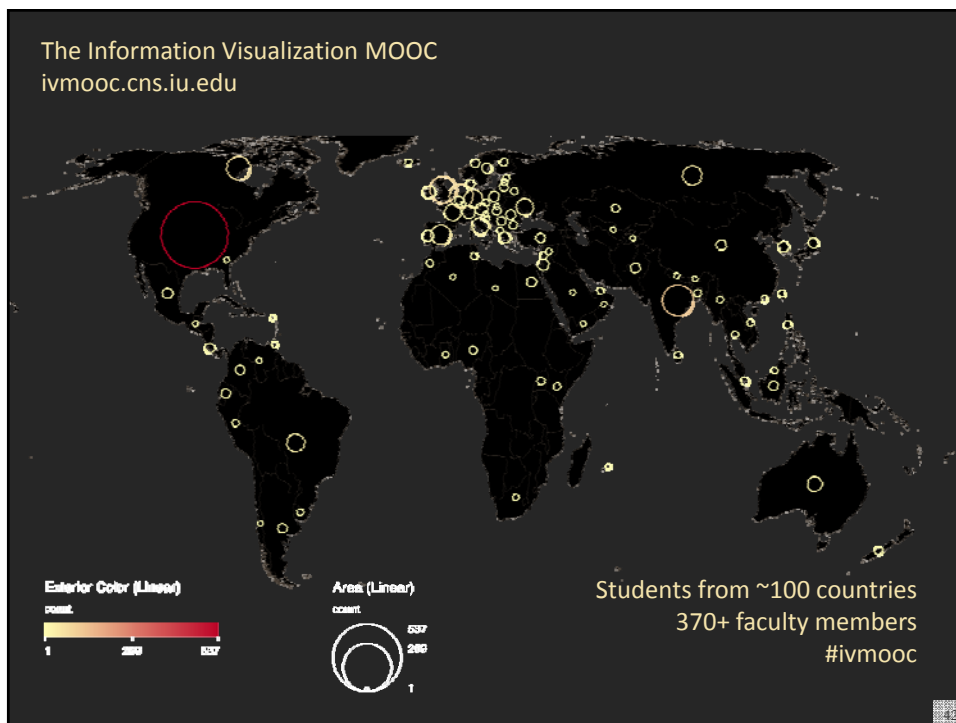


IVMOOC 2016 MENU

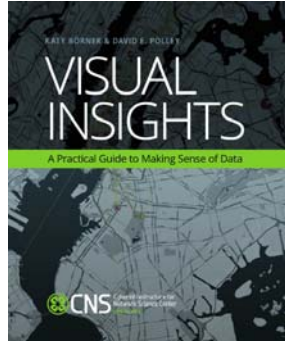


Information Visualization MOOC ivmooc.cns.iu.edu

Register for free: <http://ivmooc.cns.iu.edu>. Class restarts Jan 10, 2017.

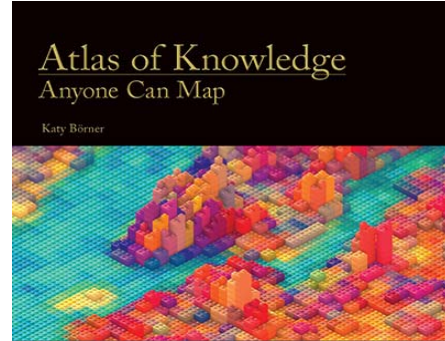


## Books Used in the IVMOOC



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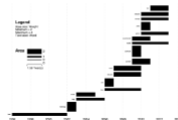
## Load **One** File and Run **Many** Analyses and Visualizations

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

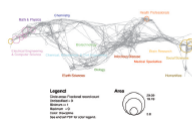


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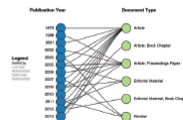
Topical Analysis—p. 56



Paper Citation Network—p. 60



Bi-Modal Network—p. 60



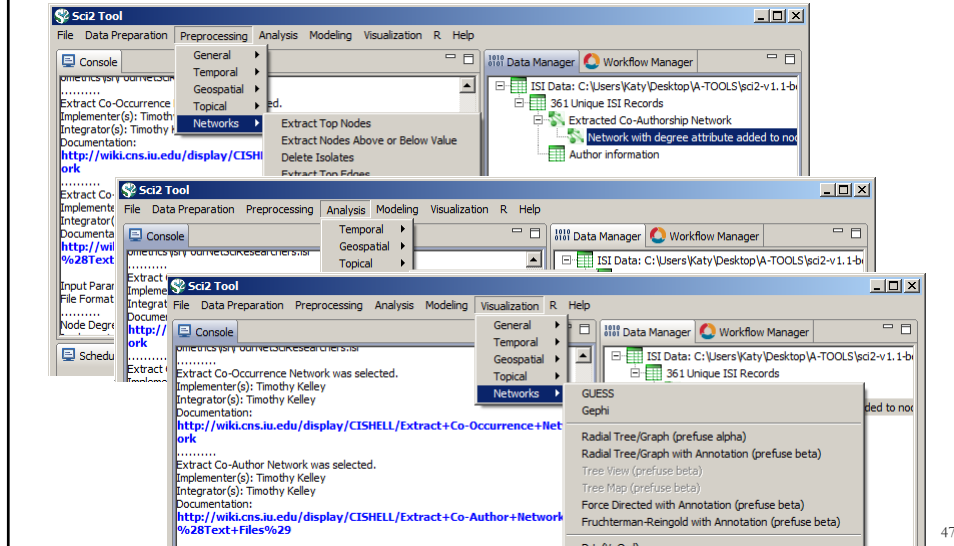
Co-author and many other bi-modal networks.

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## Sci2 Tool Interface Components

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



## References

Börner, Katy, Chen, Chaomei, and Boyack, Kevin. (2003). **Visualizing Knowledge Domains**. In Blaise Cronin (Ed.), *ARIST*, Medford, NJ: Information Today, Volume 37, Chapter 5, pp. 179-255. <http://ivl.slis.indiana.edu/km/pub/2003-borner-arist.pdf>

Shiffrin, Richard M. and Börner, Katy (Eds.) (2004). **Mapping Knowledge Domains**. *Proceedings of the National Academy of Sciences of the United States of America*, 101(Suppl\_1). [http://www.pnas.org/content/vol101/suppl\\_1/](http://www.pnas.org/content/vol101/suppl_1/)

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

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

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

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

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

Börner, Katy (2018) **Atlas of Forecasts: Predicting and Broadcasting Science, Technology, and Innovation**. The MIT Press.



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 These slides will soon be at <http://cns.iu.edu/docs/presentations>  
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