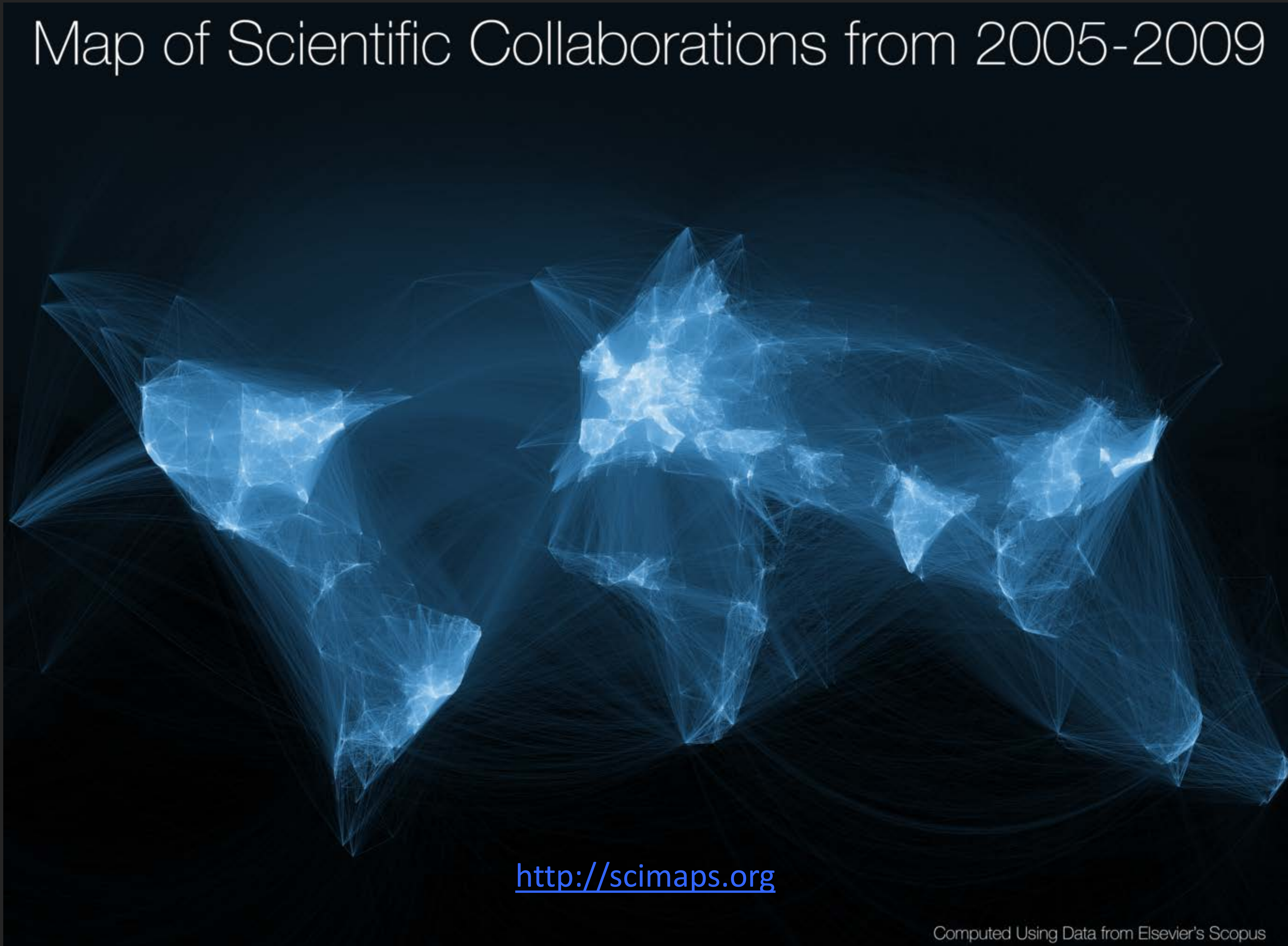
Visualizing Nanoscience and Technology

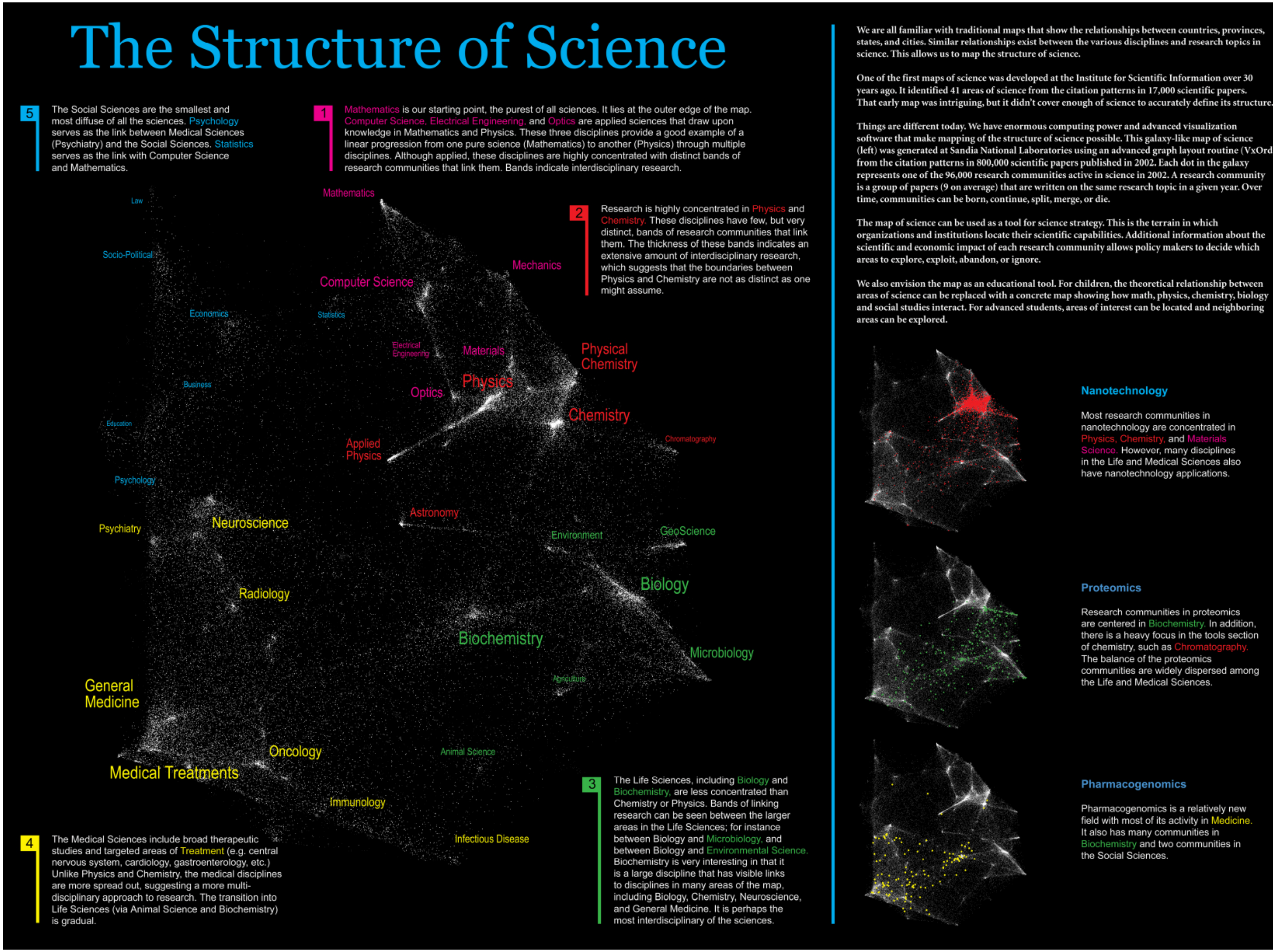
Katy Börner (@katycns)
Victor H. Yngve Distinguished Professor of Information Science
Director, Cyberinfrastructure for Network Science Center
Department of Intelligent Systems Enegineering
School of Informatics and Computing and IU Network Science Institute
Indiana University, Bloomington, USA

2016 NSF Nanoscale Science and Engineering Grantees Conference

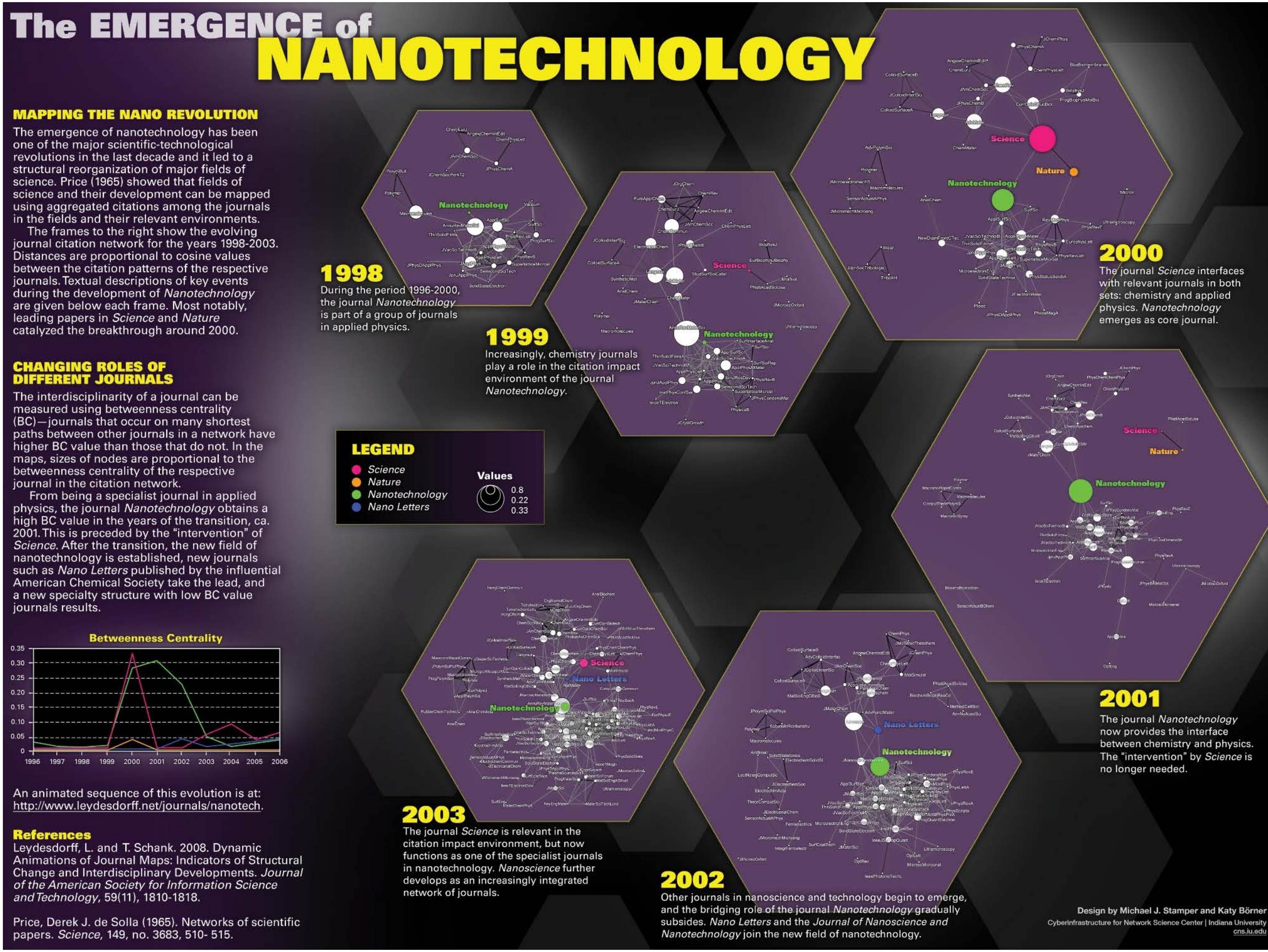
Westin Hotel, Arlington, VA
December 12, 2016



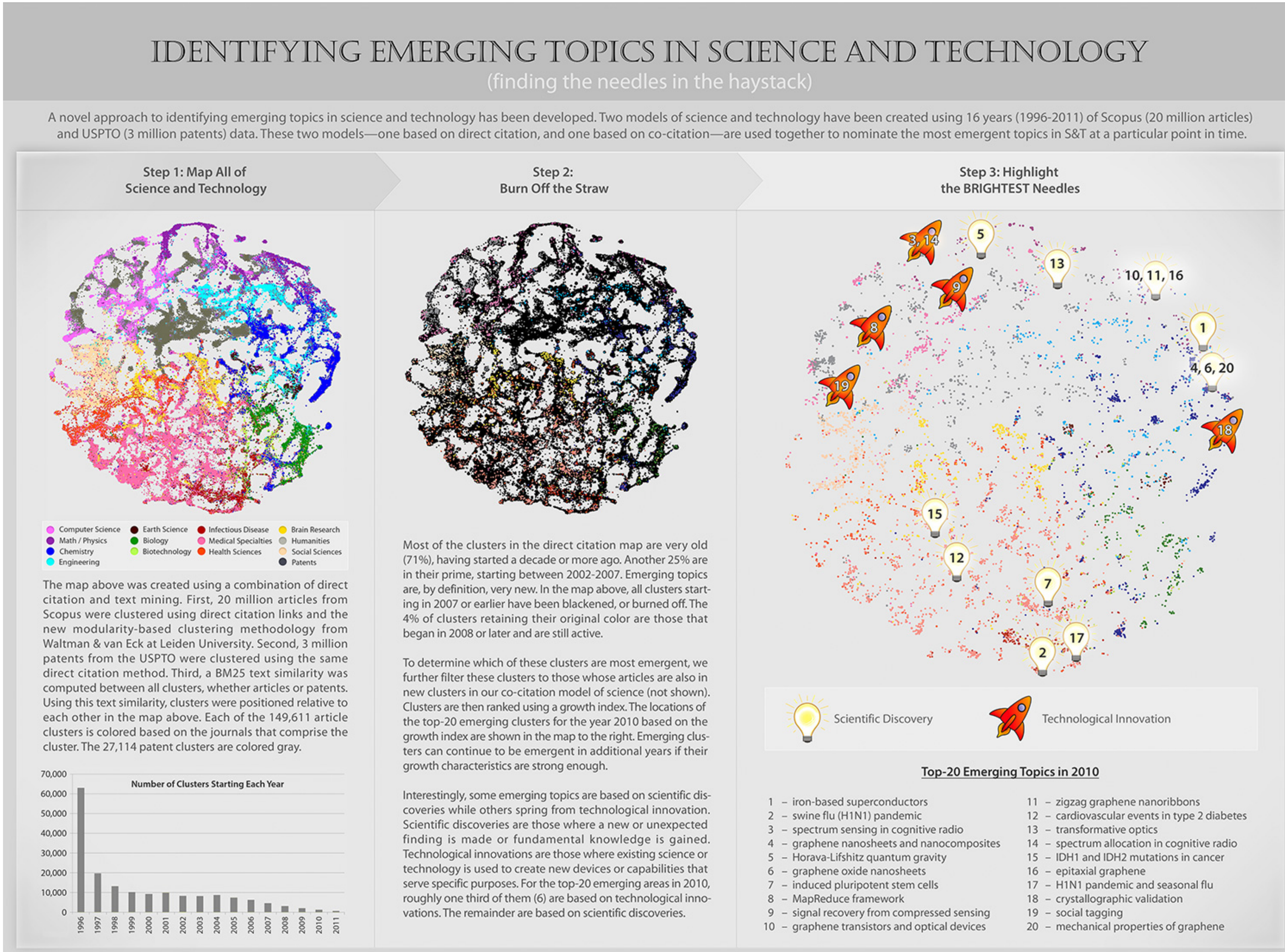
VII.6 *Map of Scientific Collaborations from 2005-2009* - Olivier H. Beauchesne - 2011



I.10 *The Structure of Science* - Kevin W. Boyack and Richard Klavans - 2005



VI.8 *The Emergence of Nanoscience & Technology* - Loet Leydesdorff - 2010



IX.9 *Identifying Emerging Topics in Science and Technology* - Kevin W. Boyack, Richard Klavans, and Henry G. Small - 2013

X.2 *Map of the Internet* - Martin Vargic - 2014

http://scimaps.org


FACEBOOK
PINTEREST
MYSPACE
BADOO
TWITTER
TUMBLR
BLOGSPOT
BING
YAHOO!
REDDIT
WIKIA
WIKIPEDIA
INFORMATION SEA
RENREN
WEIBO
CNN
BBC
NYTIMES
HIPSTER SEA
SEA OF ART
DEVIANTART
TAGGED
TMZ
ASK
ABOUT
4CHAN
9GAG
GOOGLEPLUS
GMAIL
Google Search
MAIL.RU
SOHU
163
360
YELP
BOOKING
BRITANNICA
DATA OCEAN
ATOS
GOOGLE
GOOGLE DRIVE
YANDEX
BUZZFEED
CHROME
INTERNET EXPLORER
YOUTUBE
LEAGUE OF LEGENDS
GAMESPOT
Land of Indexes
GULF OF GOOGLE
NORTH DATASTREAM
THE CAPITOL
MICROS
IGN
VIMEO
HULU
DAILY MOTION
RAPID SHARE
DROPBOX
CLOUD
SOUTH DATASTREAM
MOZILLA
OPERA
BLUEHOST
SAFARI
FAR SOUTH DATASTREAM
DEVELOPER SEA
CONDUIT
APPSTO
PLENTY OF FISH
ADULT FRIEND FINDER
MYFREECAMS
LIVE JASMIN
DESPICABLE SEA
MEGA
MEGA-UPLOAD
PREZI
SLIDESHARE
FLICKR
1&1
APP SEA
SEA OF ARCHIVES
PHOTOBUCKET
WORDPRESS.COM
GO DADDY
HOSTGATOR
GOOGLE PLAY
ANDROID
BITTORRENT
WAREZ SEA
ISOHUNT
SOFTONIC
PORNHUB
YOUPORN
SPANKWIRE
REDTUBE
HARDSEXTUBE
XTUBE
PIRATE SEA

Increasing Data Visualization Literacy

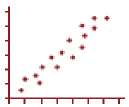
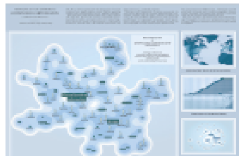
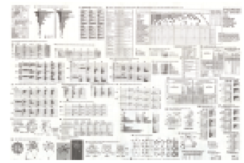
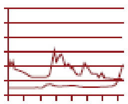
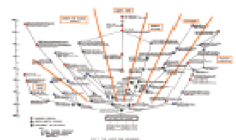
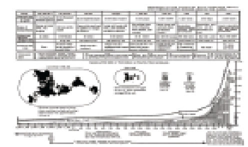
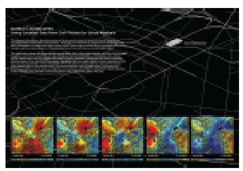
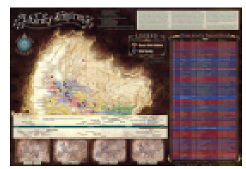
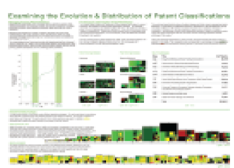
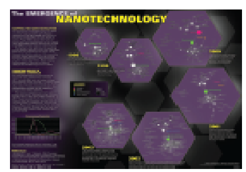
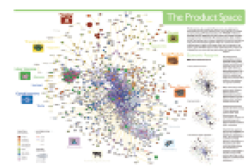
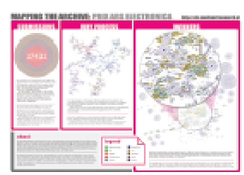
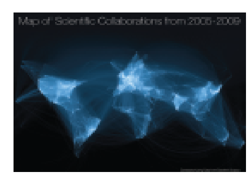
Data Visualization Literacy

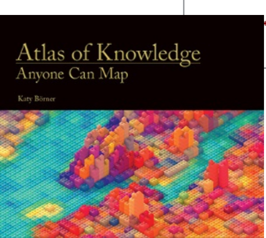
Data visualization literacy (ability to read, make, and explain data visualizations) requires

- *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).

The course can be taken for free or for Indiana University credits as part of the Online Data Science Program or the ILS M.S. program. Register for free at http://ivmooc.cns.iu.edu. Next class starts January 10, 2017.

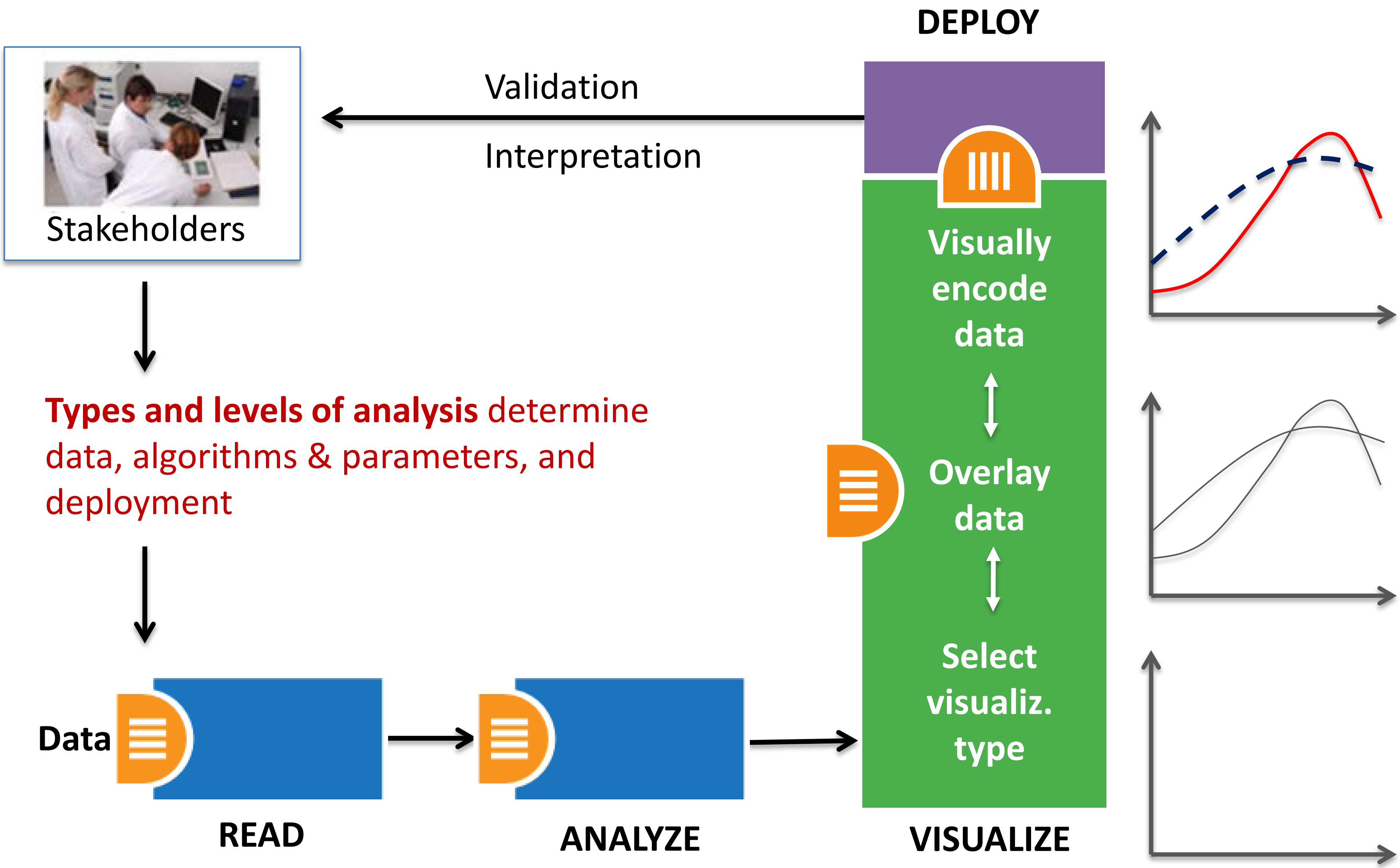
Tasks

TYPES \ 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
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

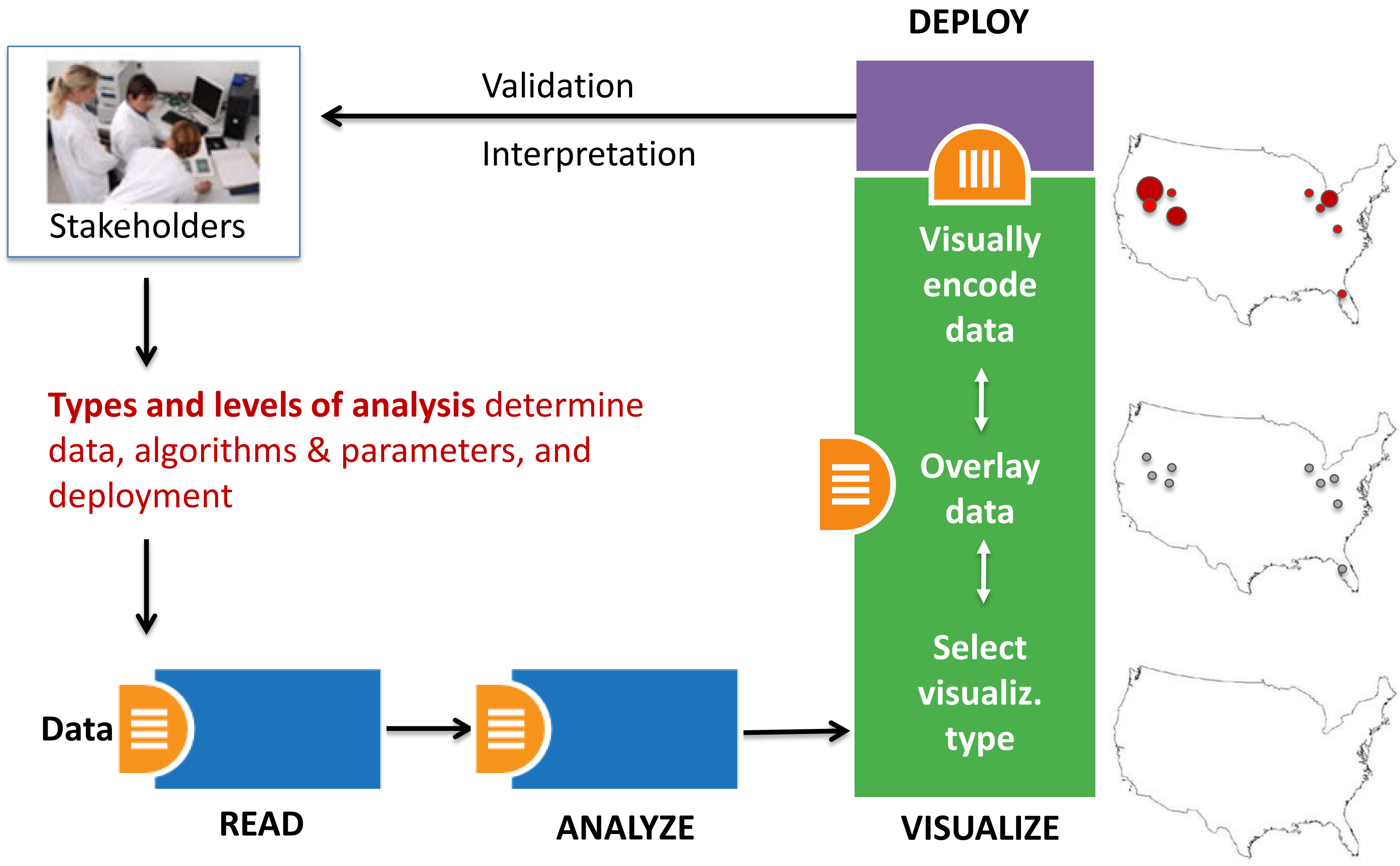


See page 5

Needs-Driven Workflow Design



Needs-Driven Workflow Design



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

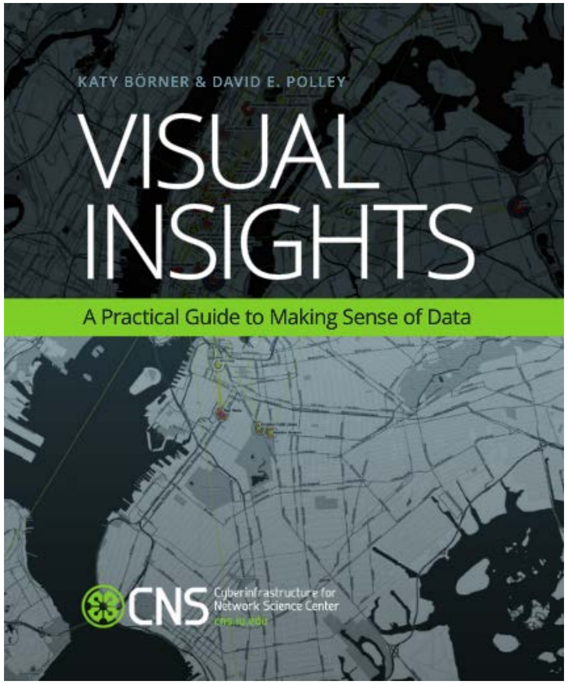
- **Session 5** – "With Whom:" Trees
- **Session 6** – "With Whom:" Networks
- **Session 7** – Dynamic Visualizations and Deployment

Final Exam

Part 2: Students work in teams on client projects.

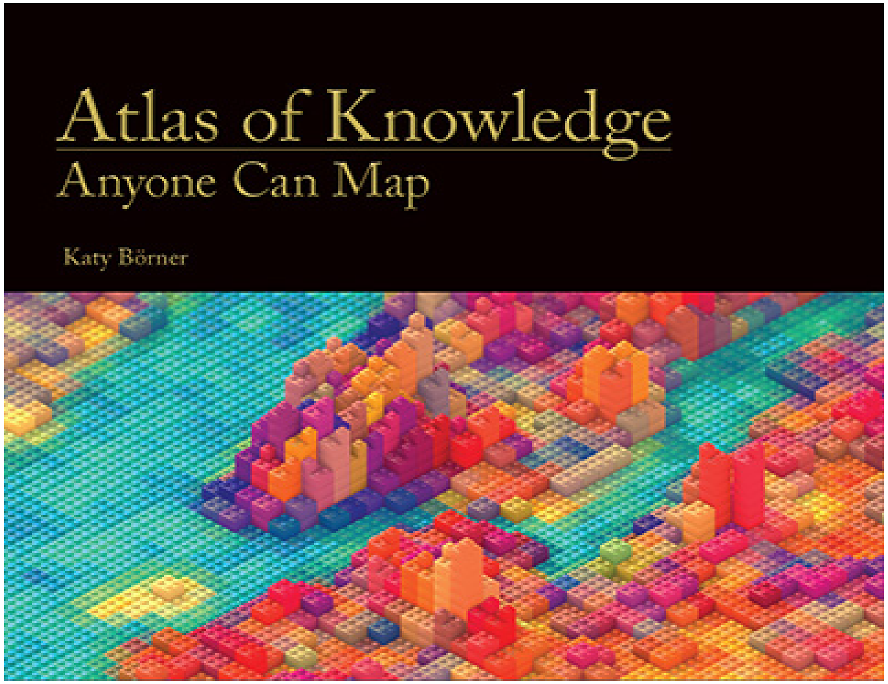
Final grade is based on Homework (10%), Midterm (20%), Final Exam (30%), Client Project (30%), and Class Participation (10%).

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.

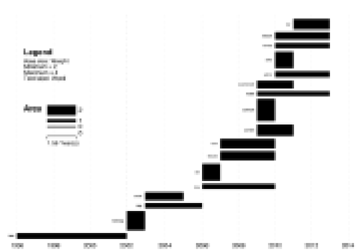
Load **One** File and Run **Many** Analyses and Visualizations

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

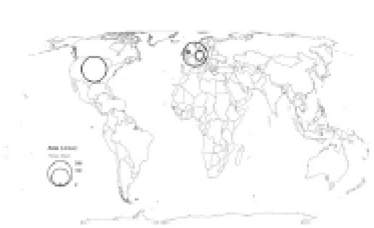
Statistical Analysis—p. 44

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

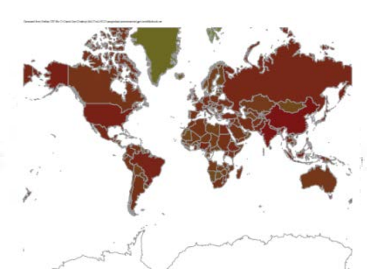
Temporal Burst Analysis—p. 48



Geospatial Analysis—p. 52

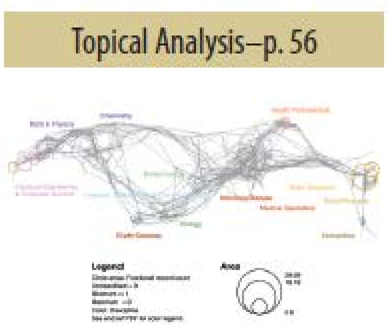


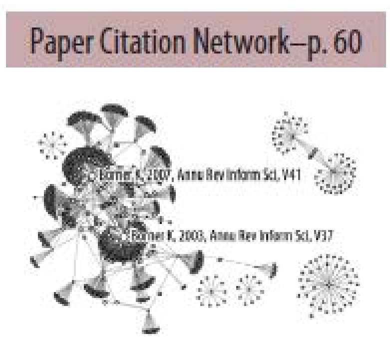
Geospatial Analysis—p. 52

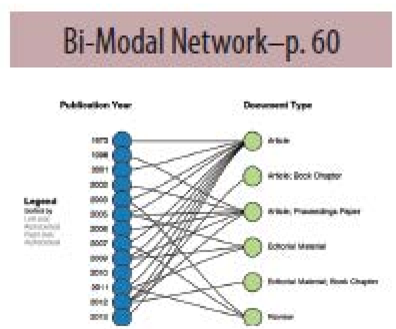


Load **One** File and Run **Many** Analyses and Visualizations

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

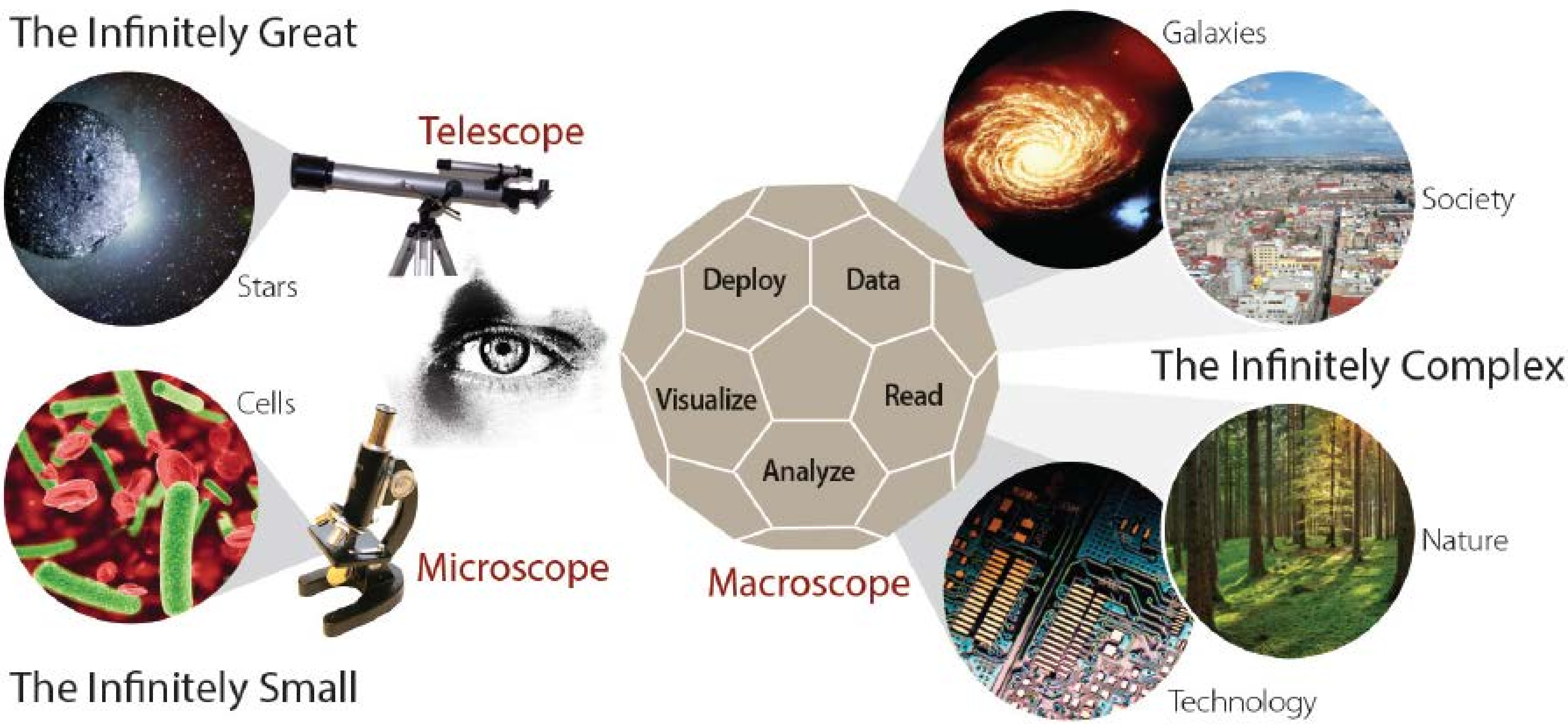






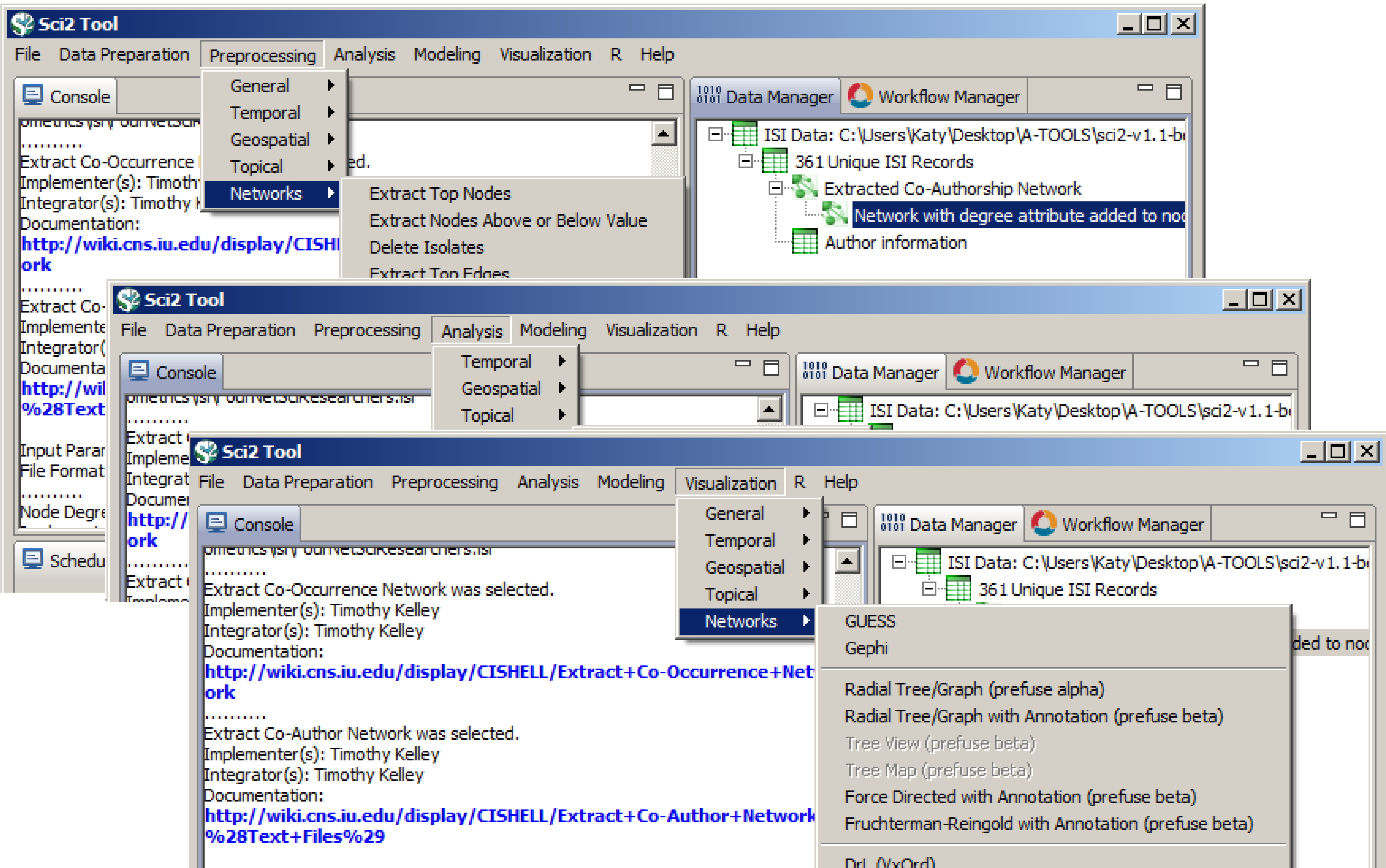
Co-author and many other bi-modal networks.

Microscopes, Telescopes, Macroscopes Plug-and-Play Macroscopes



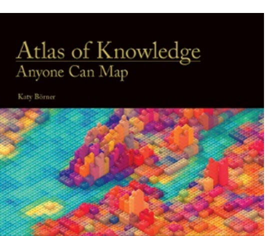
Sci2 Tool Interface Components

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



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
• categorize/cluster	• nominal	• table	• geometric symbols	• spatial	• overview
• order/rank/sort	• ordinal	• chart	point	position	• zoom
• distributions	• interval	• graph	line	• retinal	• search and locate
(also outliers, gaps)	• ratio	• map	area	form	• filter
• comparisons		• network layout	surface	color	• details-on-demand
• trends			volume	optics	• history
(process and time)			• linguistic symbols	motion	• extract
• geospatial			text		• link and brush
• compositions			numerals		• projection
(also of text)			punctuation marks		• distortion
• correlations/relationships			• pictorial symbols		
			images		
			icons		
			statistical glyphs		



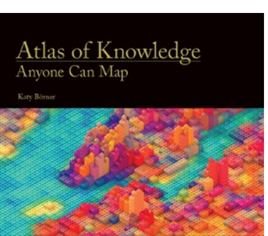
See page 24

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

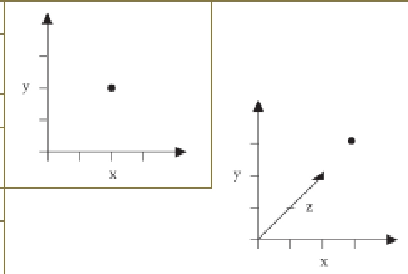
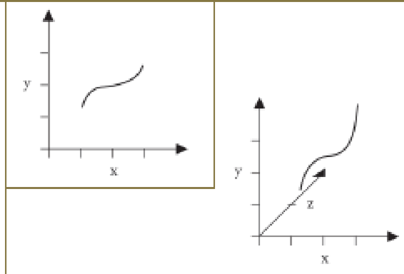
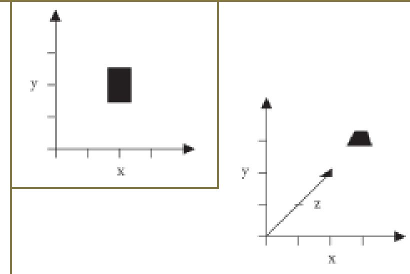
Visualization Framework

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
• categorize/cluster • order/rank/sort • distributions (also outliers, gaps) • comparisons • trends (process and time) • geospatial • compositions (also of text) • correlations/relationships	• nominal • ordinal • interval • ratio	• table • chart • graph • map • network layout	• geometric symbols point line area surface volume • linguistic symbols text numerals punctuation marks • pictorial symbols images icons statistical glyphs	• spatial position • retinal form color optics motion	• overview • zoom • search and locate • filter • details-on-demand • history • extract • link and brush • projection • distortion

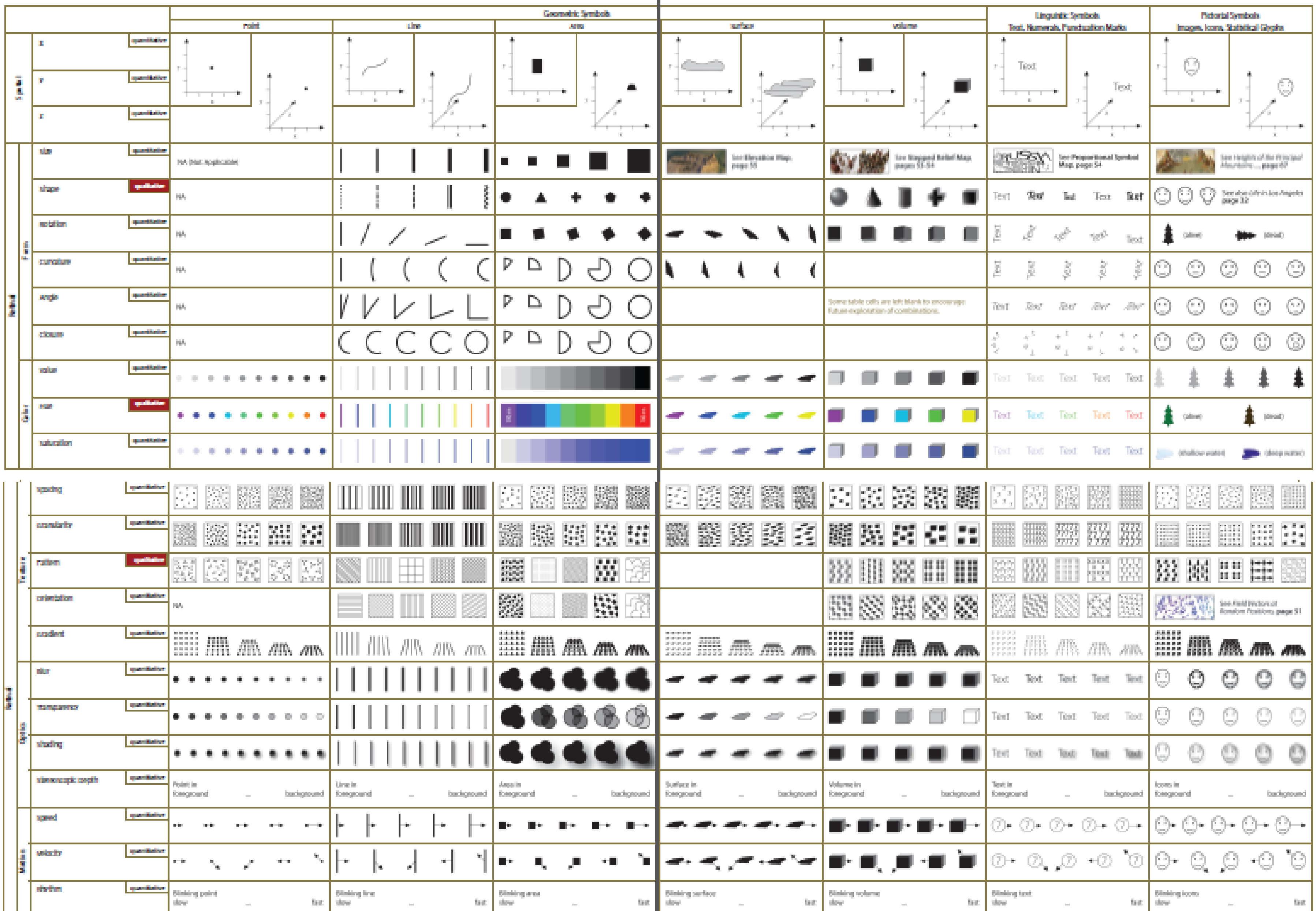


See page 24

Graphic Variable Types Versus Graphic Symbol Types

				Geometric Symbols		
				Point	Line	Area
Spatial		x	quantitative			
Spatial		y	quantitative			
Spatial		z	quantitative			
Retinal	Form	Size	quantitative	NA (Not Applicable)		
Retinal	Form	Shape	qualitative	NA		
Retinal	Form	Rotation	quantitative	NA		
Retinal	Form	Curvature	quantitative	NA		
Retinal	Form	Angle	quantitative	NA		
Retinal	Form	Closure	quantitative	NA		
Retinal	Color	Value	quantitative			
Retinal	Color	Hue	qualitative			380 nm … 780 nm
Retinal	Color	Saturation	quantitative			

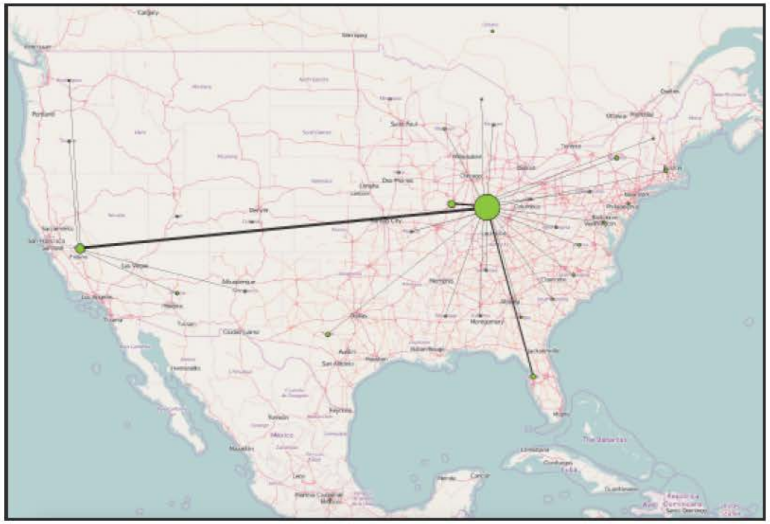
Graphic Variable Types Versus Graphic Symbol Types

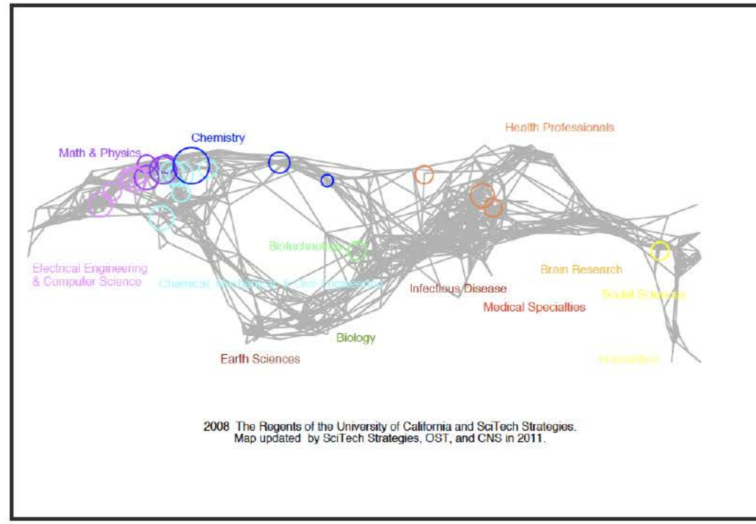


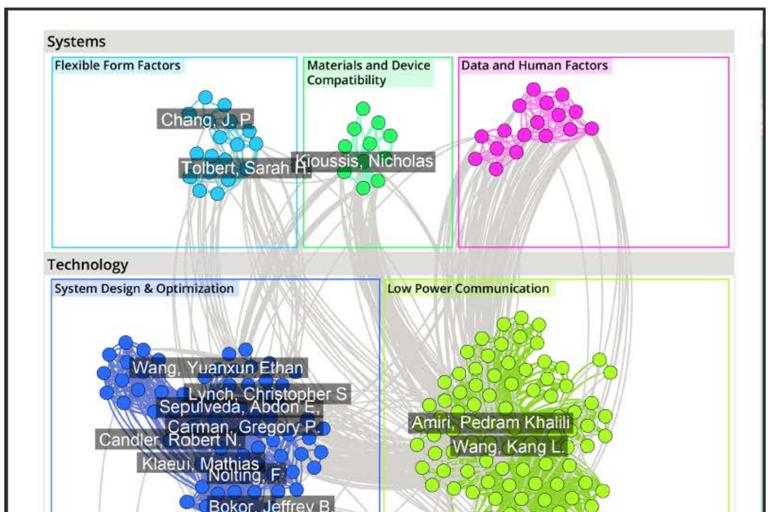
Visualizing Engineering Research Centers

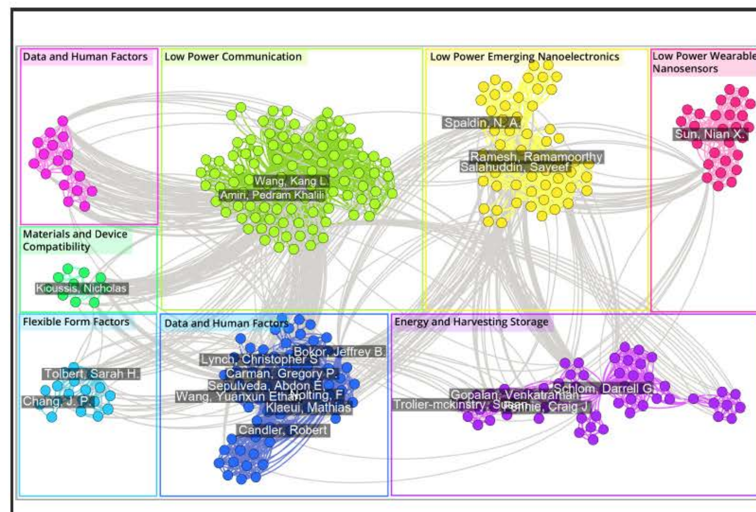
Engineering Research Observatory

CNS Team at ISE, IU and NanoHub team at Purdue U









TANMS Engineering Research Center
Evolving Co-Authorship Network
CNS @ Indiana University
2016

Displayed Year: 2012

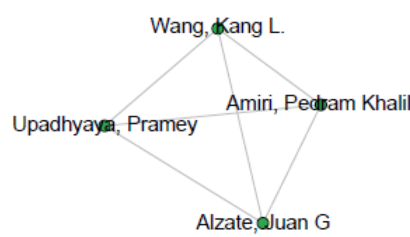
Legend
Nodes ~ Authors
Node area size ~ Number of papers published
Node color ~ Year of first paper

Edges ~ Co-authorship relations
Edge thickness ~ Number of times co-authored

Node Color Code
2012
2013
2014
2015
2016

Node Area Size
47
16
1

Edge Thickness
29
14
1



TANMS Engineering Research Center
Evolving Co-Authorship Network
CNS @ Indiana University
2016

Displayed Year: 2013

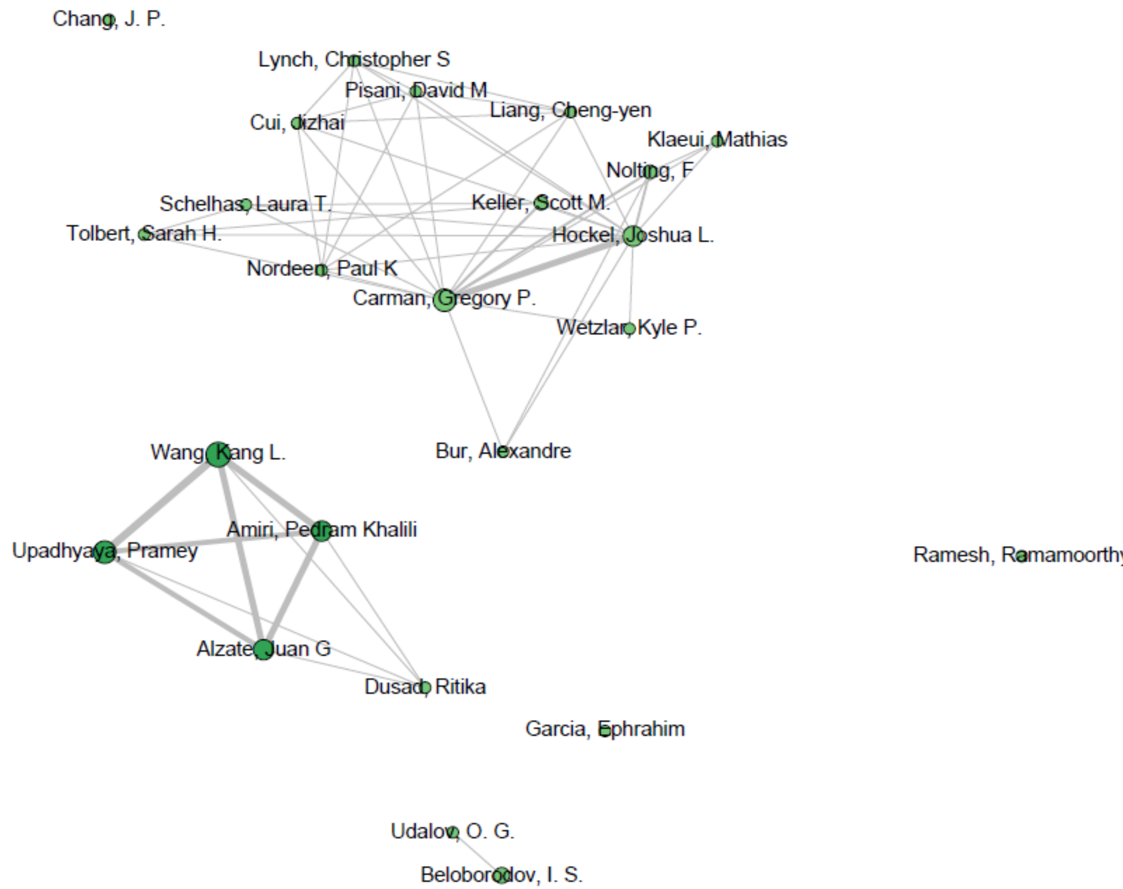
Legend
Nodes ~ Authors
Node area size ~ Number of papers published
Node color ~ Year of first paper

Edges ~ Co-authorship relations
Edge thickness ~ Number of times co-authored

Node Color Code
2012
2013
2014
2015
2016

Node Area Size
47
16
1

Edge Thickness
29
14
1



TANMS Engineering Research Center
Evolving Co-Authorship Network

CNS @ Indiana University
2016

Displayed Year: 2014

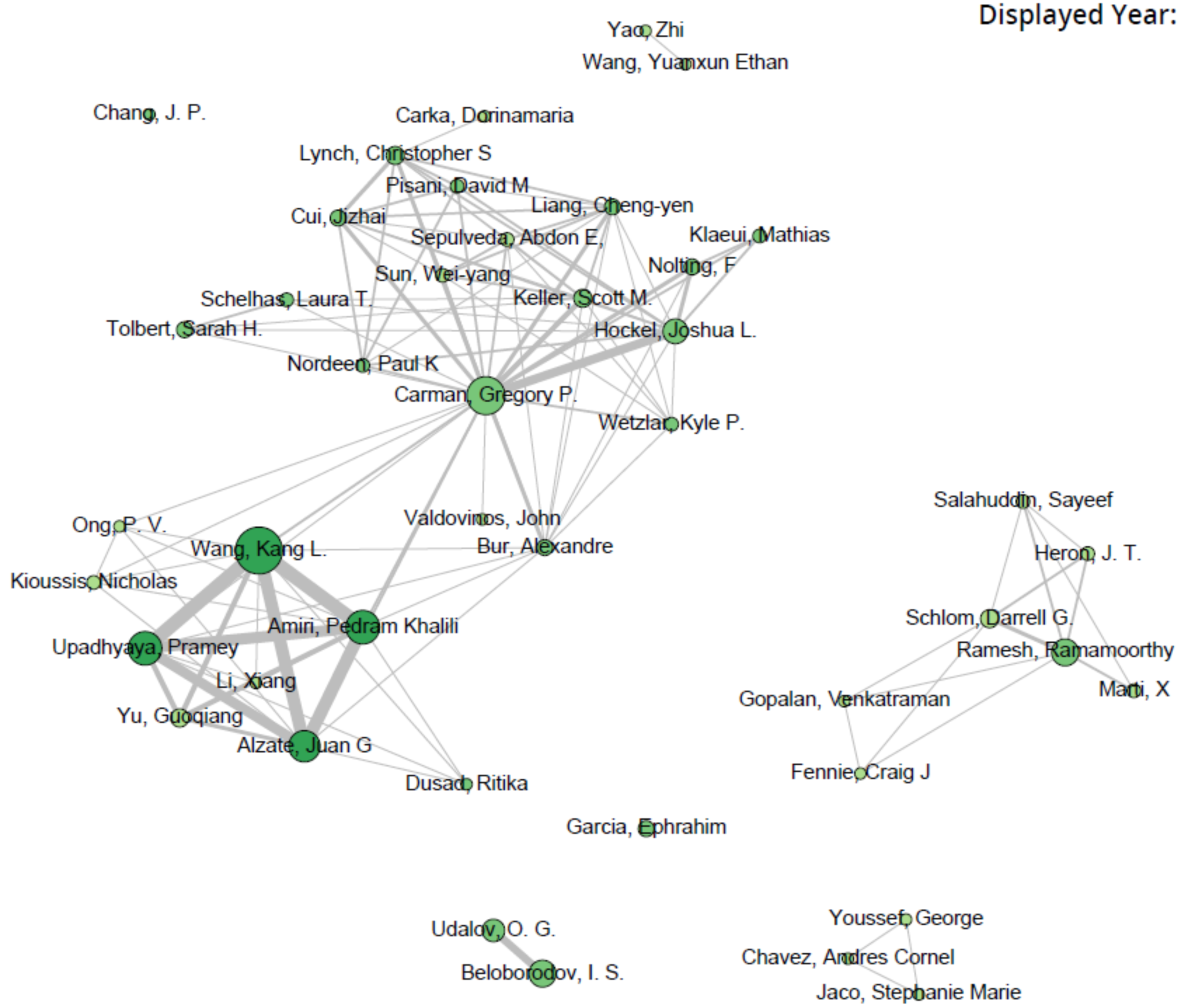
Legend
Nodes ~ Authors
Node area size ~ Number of papers published
Node color ~ Year of first paper

Edges ~ Co-authorship relations
Edge thickness ~ Number of times co-authored

Node Color Code
2012
2013
2014
2015
2016

Node Area Size
47
16
1

Edge Thickness
29
14
1



TANMS Engineering Research Center
Evolving Co-Authorship Network

CNS @ Indiana University
2016

Displayed Year: 2015

Legend

Nodes ~ Authors
Node area size ~ Number of papers published
Node color ~ Year of first paper

Edges ~ Co-authorship relations
Edge thickness ~ Number of times co-authored

Node Color Code

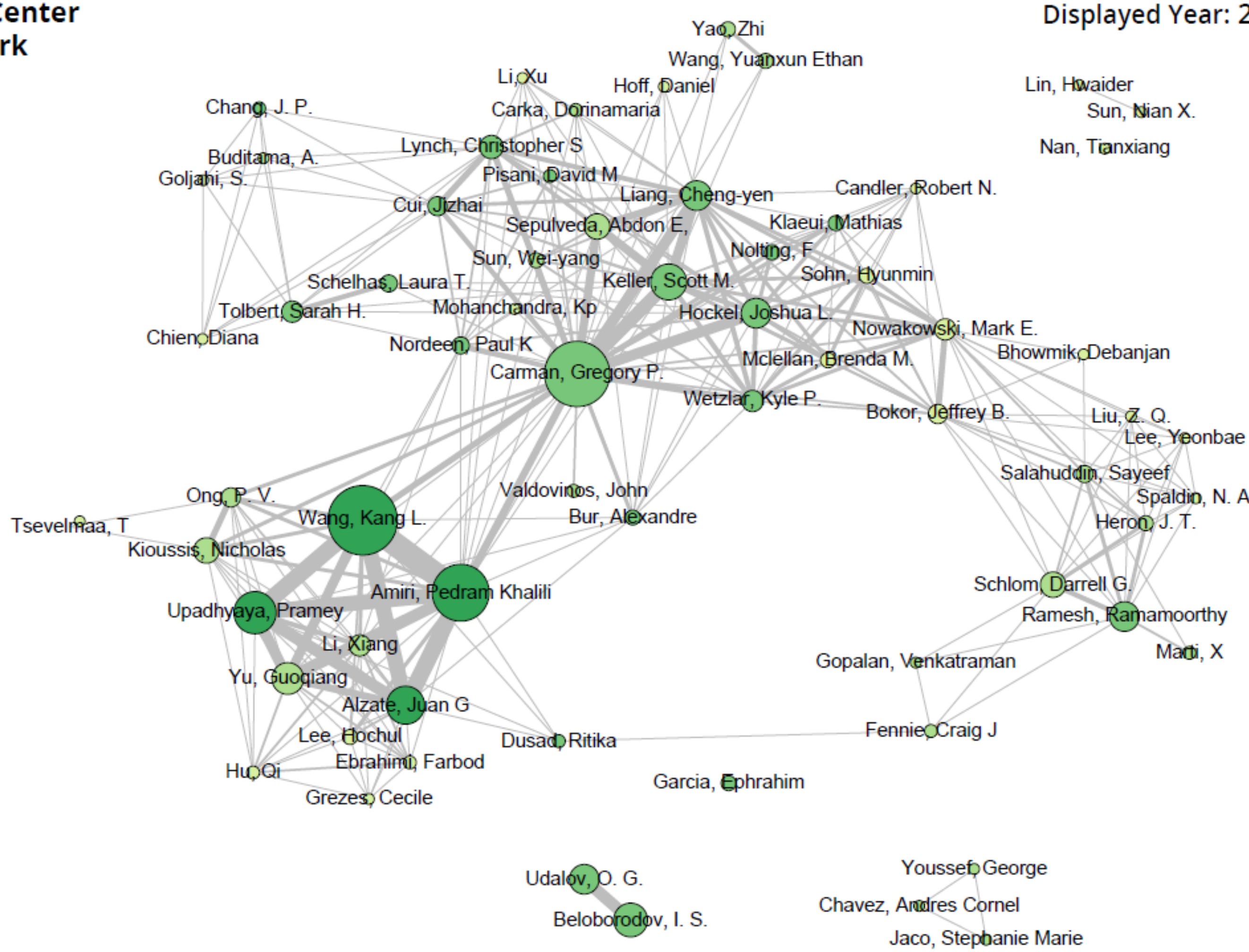
2012
2013
2014
2015
2016

Node Area Size

47
16
1

Edge Thickness

29
14
1



TANMS Engineering Research Center
Evolving Co-Authorship Network
CNS @ Indiana University
2016

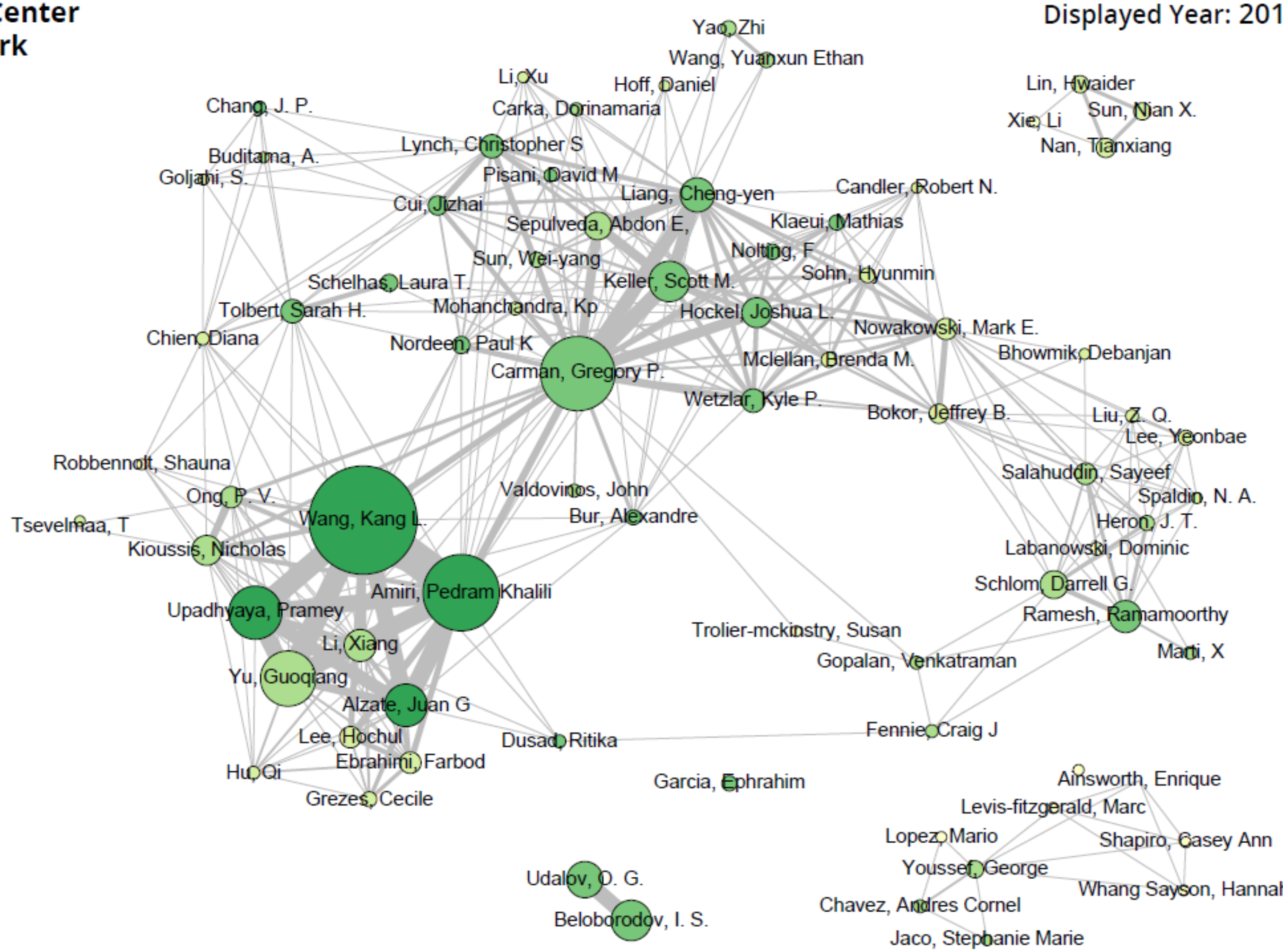
Legend
Nodes ~ Authors
Node area size ~ Number of papers published
Node color ~ Year of first paper

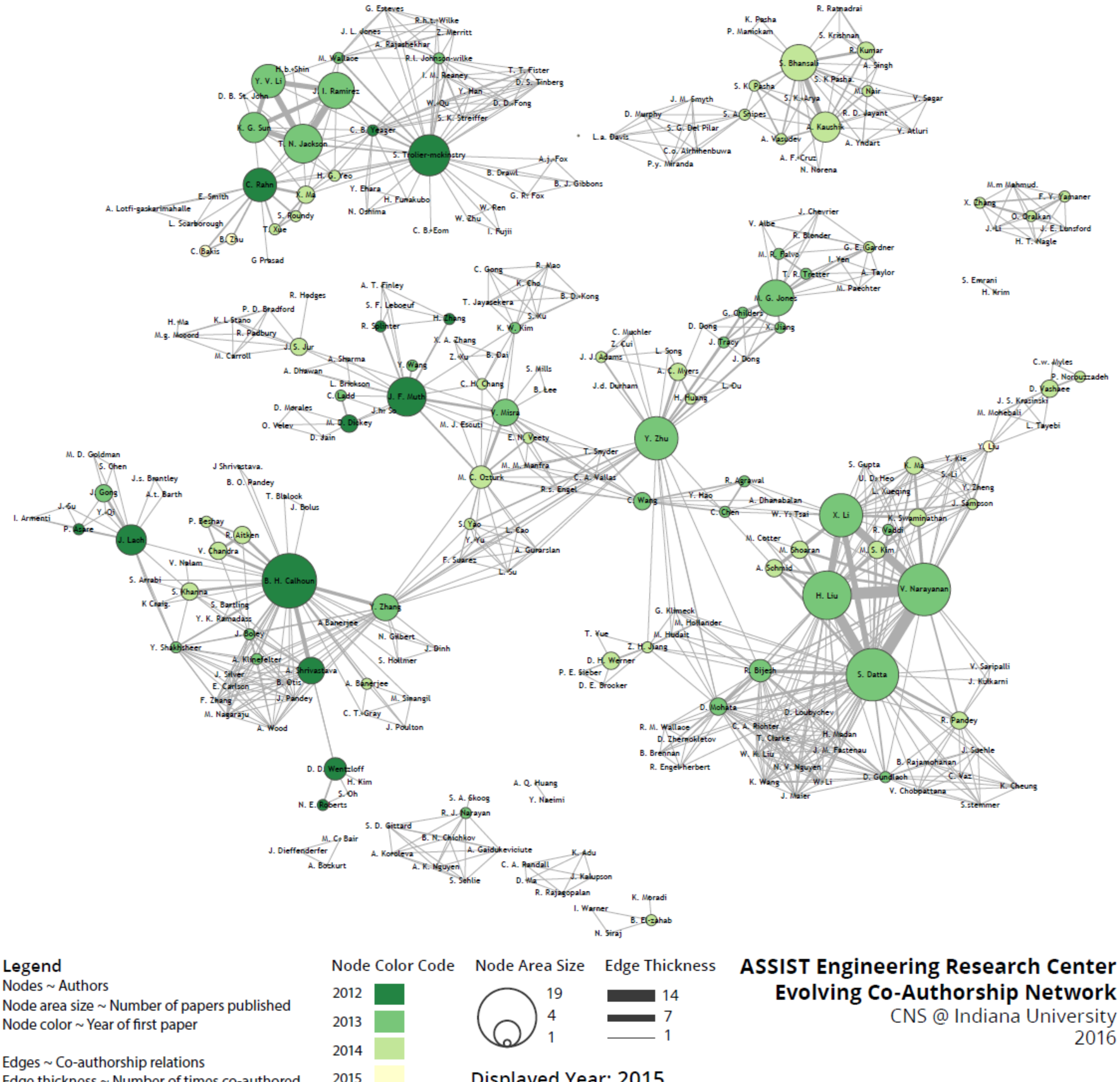
Edges ~ Co-authorship relations
Edge thickness ~ Number of times co-authored

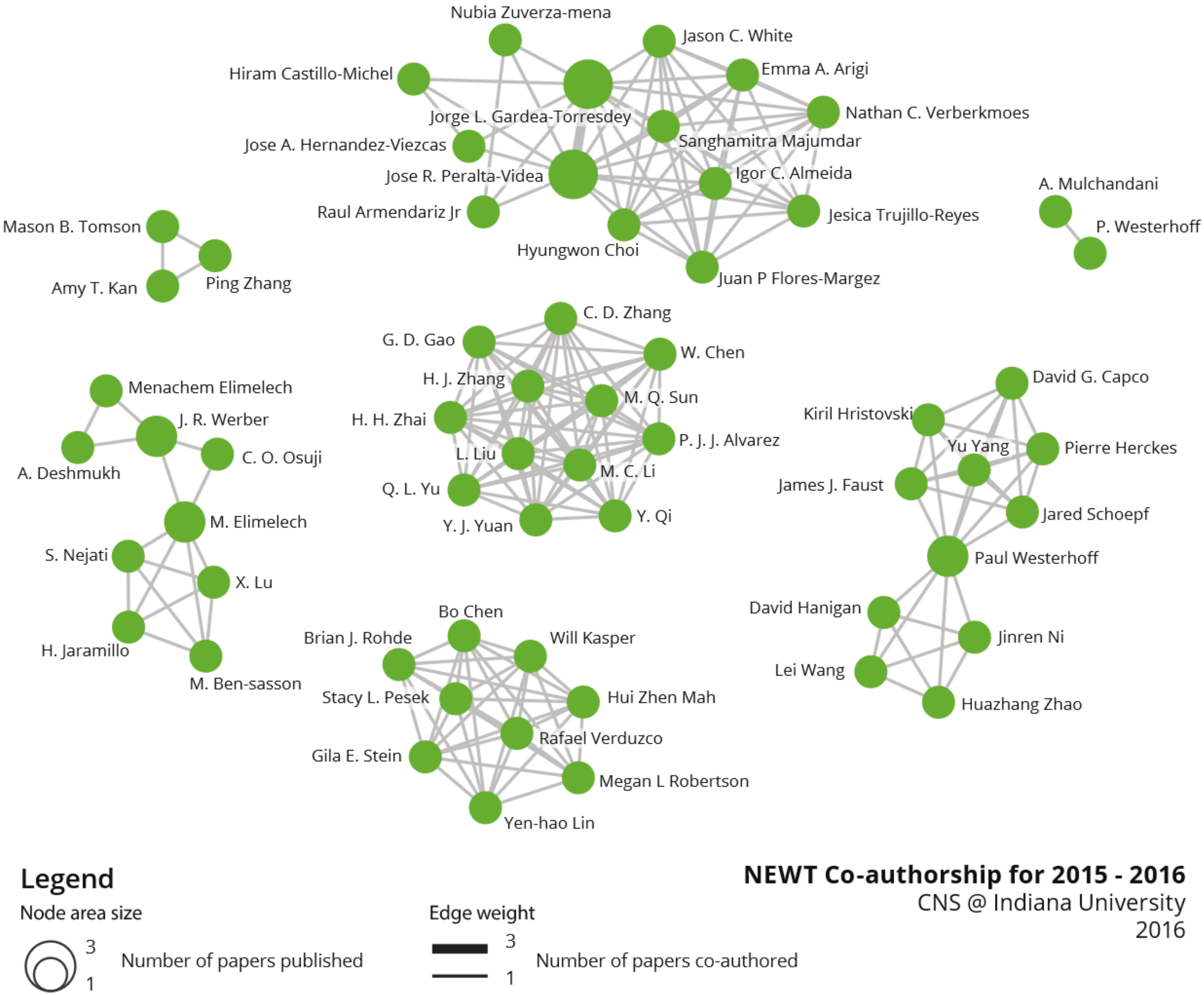
Node Color Code
2012
2013
2014
2015
2016

Node Area Size
47
16
1

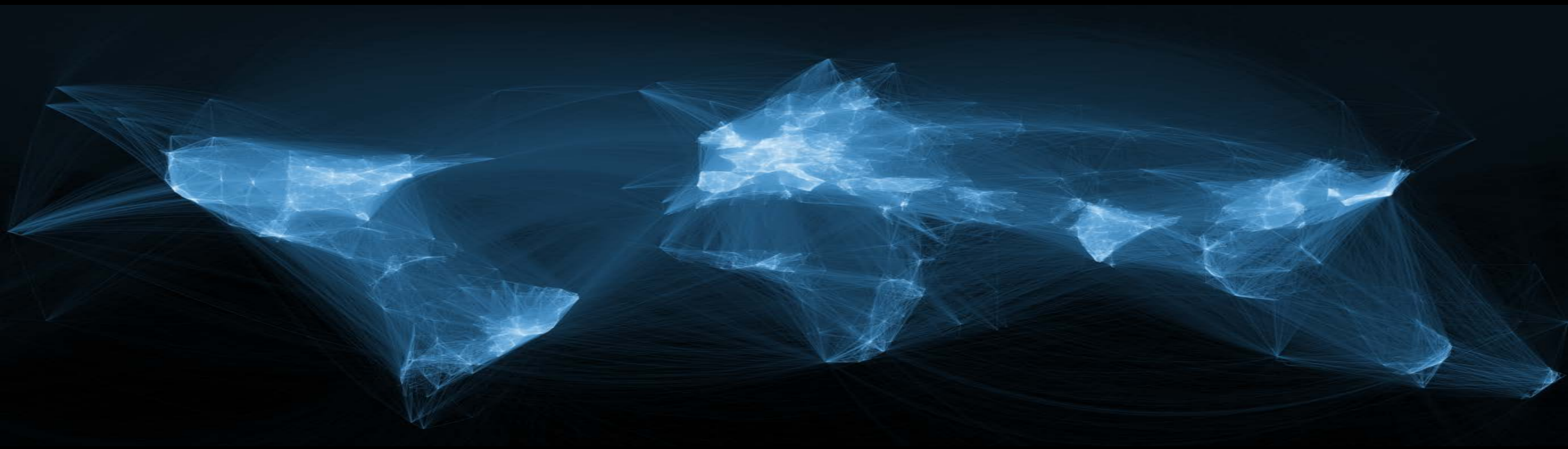
Edge Thickness
29
14
1




Legend
Nodes ~ Authors
Node area size ~ Number of papers published
Node color ~ Year of first paper
Edges ~ Co-authorship relations
Edge thickness ~ Number of times co-authored
Node Color Code
2012
2013
2014
2015
Node Area Size
19
4
1
Edge Thickness
14
7
1
Displayed Year: 2015
ASSIST Engineering Research Center
Evolving Co-Authorship Network
CNS @ Indiana University
2016


Nubia Zuverza-mena
Jason C. White
Hiram Castillo-Michel
Emma A. Arigi
Nathan C. Verberkmoes
Jorge L. Gardea-Torresdey
Jose A. Hernandez-Viezcas
Sanghamitra Majumdar
Jose R. Peralta-Videa
Igor C. Almeida
A. Mulchandani
Raul Armendariz Jr
Jesica Trujillo-Reyes
P. Westerhoff
Mason B. Tomson
Hyungwon Choi
Amy T. Kan
Ping Zhang
Juan P Flores-Margez
C. D. Zhang
G. D. Gao
W. Chen
H. J. Zhang
David G. Capco
Menachem Elimelech
M. Q. Sun
H. H. Zhai
Kiril Hristovski
J. R. Werber
P. J. J. Alvarez
Yu Yang
Pierre Herckes
L. Liu
A. Deshmukh
C. O. Osuji
M. C. Li
James J. Faust
Q. L. Yu
Jared Schoepf
Y. Qi
Y. J. Yuan
M. Elimelech
Paul Westerhoff
S. Nejati
X. Lu
David Hanigan
Bo Chen
Jinren Ni
Brian J. Rohde
Will Kasper
H. Jaramillo
Lei Wang
M. Ben-sasson
Stacy L. Pesek
Hui Zhen Mah
Huazhang Zhao
Rafael Verduzco
Gila E. Stein
Megan L Robertson
Yen-hao Lin
Legend
Node area size
3
1
Number of papers published
Edge weight
3
1
Number of papers co-authored
NEWT Co-authorship for 2015 - 2016
CNS @ Indiana University
2016

Modelling S&T Developments



NSF
NETE FEDERAL IT
THOMSON REUTERS
IUNI INDIANA UNIVERSITY NETWORK SCIENCE INSTITUTE

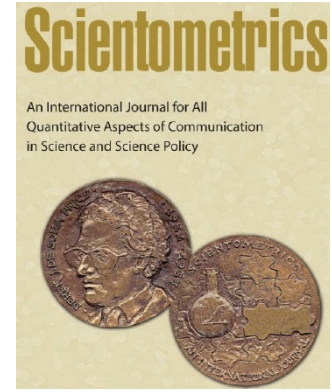
Government, academic, and industry leaders discussed challenges and opportunities associated with using big data, visual analytics, and computational models in STI decision-making.

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

Special Issue of *Scientometrics*:

Simulating the Processes of Science, Technology, and Innovation

Bruce Edmonds, Andrea Scharnhorst, Katy Börner & Staša Milojević (Editors)



- ***Rogier De Langhe:*** Towards the Discovery of Scientific Revolutions in Scientometric Data
- ***Sabine Brunswicker, Sorin Matei, Michael Zentner, Lynn Zentner and Gerhard Klimeck:*** Creating Impact in the Digital Space: Digital Practice Dependency in Scientific Developer Communities
- ***Johan Bollen et al.:*** An Efficient System to Fund Science: From Proposal Review to Peer-to-Peer Distributions
- ***Petra Ahrweiler:*** Agent-based Simulation for Science, Technology and Innovation Policy
- ***David Chavalarias:*** What's Wrong With Science? Modeling Collective Discovery Processes With the Nobel Game
- ***Jeff Alstott, Giorgio Triulzi, Bowen Yan and Jianxi Luo:*** Mapping Technology Space by Normalizing Patent Technology Networks

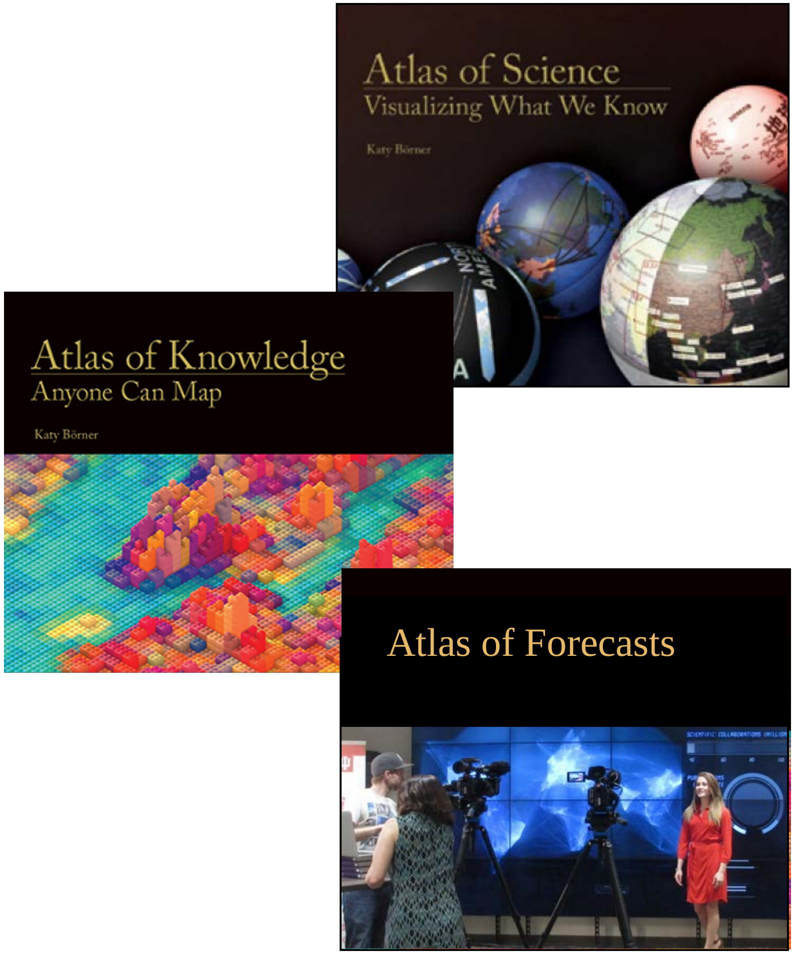
Atlas Trilogy

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

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

Börner, Katy (2020) **Atlas of Forecasts: Predicting and Broadcasting Science, Technology, and Innovation**. The MIT Press.

Upcoming Sackler Colloquium on "**Modelling and Visualizing Science and Technology Developments**" will take place in December 2017 at the Beckman Center, Irvine, CA.



Communicating S&T Development to Different Audiences

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

Curated by the Cyberinfrastructure for Network Science Center

search scimaps.org Search

About | People | Maps & More | Exhibitions | Hosting | Publications | Store | News | Contact

Hidalgo, César A., Bailey Klinger, 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 (2017) http://scimaps.org/call

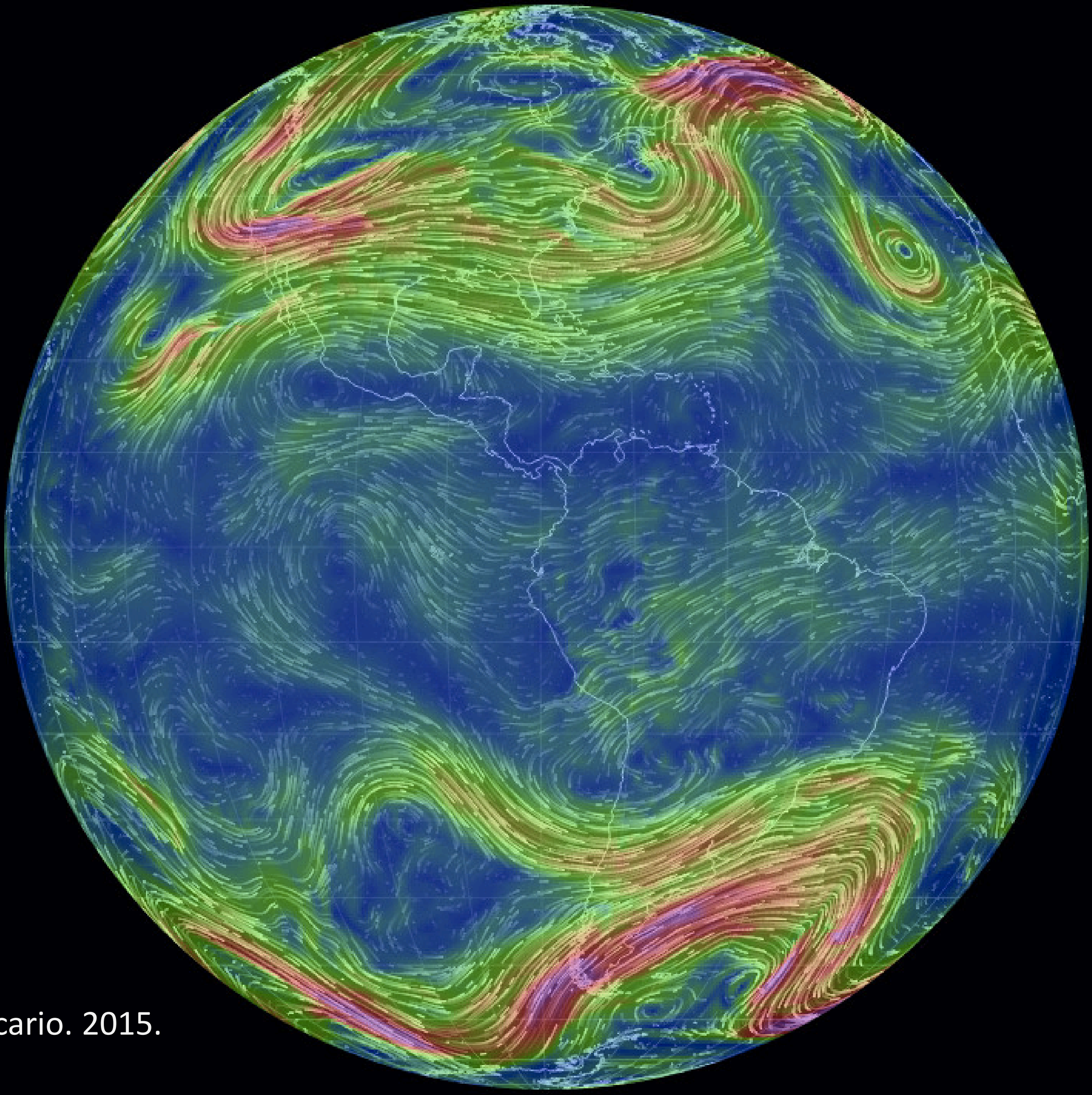
Background and Goals

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 t

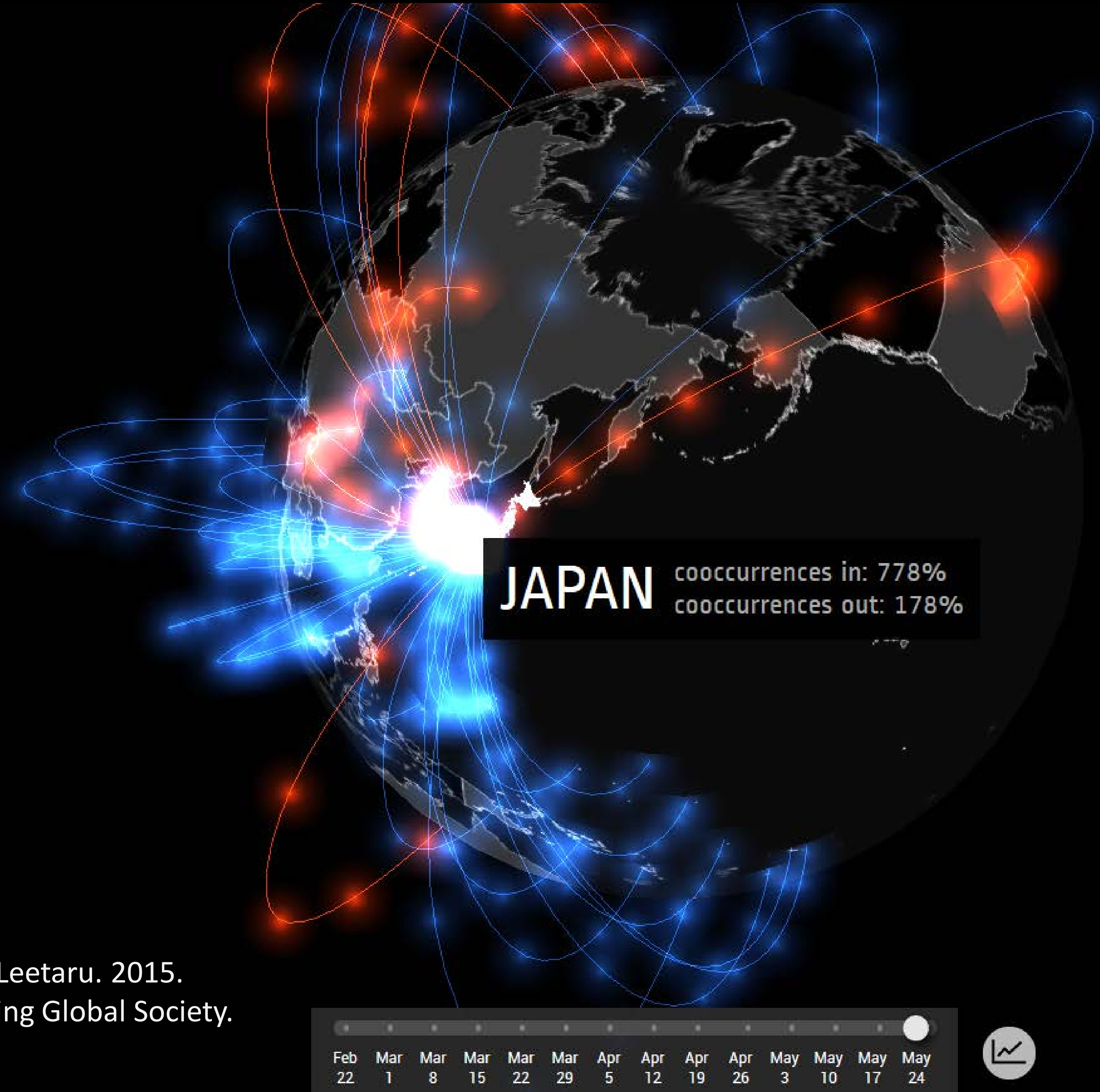
Themes for the upcoming iterations/years are:

- 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

http://scimaps.org/iteration/11



Cameron Beccario. 2015.
Earth.



Kalev Leetaru. 2015.
Mapping Global Society.

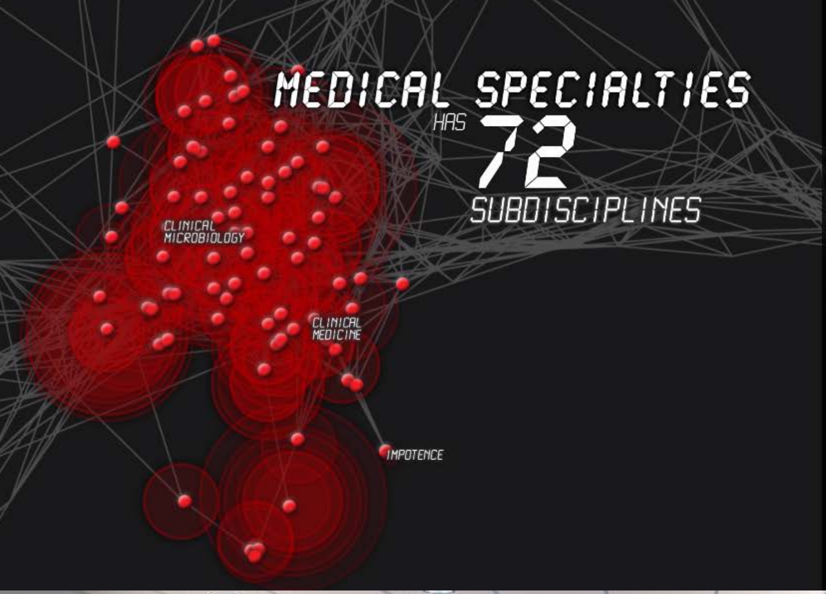
Places & Spaces Exhibit at the David J. Sencer CDC Museum, Atlanta, GA
January 25-June 17, 2016

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

Maps of Health Exhibit
David J. Sencer CDC Museum
Atlanta, GA

Jan 25-Jun 17, 2016

Science Forecast
S1:E1, 2015



Dr. Johan Bollen

Science Forecast
S1:E2, 2016

Dr. Rob Porter

Science Forecast
S1:E3, 2016

Dr. Bernice Pescosolido

All papers, maps, tools, talks, press are linked from http://cns.iu.edu

These slides are at http://cns.iu.edu/presentations

CNS Facebook: http://www.facebook.com/cnscenter

Mapping Science Exhibit Facebook: http://www.facebook.com/mappingscience