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Engineering Research Center Observatory Visualizations

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Joint work with Gerhard Klimeck, Michael Zentner, Steven Snyder at Purdue University

Cyberinfrastructure for Network Science Center
Department of Intelligent Systems Engineering & Department of Information and Library Science
School of Informatics, Computing, and Engineering | IU Network Science Institute
Indiana University, Bloomington, USA

Virtual Presentation to HUBzero community

March 28, 2018

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- Dec 09, 2015: Gerhard Klimeck, Michael Zentner, and Katy Börner present *Engineering Research Center Observatory* at Engineering Research Center Observatory Kick-Off Meeting, Washington, DC.
- Dec 12, 2016: Katy Börner presents *Visualizing Nanoscience and Technology* at 2016 NSF Nanoscale Science and Engineering Grantees Conference, Arlington, VA.
- June 1, 2016: Katy Börner presents *Engineering Research Center Observatory Visualizations* at Virtual Presentation to NSF EEC Staff, Bloomington, IN.
- Börner, Katy, and Steve Snyder, Gagandeep Singh, Sara Bouchard, Adam Simpson, Gerhard Klimeck, Michael Zentner, and Steve Snyder. 2017. "Engineering Research Center Observatory". Poster at *ERC Biennial Conference*.

Engineering Research Center Observatory

Indiana University: Katy Börner, Gagandeep Singh, Sara E. Bouchard, Adam H. Simpson, Scott C. Hutcheson
Purdue University: Gerhard Klimeck, Michael Zentner, Steve Snyder

Goal: Develop and deploy interactive data visualizations for NSF staff, researchers, and students to increase their understanding of temporal, geospatial, topical, and network patterns and trends in engineering.

http://cns.iu.edu/docs/publications/2017-hutcheson-erc.pdf

BibTeX Data Upload & Curation

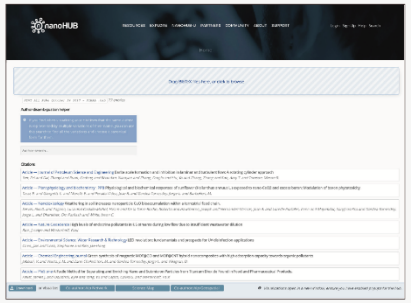
Importing data
BibTeX (.bib) file format is supported.
Upload files via drag and drop into the indicated area at the top of the page, or click and browse files. You may add multiple files.

Data Curation
Interface allows the user to clean and correct data in their publication BibTeX file.

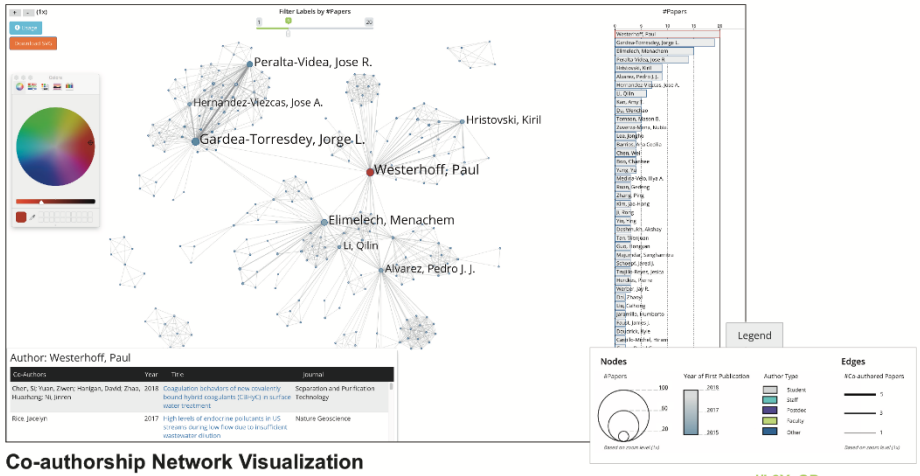
Author Disambiguation
The same author may be represented by multiple variations, this feature allows the user to find all variations and combine all to the preferred name.

Editing Citations
- Role: Allows the user to select an author role (student, faculty, post-doc, staff, other).
- Gender: User has the option to select either unreported, female, or male.
- Geolocation: Location field accepts several types of input including city names and zip codes. After entering the information, the field will turn green if the information was found.

Exporting and Visualizing
- Download allows user to save their BibTeX file after making edits.
- Visualization buttons open a new tab for each visualization.



nanohub.org/erc-citations

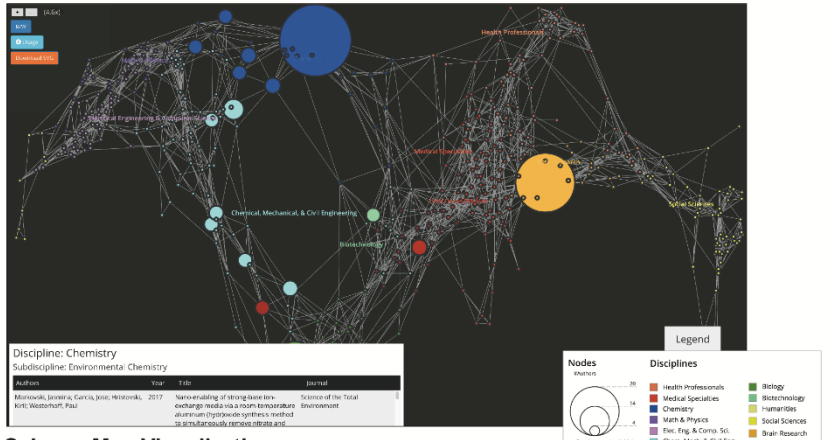


Co-authorship Network Visualization

This interactive visualization shows the collaboration network based on co-authorship relations extracted from the bibtex file. It helps identify clusters of authors that collaborate frequently; to detect those authors that serve as gatekeepers by interconnecting different clusters; understand the backbone of strong co-author linkages that likely serve as main collaboration and knowledge diffusion pathways.

- Each node represents an author.
- Two authors are connected if they have authored a paper together.
- Fill color denotes the year of first publication.
- Node outline color indicates author type (student, faculty, post-doc, staff, other)
- Node size and label size denote the number of papers authored.
- Edge thickness denotes the number of times two authors appeared on a paper together.
- The horizontal bar graph on the right shows the number of papers per author.
- Clicking on a node in the network highlights publications by that author.
- Clicking on an author node in the network or in the bar-graph brings up a listing of publications by that author.
- Click on usage button in top left to learn how to color code nodes, etc.
- The legend details how the information is being encode

goo.gl/k8YvGD

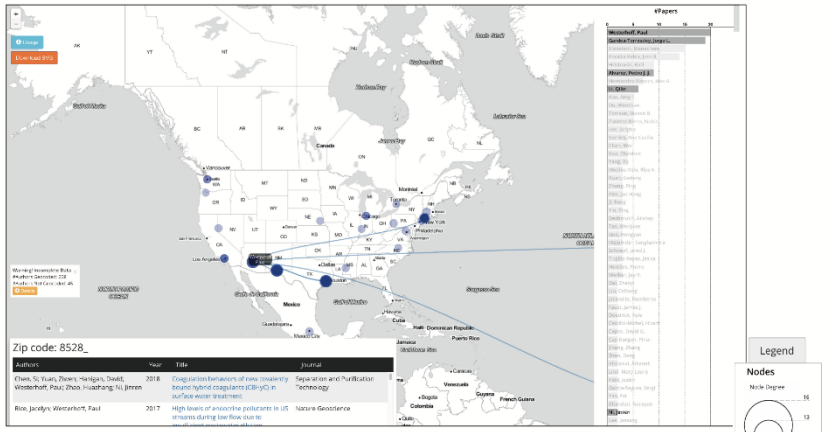


Science Map Visualization

This interactive map supports the exploration of expertise profiles for a researcher, center, department, or university overlaid on a science map so that outliers, clusters, and trends can be discerned.

- 554 subdisciplines of science are shown, aggregated into 13 color-coded, labelled disciplines.
- Each circle denotes a subdiscipline.
- Circle area sizes are proportional to the number of papers published per subdiscipline.
- Clicking on a subdiscipline brings up a panel in lower-left with a listing of papers in that subdiscipline.
- The legend details how the information is being encoded.

goo.gl/ZshV4a



Co-authorship Geospatial Visualization

This interactive visualization shows the co-authorship network overlaid on a geospatial map of the world.

- Each node represents an author.
- Two authors are connected if they have authored a paper together.
- Circle area sizes encode the number of links per node, also called node degree.
- Horizontal bar-graph aids in better understanding of data.
- Clicking on a node highlights the co-authors in the bar graph.
- The legend details how the information being encoded.

goo.gl/nd1ojc

Acknowledgements

This work is funded by NSF via a supplement to Network for Computational Nanotechnology - Cyber Platform - Engineering Research Center Observatory. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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Goal, Use Cases, Users, Data, Visualizations

Engineering Observatory: Goal

Facilitate near real-time monitoring of Engineering Research Centers (ERCs) in support of better-informed resource allocation, priority setting, and evaluation.

Data mining and visualization web services will be provided for different stakeholders (NSF staff, researchers, students) to increase their understanding of temporal, geospatial, topical, and network patterns and trends in engineering.

This collaborative work with the nanoHUB team at Purdue University is funded by NSF, Dec 15 – Nov 17.

Engineering Observatory: Use Cases

Use Cases:

- Day-to-day operations
- Strategic decision making
- Prepare for site visits

Initial Power Users:

- Mehmet Ozturk, Nanosystems ERC for Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST)
- Paul Westerhoff, Nanotechnology Enabled Water Treatment Systems (NEWT)
- Greg Carman, Nanosystems ERC for Translational Applications of Nanoscale Multiferroic Systems (TANMS)

Engineering Observatory: Data & Visualizations

Data

- nanoHUB data + bibliography files

Visualizations

- Evolving collaboration networks obtained from bibliography files, network layout or overlaid on geographic map
- Evolving expertise profiles; overlaid onto the UCSD map of science

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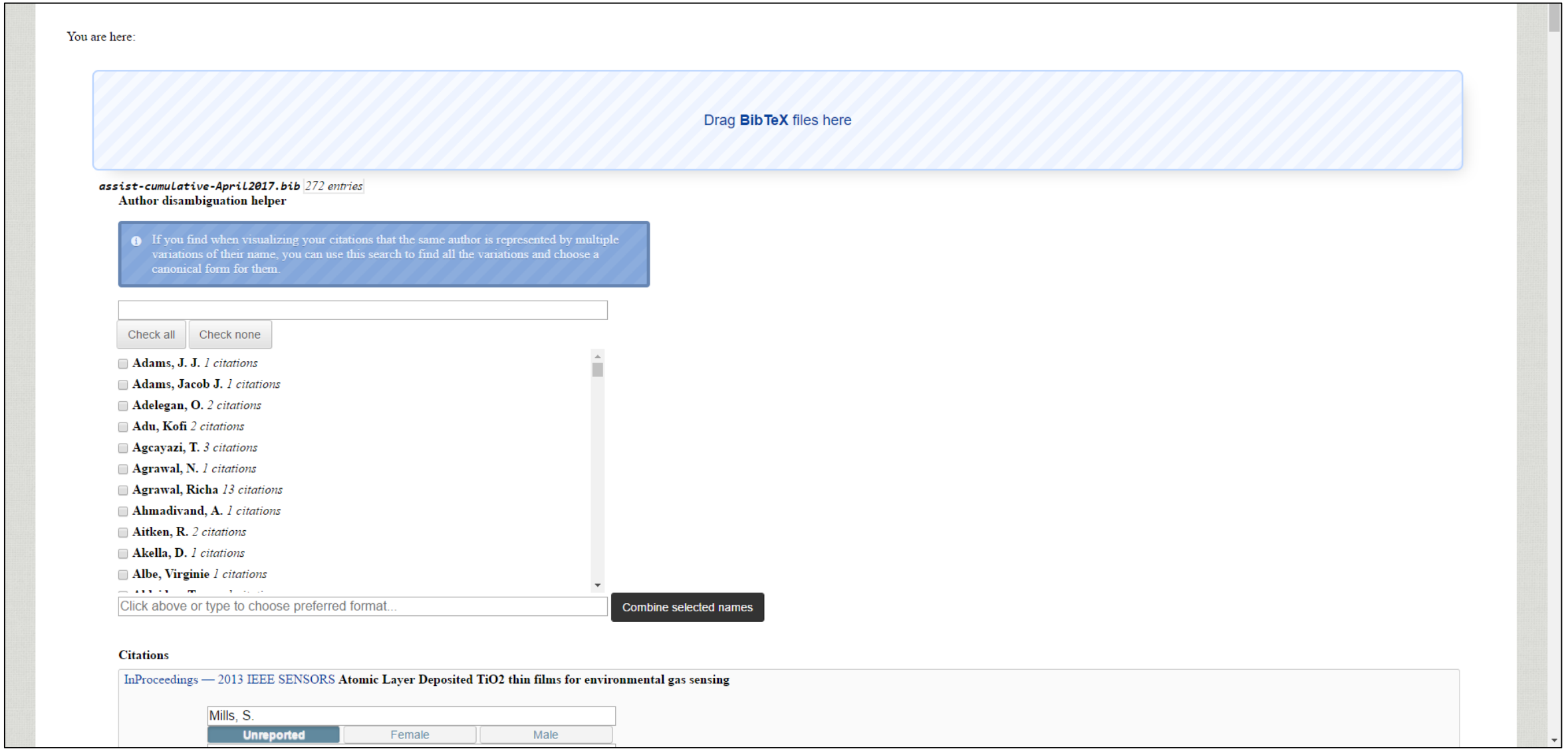
Interactive Data Visualizations

Importing Data

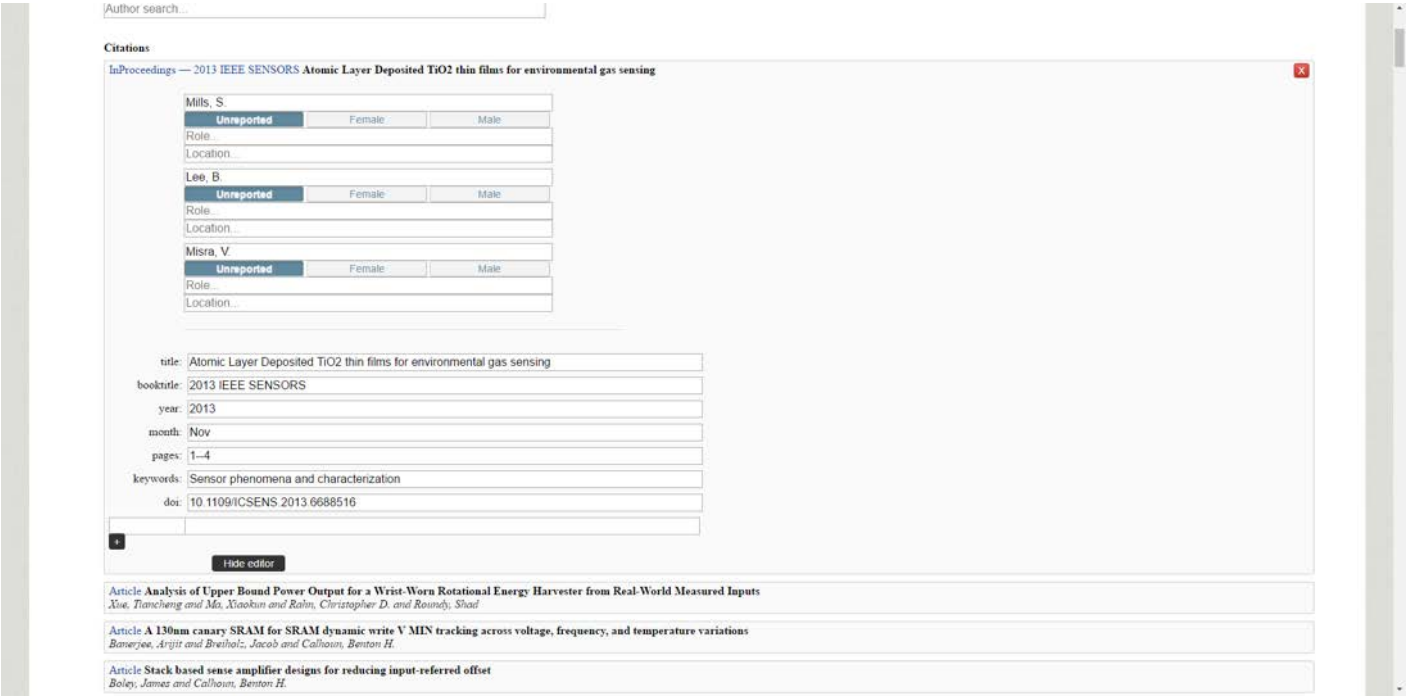


https://nanohub.org/erc-citations

Curating Data

After the file is loaded, brief summaries will be shown for each entry. You may click any entry to expand it and give a full, editable view of the properties of that entry

Here, one should make sure that fields that are pertinent to the visualizations being performed are correct and consistent across entries.



Name disambiguation: If the same author is represented by multiple variations of their name in the visualization, use the “Author Search” feature to find all variations and choose a canonical form for them.

Sex: User is provided the choice to select either Female, Male, or Unreported.

Role: User is able to select the role of each author, e.g., Student, Staff, Postdoc.

Geolocation: The location field accepts several types of input including city names and zip codes. After entering that information, either press ‘Enter’ or move on to the next field and in a few seconds the field will reflect whether geocoding information was found, turning green for success and red for failure.

Downloading and Visualizing Data

At the end of the page there are buttons to download changes as BibTeX or to launch a number of visualizations that highlight different aspects of the data.

Article — European Physical Journal-Special Topics **Theoretical and technological building blocks for an innovation accelerator**
van Harmelen, F. and Kampis, G. and Borner, Katy and van den Besselaar, P. and Schultes, E. and Goble, C. and Groth, P. and Mons, B. and Anderson, S. and Decker, S. and Hayes, C. and Buecheler, T. and Helbing, D.

Article — Journal of Informetrics **Approaches to understanding and measuring interdisciplinary scientific research (IDR): A review of the literature**
Wagner, C. S. and Roessner, J. D. and Bobb, K. and Klein, J. T. and Boyack, K. W. and Keyton, J. and Rafols, I. and Borner, Katy

Article — Scientometrics **Mapping interactions within the evolving science of science and innovation policy community**
Zoss, A. M. and Borner, Katy

Download BibTeX

Visualize 29 journals using map of science

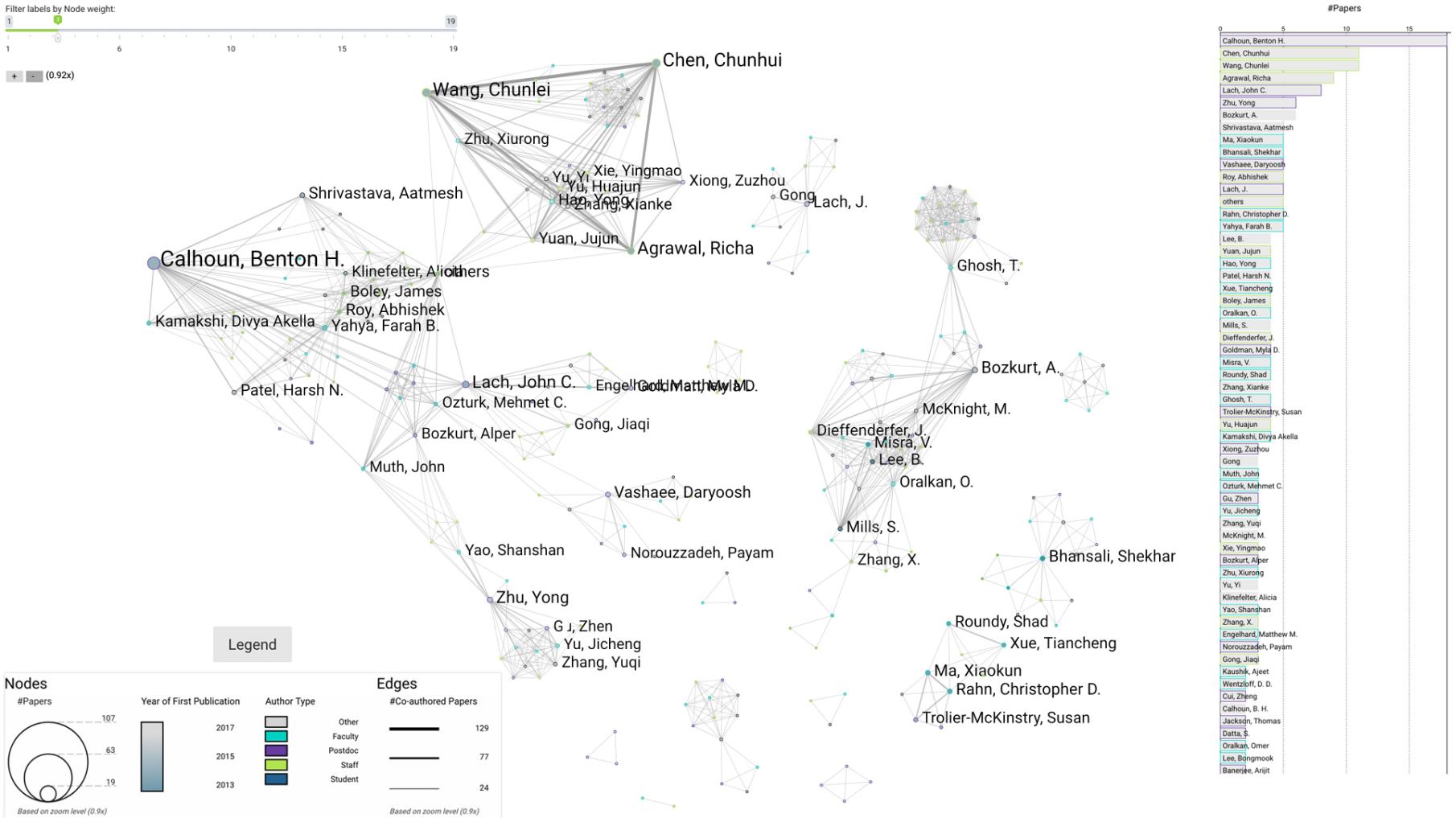
Visualize author geolocation network

Visualize co-authorship network

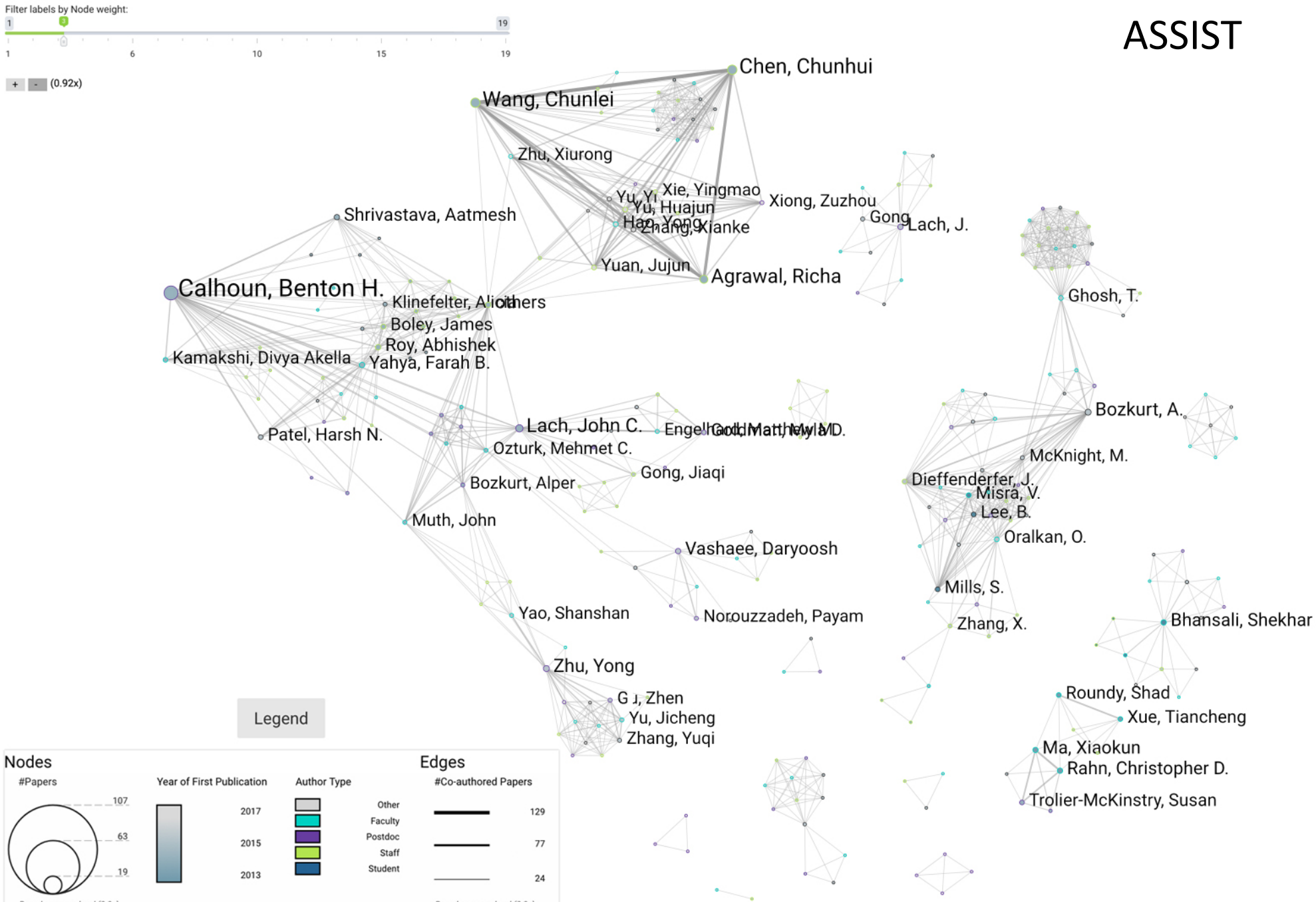
Visualizations open in a new window, ensure you have enabled popups for the hub.

Co-Author Visualization – Network Layout

Each node in the figure represents an author, and author node area size scales with the number of publications. Author nodes with three publications or more are labelled by the author's name. Two authors are connected if they have authored a publication together and link width scales with the number of joint publications between those authors.



ASSIST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19
1
6
10
15
19
+
-
(0.92x)
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Wang, Chunlei
Zhu, Xiurong
Xie, Yingmao
Yu, Yi
Yu, Huajun
Hao, Yong
Zhang, Xianke
Xiong, Zuzhou
Gong
Lach, J.
Shrivastava, Aatmesh
Yuan, Jujun
Agrawal, Richa
Calhoun, Benton H.
Klinefelter, Alicia
others
Boley, James
Roy, Abhishek
Kamakshi, Divya Akella
Yahya, Farah B.
Patel, Harsh N.
Lach, John C.
Engelhard, Matthew M.
Goldman, Myla D.
Ozturk, Mehmet C.
Gong, Jiaqi
Bozkurt, Alper
Muth, John
Vashaee, Daryoosh
Yao, Shanshan
Norouzzadeh, Payam
Zhu, Yong
Gu, Zhen
Yu, Jicheng
Zhang, Yuqi
Ghosh, T.
Bozkurt, A.
McKnight, M.
Dieffenderfer, J.
Misra, V.
Lee, B.
Oralkan, O.
Mills, S.
Zhang, X.
Bhansali, Shekhar
Roundy, Shad
Xue, Tiancheng
Ma, Xiaokun
Rahn, Christopher D.
Trolier-McKinstry, Susan
Legend
Nodes
#Papers
107
63
19
Based on zoom level (0.9x)
Year of First Publication
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2015
2013
Author Type
Other
Faculty
Postdoc
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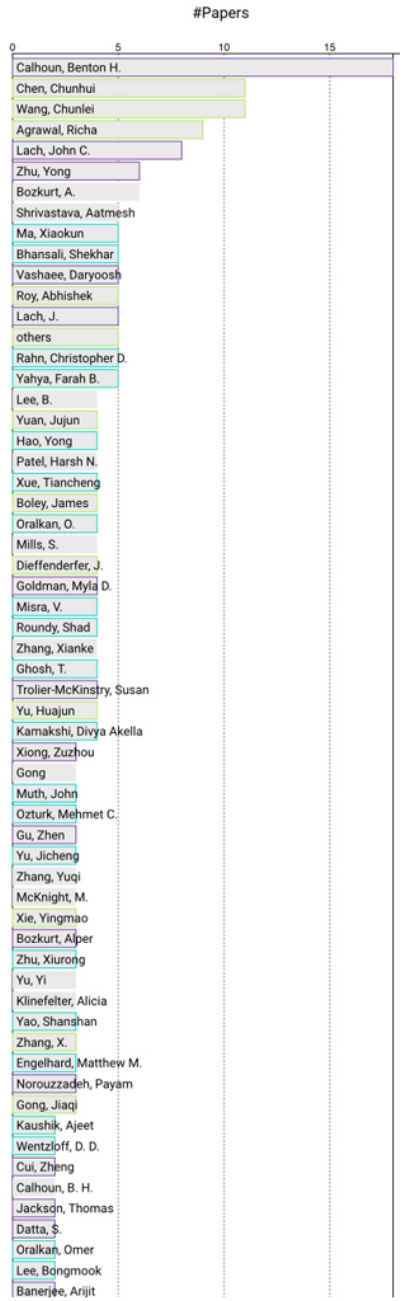
Student
Edges
#Co-authored Papers
129
77
24
Based on zoom level (0.9x)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Gong, Jiaqi
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Wentzloff, D. D.
Cui, Zheng
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Datta, S.
Oralkan, Omer
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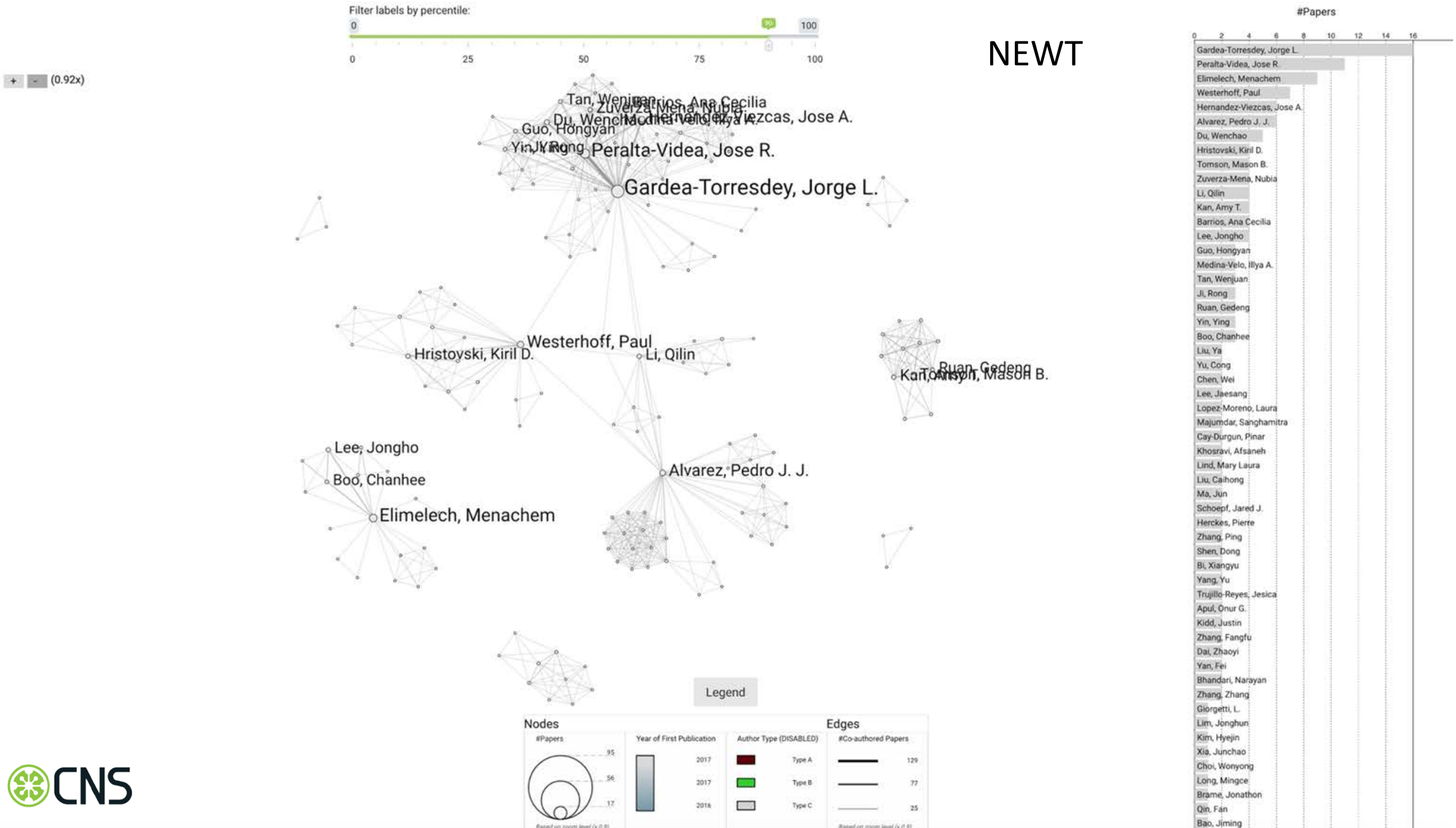
Banerjee, Arijit

NEWT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Du, Wenchao
Hernandez-Viezcas, Jose A.
Guo, Hongyan
Yin, Ying
Ji, Rong
Peralta-Videa, Jose R.
Gardea-Torresdey, Jorge L.
Westerhoff, Paul
Hristovski, Kiril D.
Li, Qilin
Ruan, Gedeng
Kan, Amy T.
Tomson, Mason B.
Lee, Jongho
Boo, Chanhee
Elimelech, Menachem
Alvarez, Pedro J. J.
Legend
Nodes
Edges
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Year of First Publication
2017
2017
2016
Author Type (DISABLED)
Type A
Type B
Type C
#Co-authored Papers
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Hernandez-Viezcas, Jose A.
Alvarez, Pedro J. J.
Du, Wenchao
Hristovski, Kiril D.
Tomson, Mason B.
Zuverza-Mena, Nubia
Li, Qilin
Kan, Amy T.
Barrios, Ana Cecilia
Lee, Jongho
Guo, Hongyan
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Ji, Rong
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Yu, Cong
Chen, Wei
Lee, Jaesang
Lopez-Moreno, Laura
Majumdar, Sanghamitra
Cay-Durgun, Pinar
Khosravi, Afsaneh
Lind, Mary Laura
Liu, Caihong
Ma, Jun
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Herckes, Pierre
Zhang, Ping
Shen, Dong
Bi, Xiangyu
Yang, Yu
Trujillo-Reyes, Jesica
Apul, Onur G.
Kidd, Justin
Zhang, Fangfu
Dai, Zhaoyi
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Bhandari, Narayan
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Giorgetti, L.
Lim, Jonghun
Kim, Hyejin
Xia, Junchao
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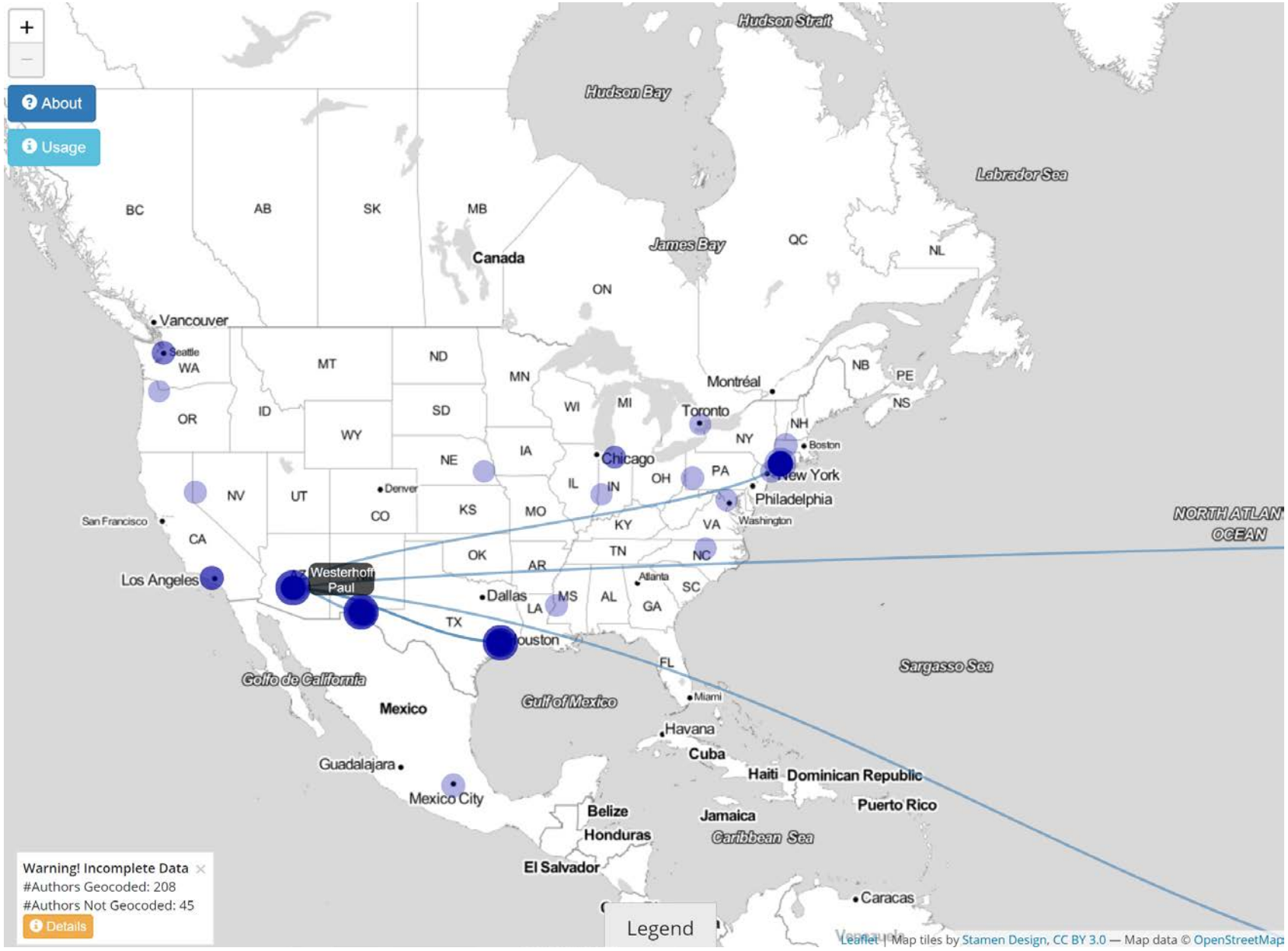
Qin, Fan
Bao, Jiming

CNS

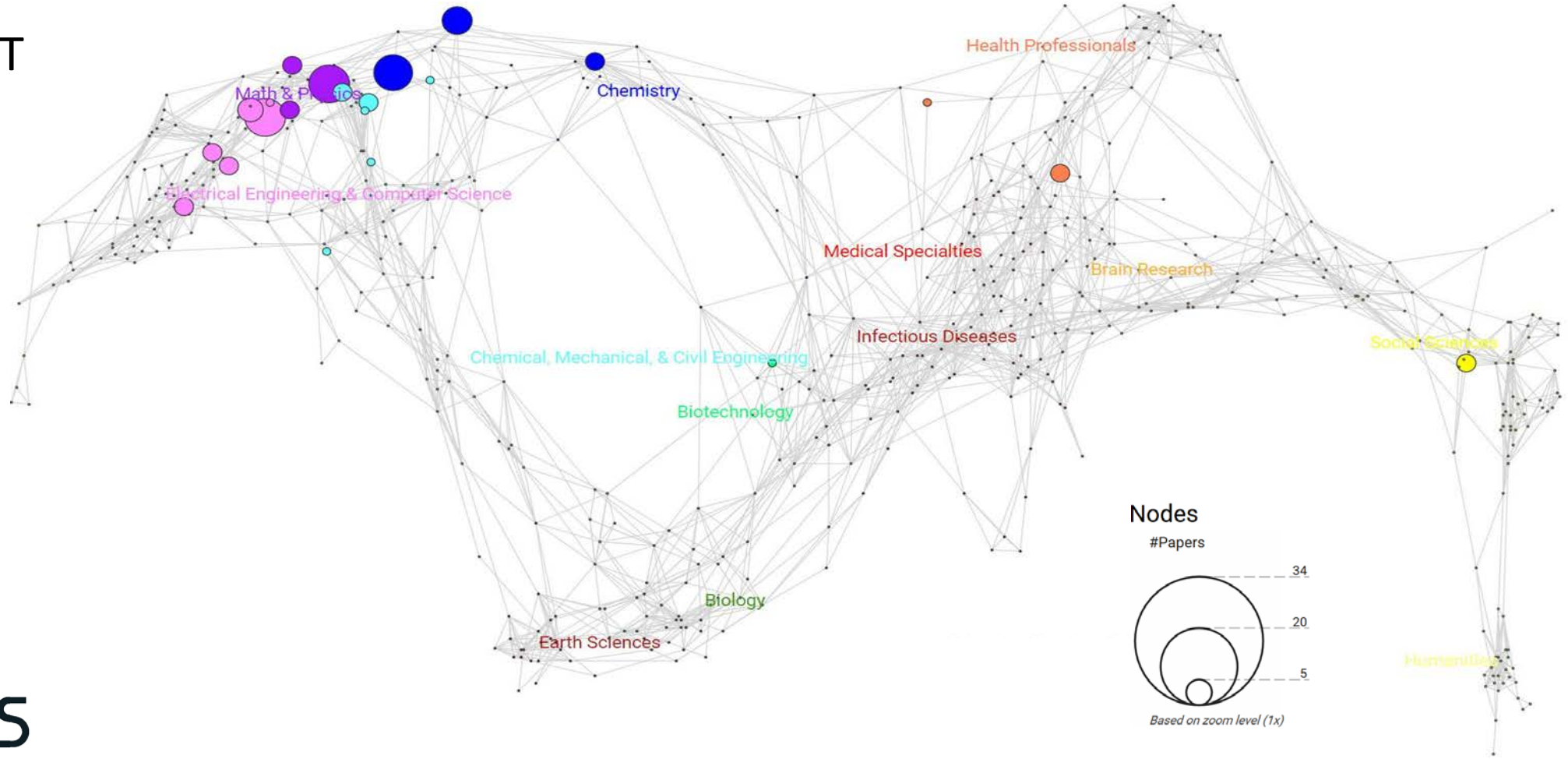
Co-Author Visualization – Geomap



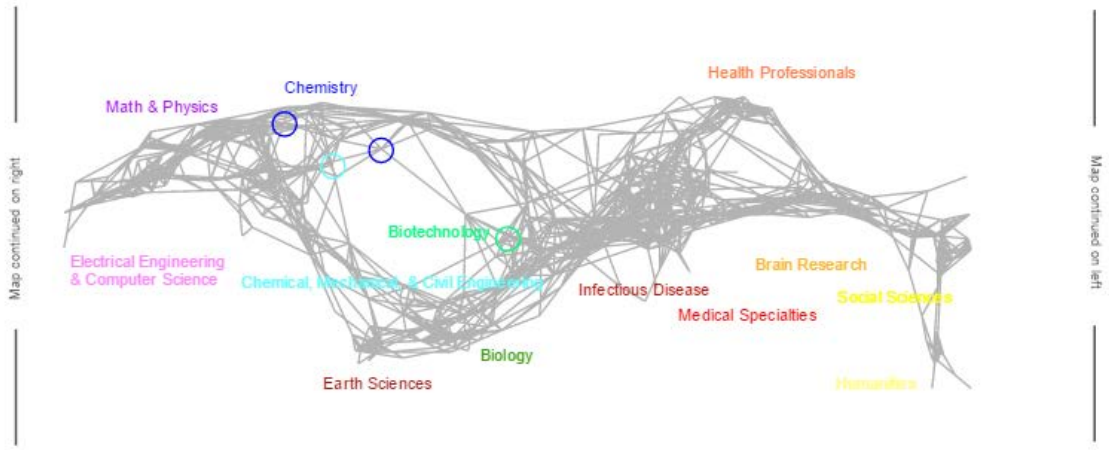
Expertise Profile Visualization -- UCSD Map of Science

Maps of science can be used to explore, understand, and communicate the expertise profiles of institutes or nations; to chart career trajectories; to identify emerging research frontiers. They allow us to track the emergence, evolution, and disappearance of topics and help to identify the most promising areas of research.

ASSIST

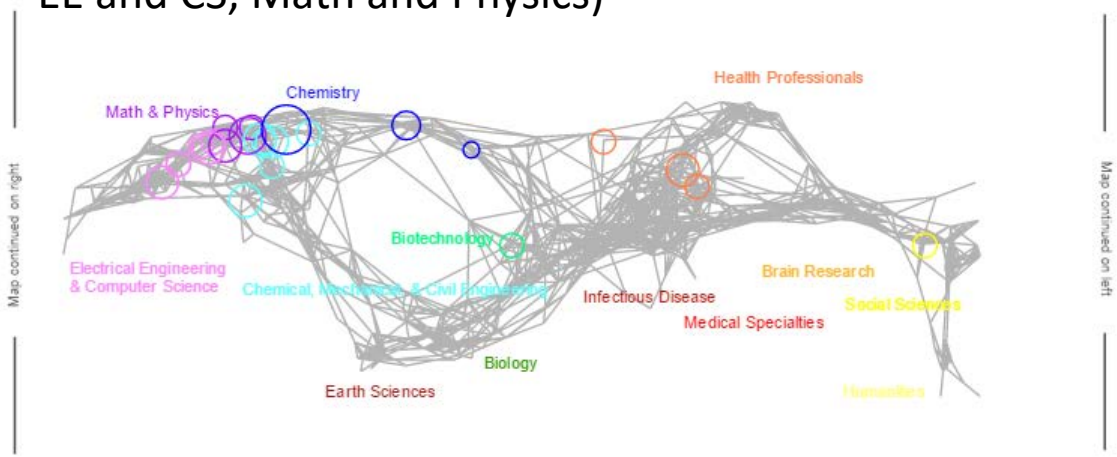


NEWT (new ERC)



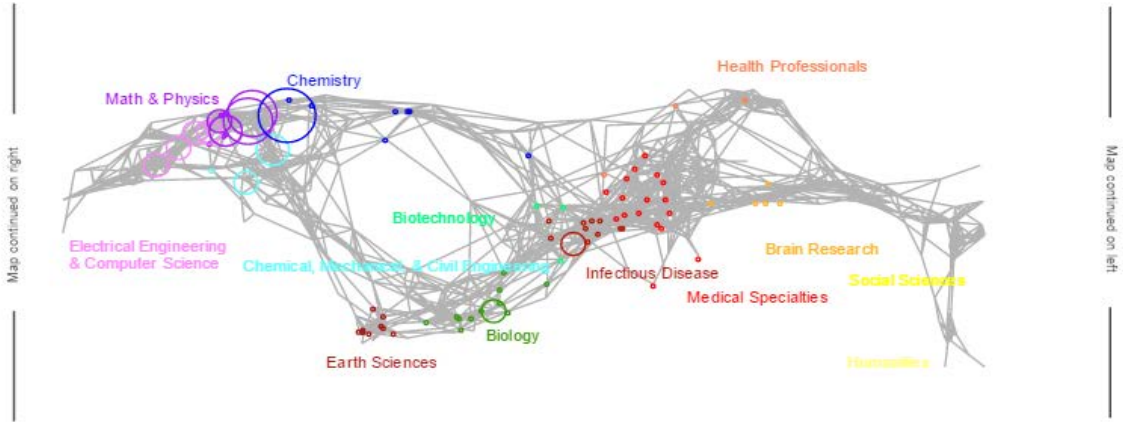
2008 The Regents of the University of California and SciTech Strategies.
Map updated by SciTech Strategies, OST, and CNS in 2011.

ASSIST (most pubs are in Chem, Mech & Civil Eng, EE and CS, Math and Physics)



2008 The Regents of the University of California and SciTech Strategies.
Map updated by SciTech Strategies, OST, and CNS in 2011.

TANMS (most interdisciplinary, *Nature* paper)



2008 The Regents of the University of California and SciTech Strategies.
Map updated by SciTech Strategies, OST, and CNS in 2011.

Legend

Circle area: Fractional Journal Count

How To Read This Map

The *UCSD map of science* depicts a network of 554 subdiscipline nodes that are aggregated to 13 main disciplines of science. Each discipline has a distinct color and is labeled. Overlaid are circles, each representing all records per unique subdiscipline. Circle area is proportional to the number of fractionally assigned records. Minimum and maximum data values are given in the legend.

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Visualizations Used in ERC Annual Reports

NEWT Report

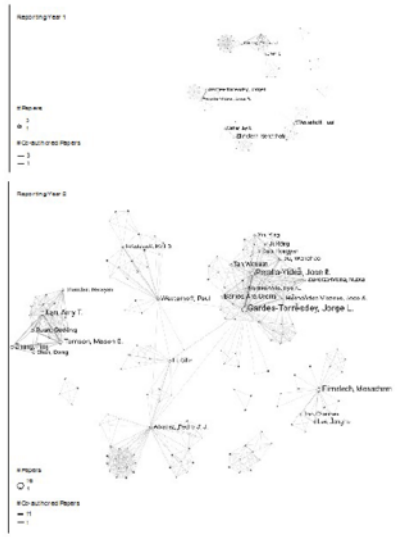


Figure A. NEWT Year 1 and Year 2 network-based co-authorship map illustrating publication collaborations. Credit: Cyberinfrastructure for Network Science Center, University of Indiana.

Translational Research Awards

Translational research has begun to ramp up in Year 2, below we summarize some highlighted outcomes from those projects.

We investigated membrane fouling mechanisms in Cambrian's hybrid membrane bioreactor-ion exchange membrane process for winery wastewater treatment applications, evaluated and developed fouling control strategies. The recommended fouling control strategy will be used by Cambrian in its full scale system operation.

We collaborated with the nanophotonics materials team at Luna Innovations Inc. to develop and evaluate new photothermal nano materials that can improve the photothermal efficiency of the MD membrane. Titanium nitride nanoparticles, mixture of carbon black and titanium nitride, and carbon coated titanium nitride were evaluated both in suspension and membrane coatings. The Phase (II) proposal was submitted in April for

The figures below show the evolving NEWT collaboration network based on co-authorship extracted from bibliography files (Figure A). Legends are included in the bottom-left of each visualization to explain the sizing of author nodes and collaboration links. Each node represents an author, and author node area size scales with the number of publications. Author nodes with two publications or more are labelled by the author's name in the top visualization, while author nodes with three publications or more are labelled on the bottom visualization. Two authors are connected if they have authored a publication together and link width scales with the number of joint 26publications between those authors. Note that size coding differs for the two visualizations.

Network layouts differ structurally as each is spatially optimized for each of the two periods. The network on top shows the 78 authors that published 15 publications in 2015/2016. Note that one publication has 16 authors resulting in a so-called fully connected clique network that is connected to other subnetworks via Pedro J.J. Alvarez. The network below shows 173 authors that published 48 journal articles in 2016/2017. Comparing the two visualizations reveals that NEWT impact in terms of authors and publications has increased considerably—there are about more than twice the number of authors publishing almost four times more publications within 2016/2017 than in previous years. Plus, there are many larger subnetworks that are more interlinked—showcasing intense collaboration and communication. Authors like Pedro J.J. Alvarez, Jorge Gardea-Torresdey, and Paul Westerhoff have not only many publications to their credit but they also interconnect different subnetworks—effectively serving as gatekeepers. Thickness coding of lines supports the identification of major collaboration (and most likely communication) pathways in this rapidly evolving professional network.

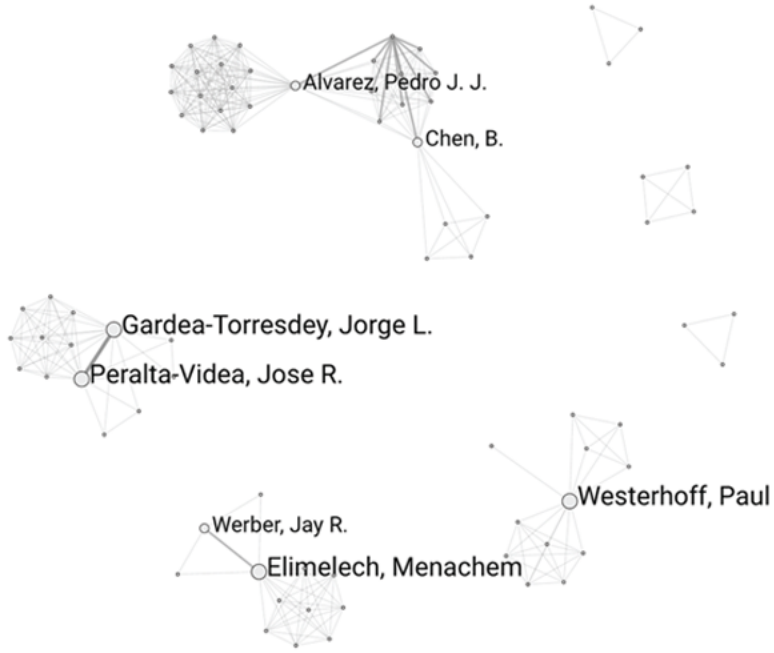
NEWT Reporting Year 1

#Papers

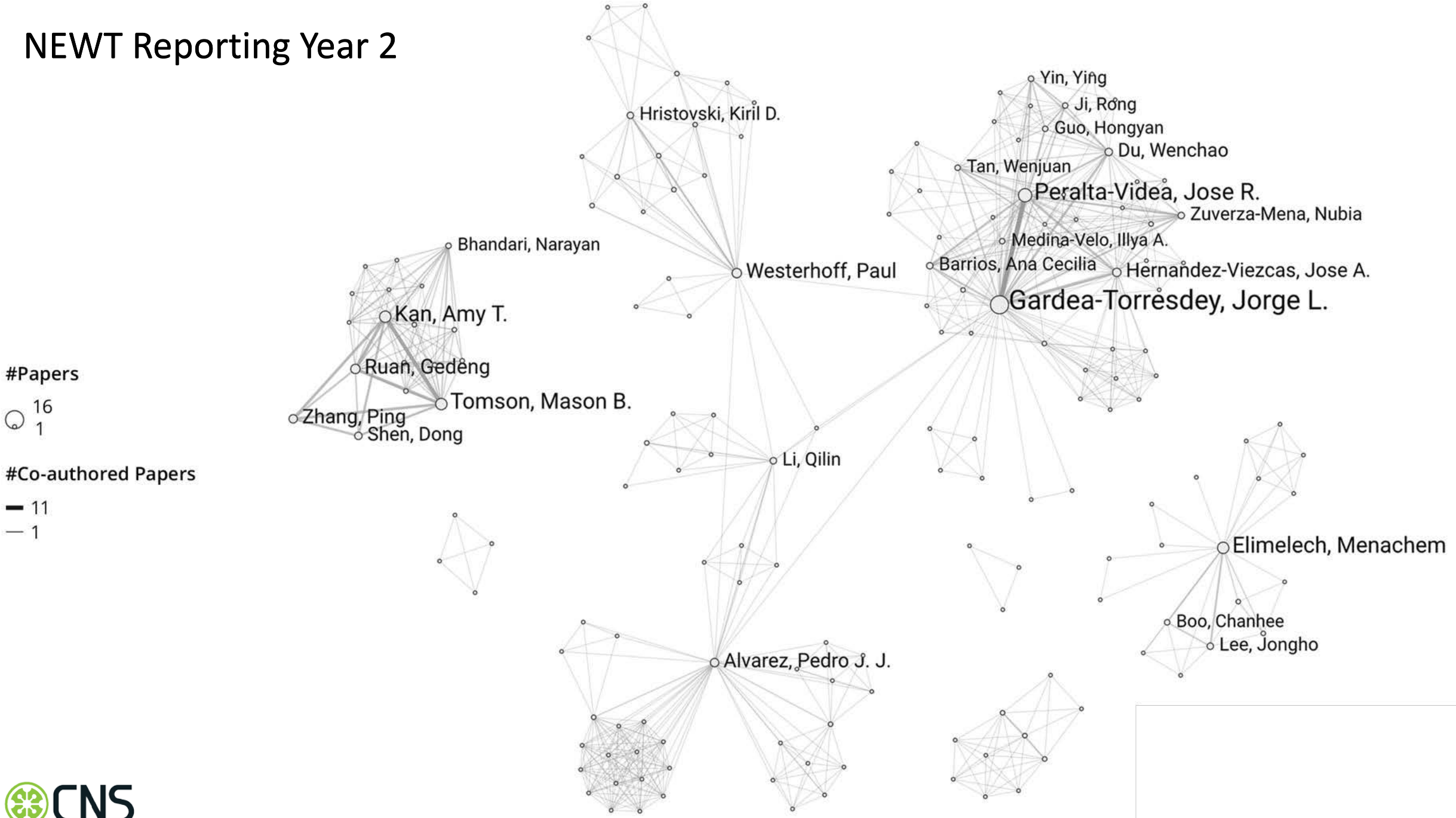
3
1

#Co-authored Papers

11
1



NEWT Reporting Year 2



TANMS Report

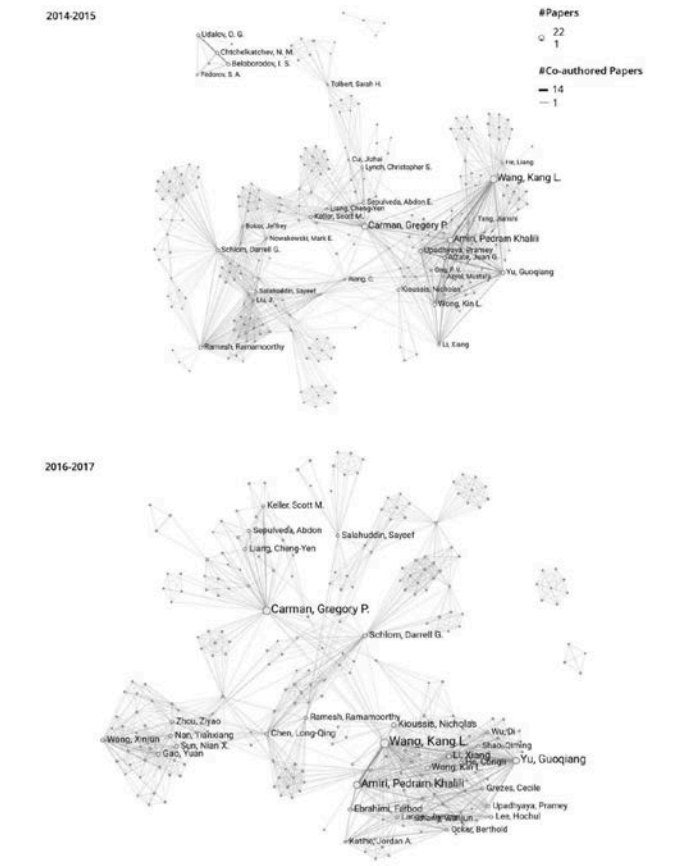


Figure 3-2 TANMS Authoring Network 2014-15 (top) and 2016-17 (bottom)

21

ERC Web Table 1 provides a quantifiable summary of the TANMS's research productivity related to the three testbeds. Research productivity, in addition to testbed development, is a required reporting metric by NSF to assess the health and quality of a center's program. As can be seen in this table TANMS continues to have a healthy number of journal publications, i.e. 36 publications in the last year from core funding and 35 from associated projects or a total of 229 since center inception. Maybe more complete publication information is provided in the coauthor network visualization provided in Figure 3.2.1-1 for the last couple of years.

Each node in the figure represents an author, and author node area size scales with the number of publications. Author nodes with four publications or more are labelled by the author's name. Two authors are connected if they have authored a publication together and link width scales with the number of joint publications between those authors. The network on top shows the authors network for 2014/2015. The top-three authors with the most publications are Kang L. Wang, Greg P. Carman, and Pedram Khalil Amiri. The network at the bottom of the figure shows publications for 2016/2017. The top-three authors with the most publications are Kang L. Wang, Gregory P. Carman, and Guoqiang Yu. Comparing these two visualizations reveals that the TANMS impact in terms of authors and publications was unusually high in the initial years and is increasing continuously—i.e. there are many more unique authors publishing within 2016/2017 than in previous years. Plus, there are large, strongly interlinked subnetworks— showcasing intense collaboration and communication. Authors like Kang L. Wang and Greg P. Carman, to their credit, also interconnect different subnetworks—effectively serving as gatekeepers. Thus, TANMS has a vibrant publication record showing extensive collaboration across all campuses. This brief snapshot clearly shows that TANMS system/team approach representing the corner stone of an NERC is alive and well.

TANMS 2014-2015

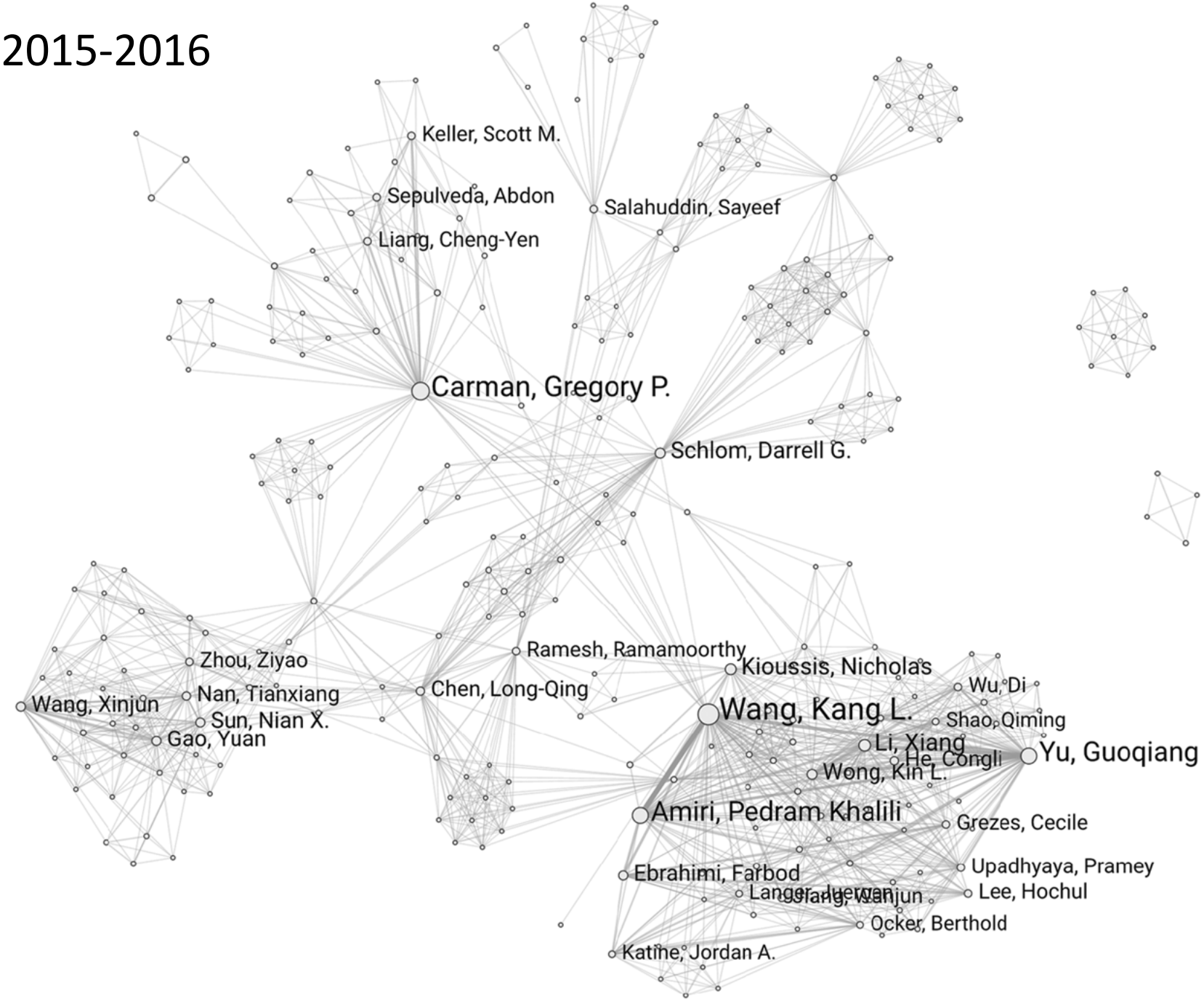
#Papers

22
1

#Co-authored Papers

14
1

TANMS 2015-2016



#Papers

22
1

#Co-authored Papers

14
1

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Visualizations Used in ERC Site Visit Presentations

ASSIST Co-authorship Network 2012-2017

CNS @ Indiana University

2017

Displayed Year: 2012

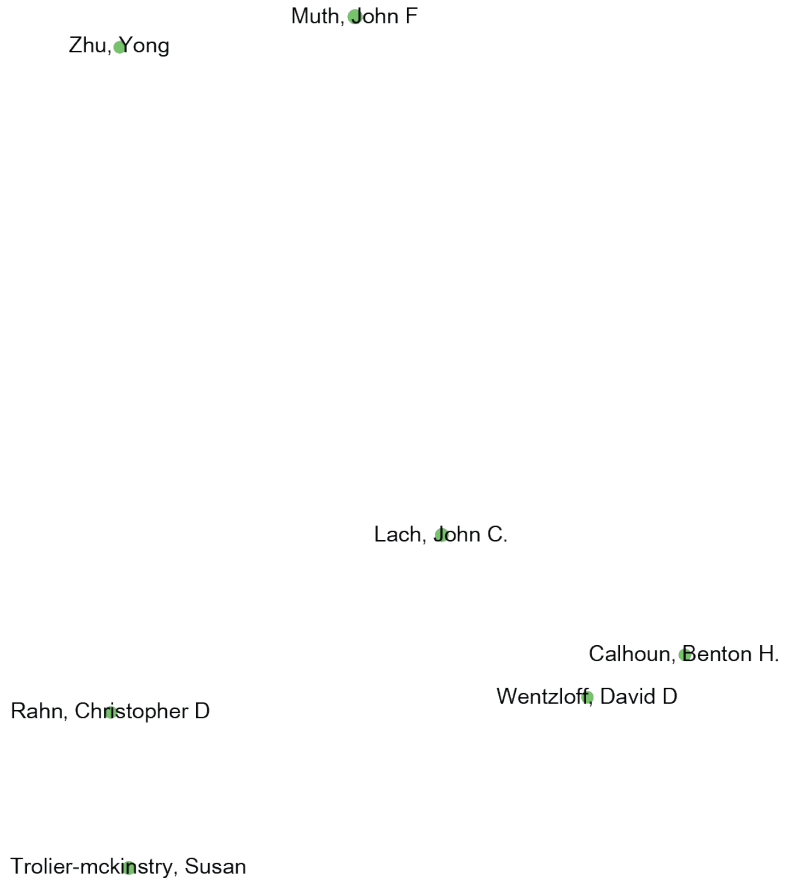
#Papers

38
18
1

#Co-authored Papers

13
7
1

This network was generated from 271 ASSIST publications. It comprises 48 authors and 128 edges and covers the years 2012 through March 2017. Nodes are sized by the cumulative number of publications associated with an author. Edges are sized by the cumulative number of ASSIST related papers published by an author.



ASSIST Co-authorship Network 2012-2017

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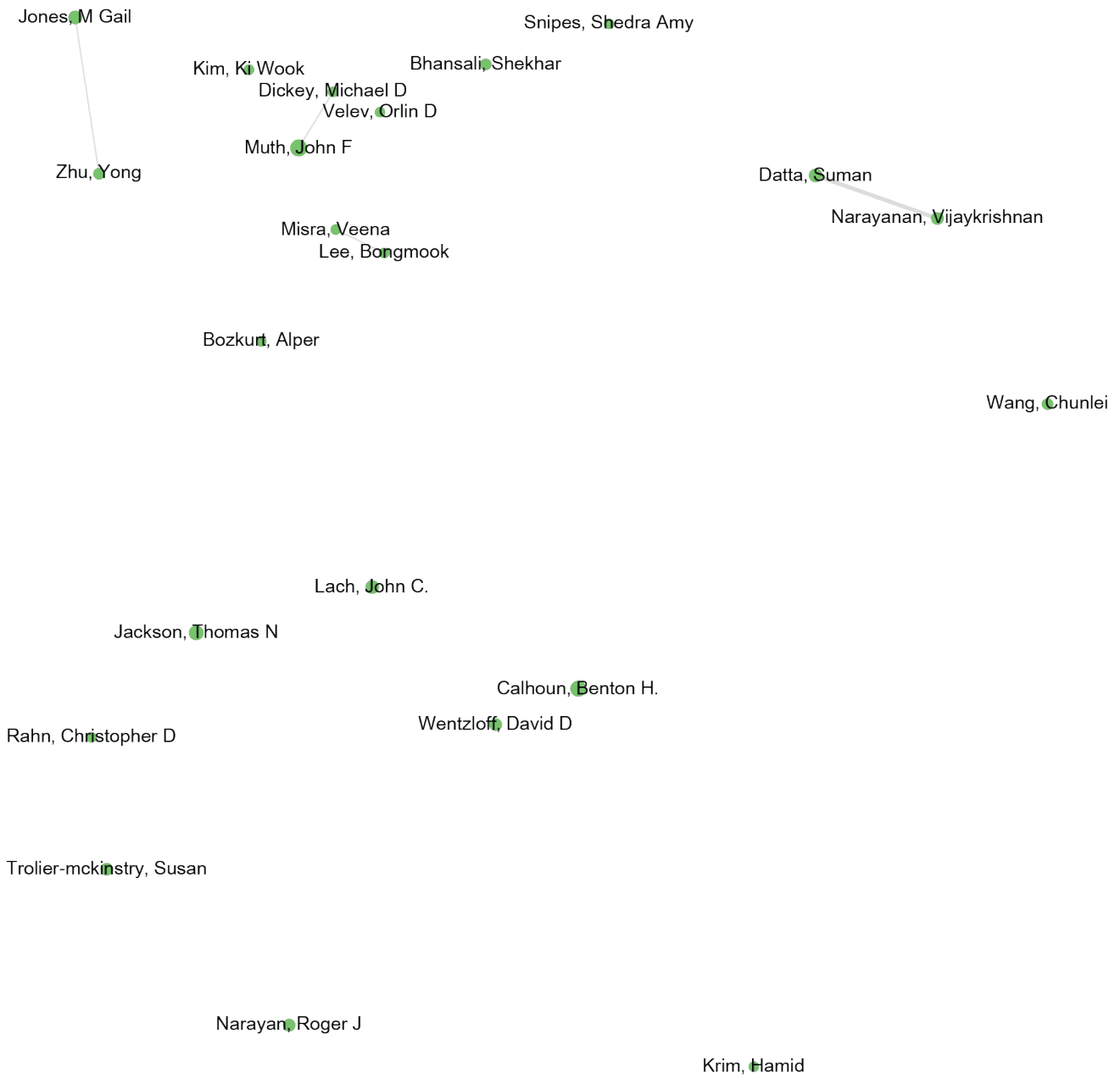
2017

Displayed Year: 2012-2013



#Papers

38
18
1

#Co-authored Papers

13
7
1

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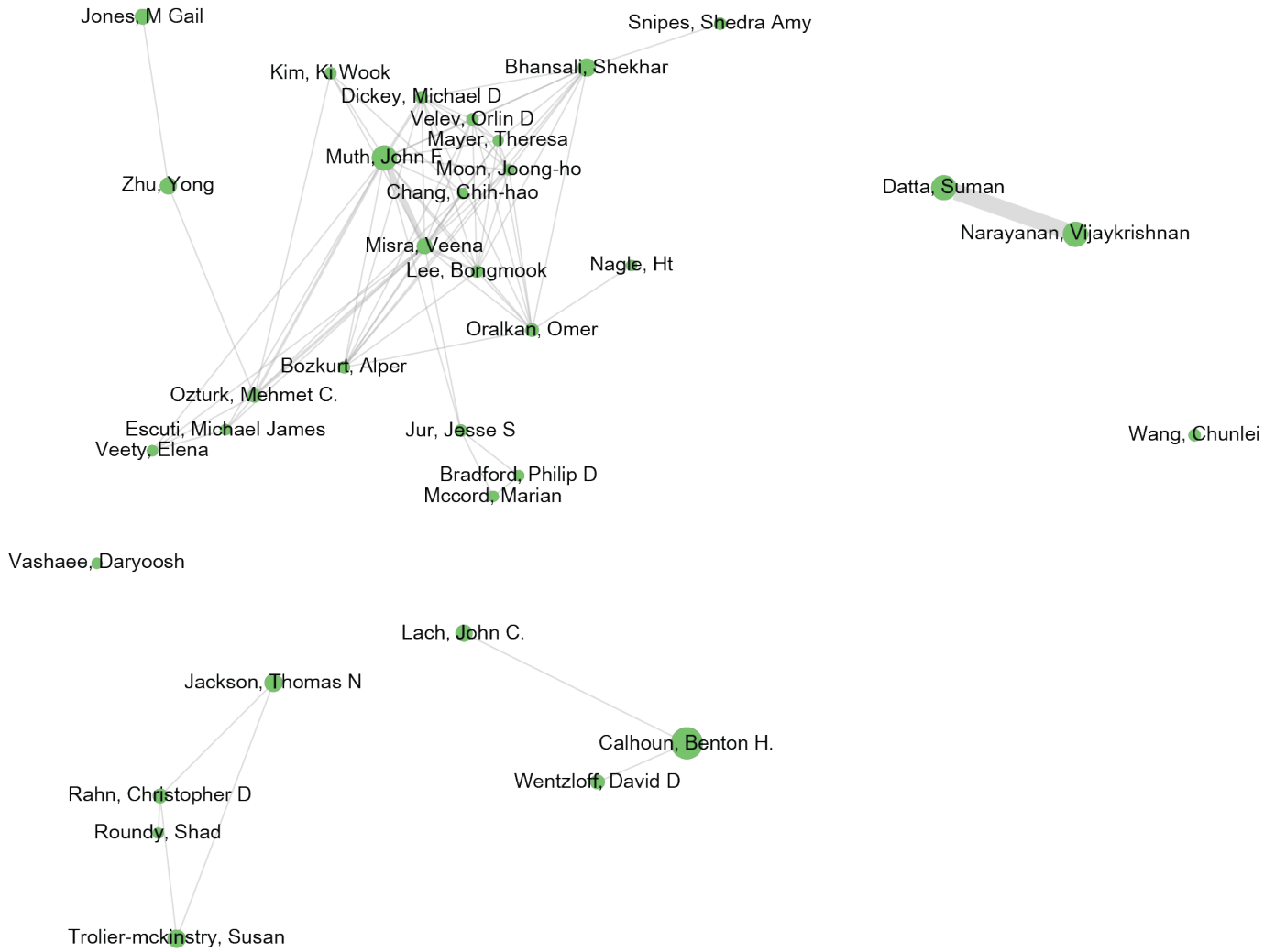
ASSIST Co-authorship Network 2012-2017

CNS @ Indiana University

2017

Displayed Year: 2012-2014



#Papers

38
18
1

#Co-authored Papers

13
7
1

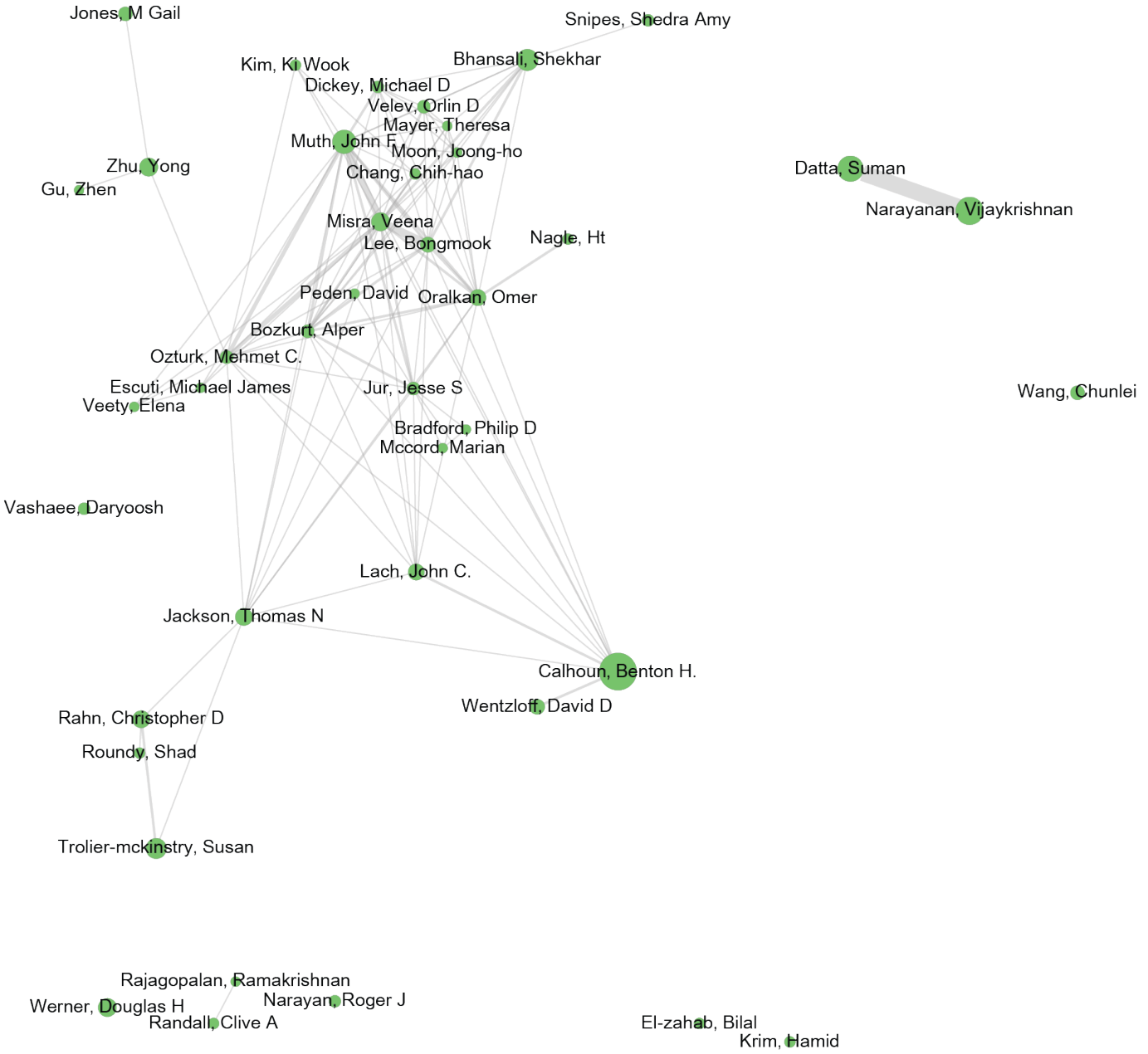
This network was generated from 271 ASSIST publications. It comprises 48 authors and 128 edges and covers the years 2012 through March 2017. Nodes are sized by the cumulative number of publications associated with an author. Edges are sized by the cumulative number of ASSIST related papers published by an author.

ASSIST Co-authorship Network 2012-2017

CNS @ Indiana University

2017

Displayed Year: 2012-2015



#Papers

38
18
1

#Co-authored Papers

13
7
1

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ASSIST Co-authorship Network 2012-2017

CNS @ Indiana University

2017

Displayed Year: 2012-2016

#Papers

38
18
1

#Co-authored Papers

13
7
1

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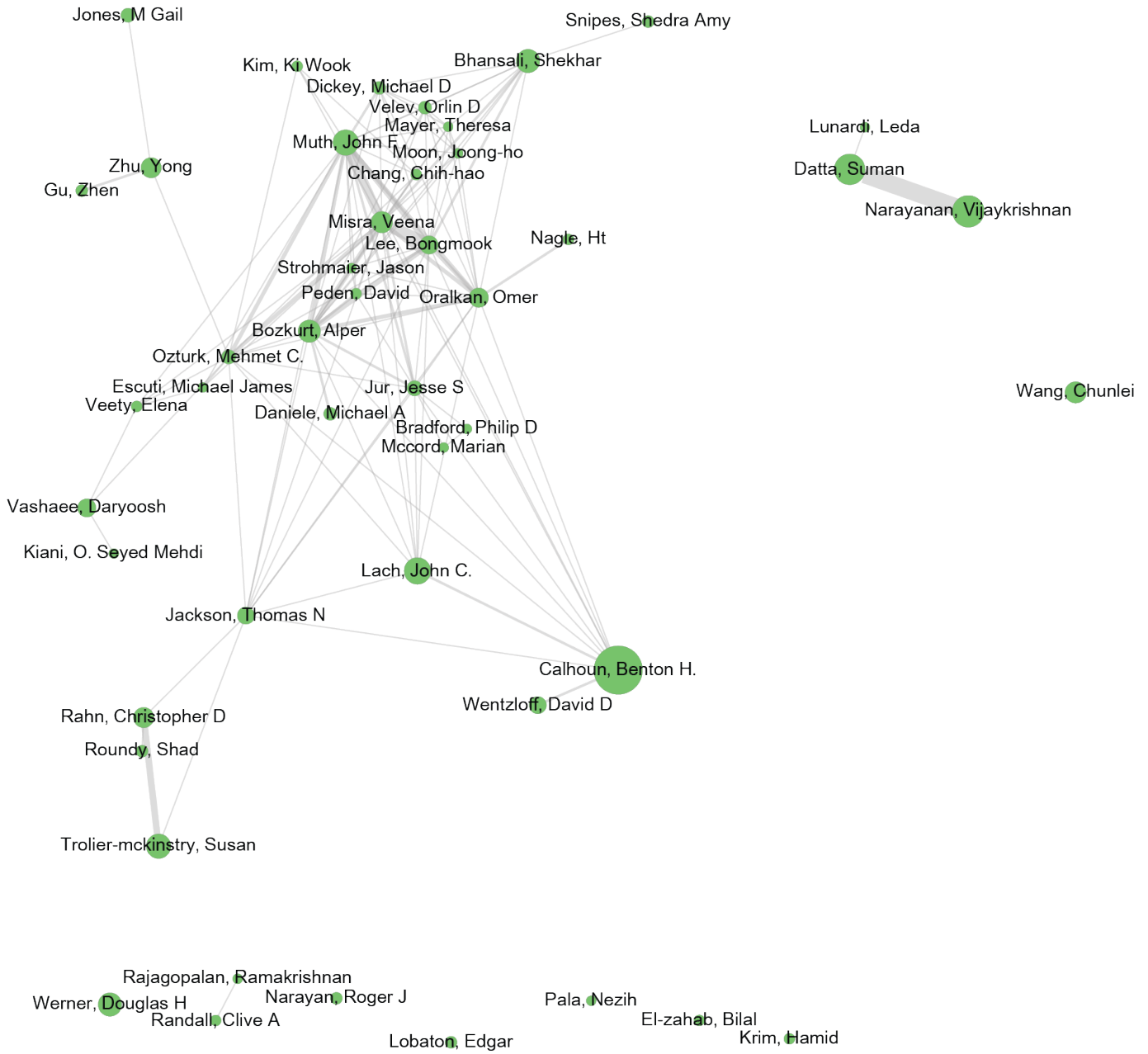
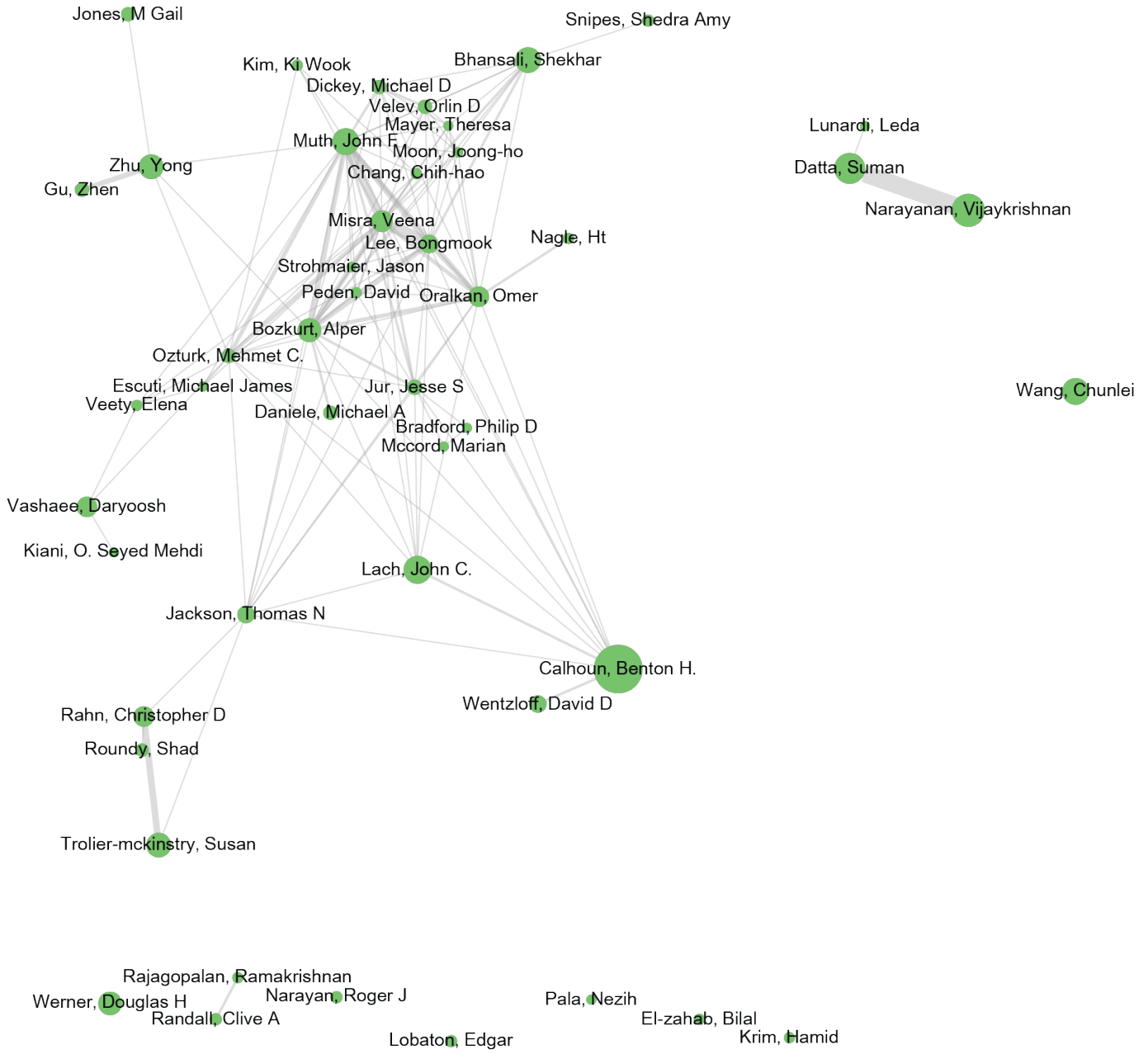


ASSIST Co-authorship Network 2012-2017

CNS @ Indiana University

2017

Displayed Year: 2012-2017



#Papers

38
18
1

#Co-authored Papers

13
7
1

This network was generated from 271 ASSIST publications. It comprises 48 authors and 128 edges and covers the years 2012 through March 2017. Nodes are sized by the cumulative number of publications associated with an author. Edges are sized by the cumulative number of ASSIST related papers published by an author.

ASSIST Co-authorship Network 2012-2017

CNS @ Indiana University

2017

#Papers

38
18
1

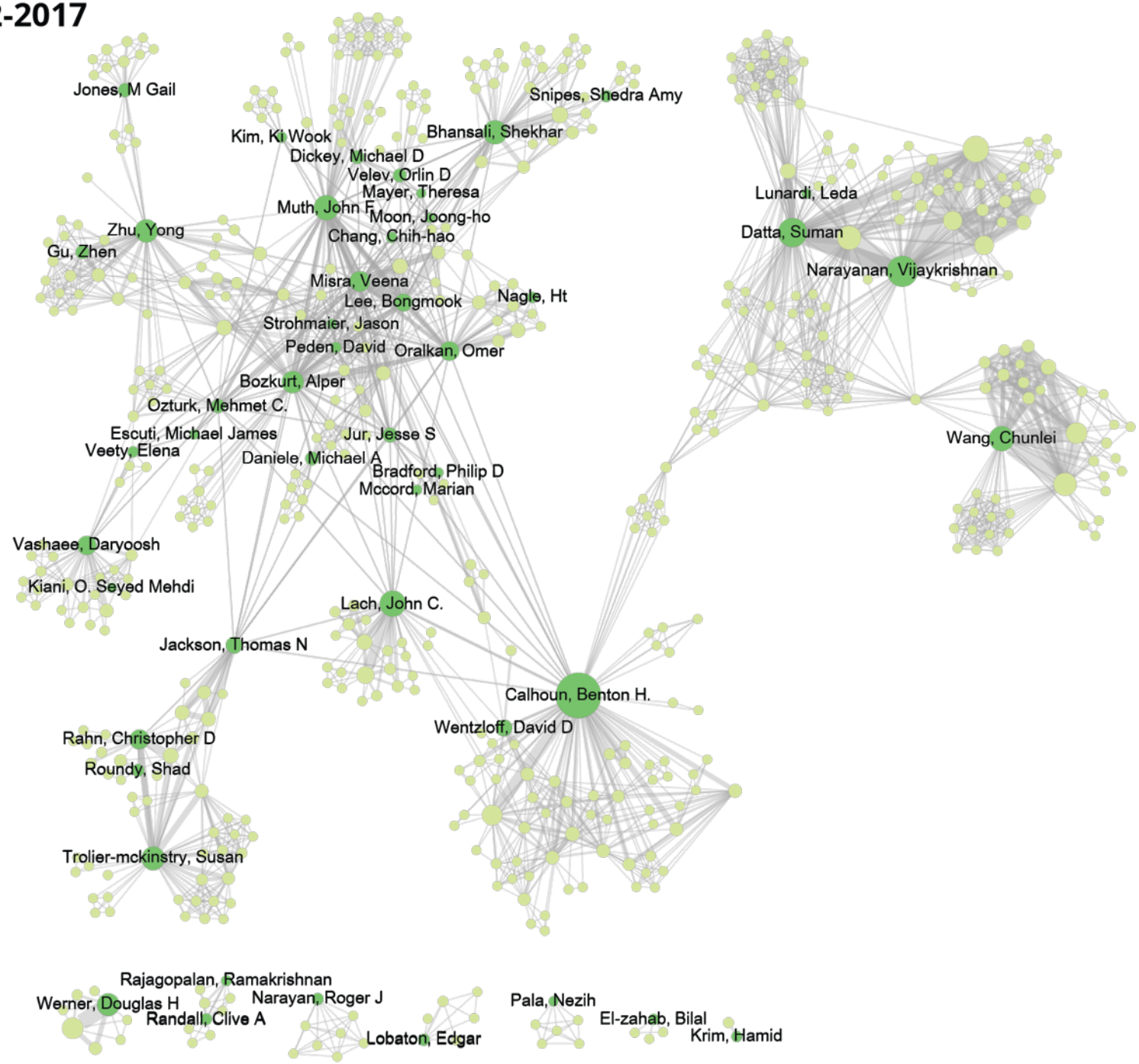
#Co-authored Papers

13
7
1

Other authors

ASSIST student authors

This network was generated from 271 ASSIST publications. It comprises 551 authors and 2,511 edges and covers the years 2012 through March 2017. The 48 faculty associated with ASSIST are colored in green. All other authors are colored in light green.



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Next Steps & Possible Future Visualizations

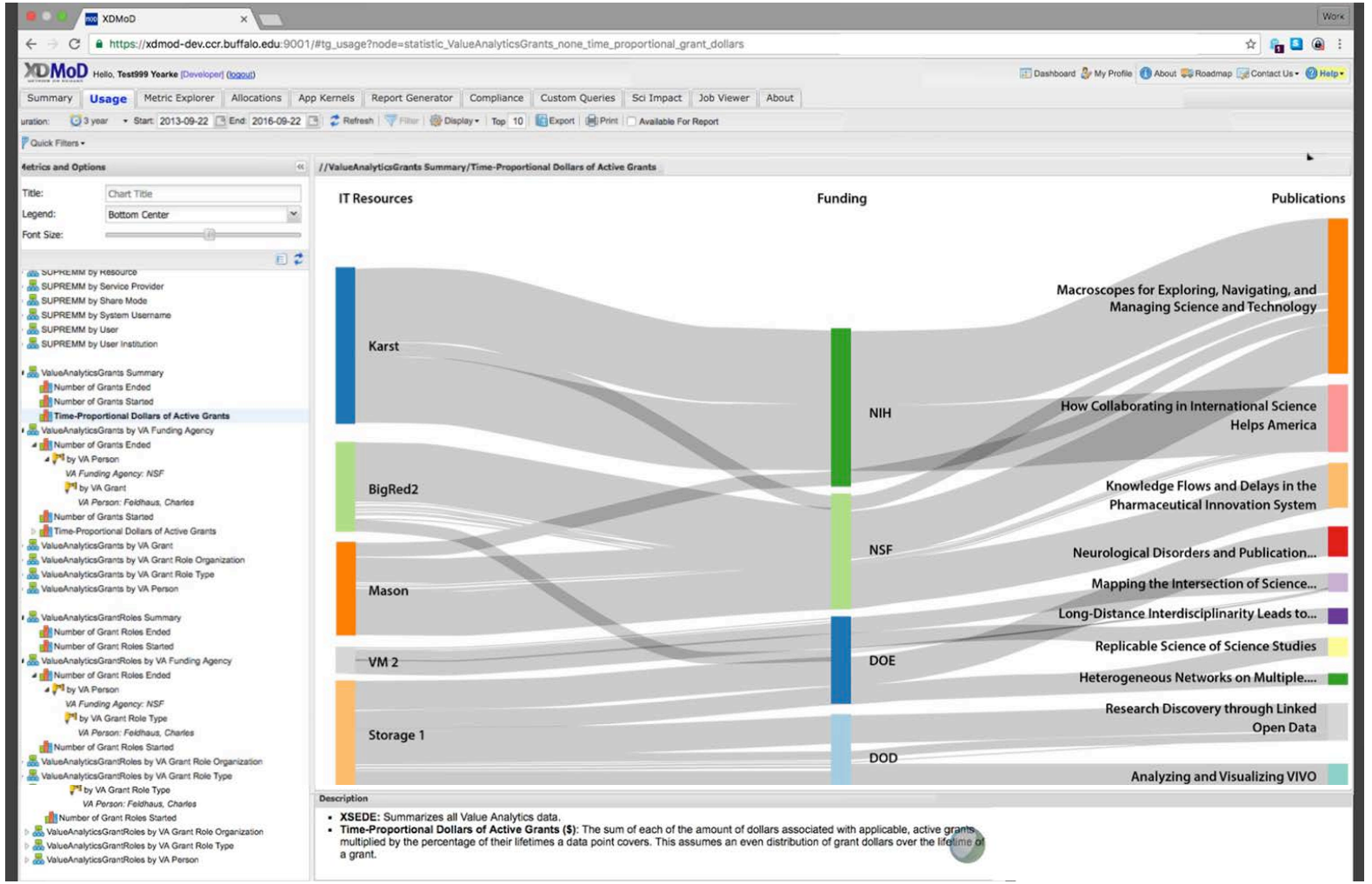
Next Steps

- Visualization code is fully integrated in nanoHUB. Decide if visualizations should be added to HUBzero.
- Optimize current visualizations based on user feedback. Interactive visualizations are best for exploration; static visualizations are required for slides, reports, publications.
- Provide guidance on ERC activity data acquisition—what data should be captured in which format to support what kind of decision making.
- Explore visualizations that provide additional insights into ERC usage and the impact of resources on S&T progress, see subsequent two slides.

XDMOD: Sankey Diagram of IT Resource Impact on Research (funded by different NSF project)

Visualization displays the relationship between IT resources, funding, and publications. The width of each line represents grant dollars awarded to researchers at one institution.

Scrivner, Olga, Gagandeep Singh, Sara Bouchard, Scott Hutcheson, Ben Fulton, Matt Link, and Katy Börner. 2018. "XD Metrics on Demand Value analytics: Visualizing the impact of internal information Technology investments on external Funding, Publications, and collaboration networks". *Frontiers Research Metrics and Analytics* 2 (10).

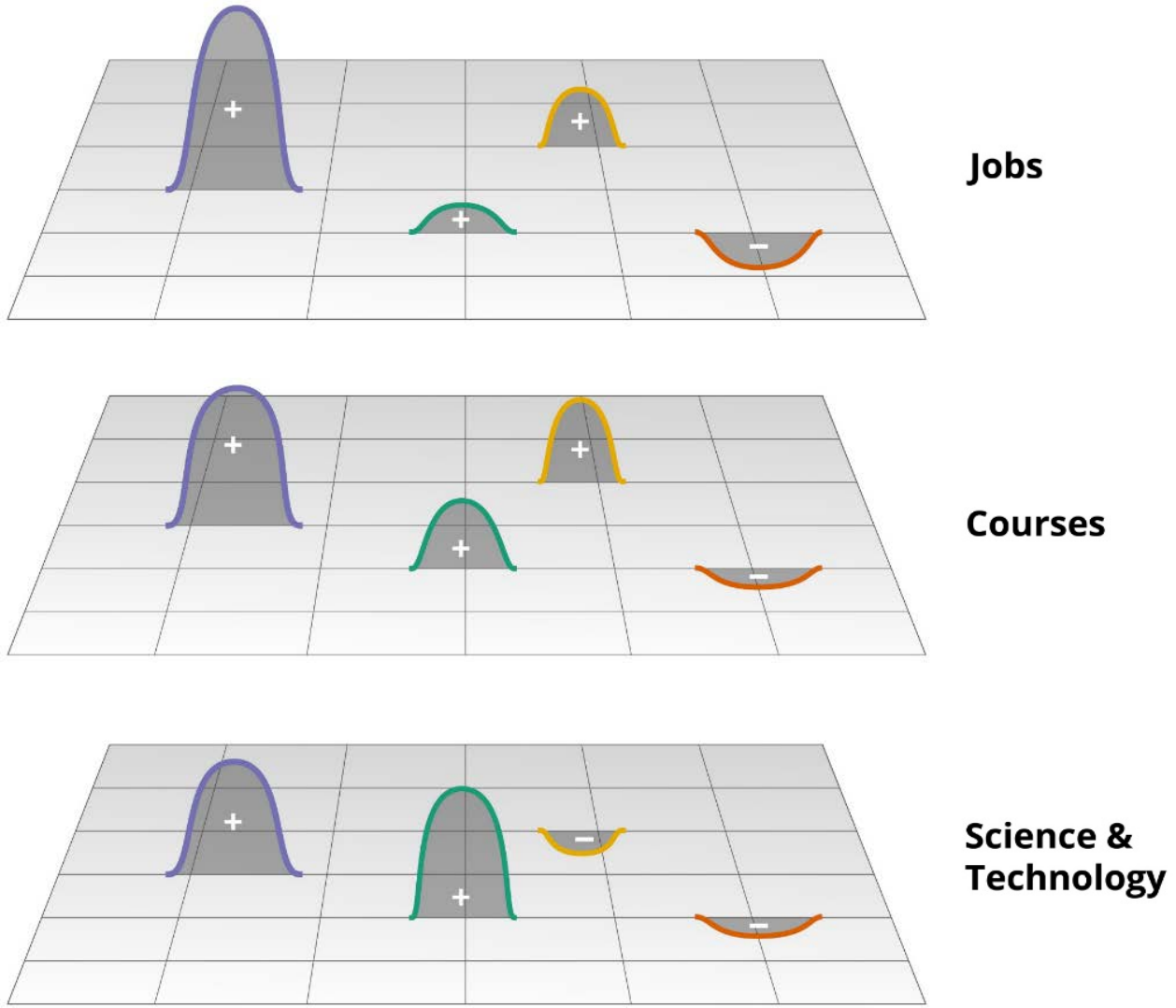


Future Work (Outside current project scope)

Study and visualize the structure and dynamics of Engineering, particularly the interplay of

- Job market demands
- Education and training (residential and online) S&T progress

Communicate S&T dynamics to general audiences via moderated news broadcasts



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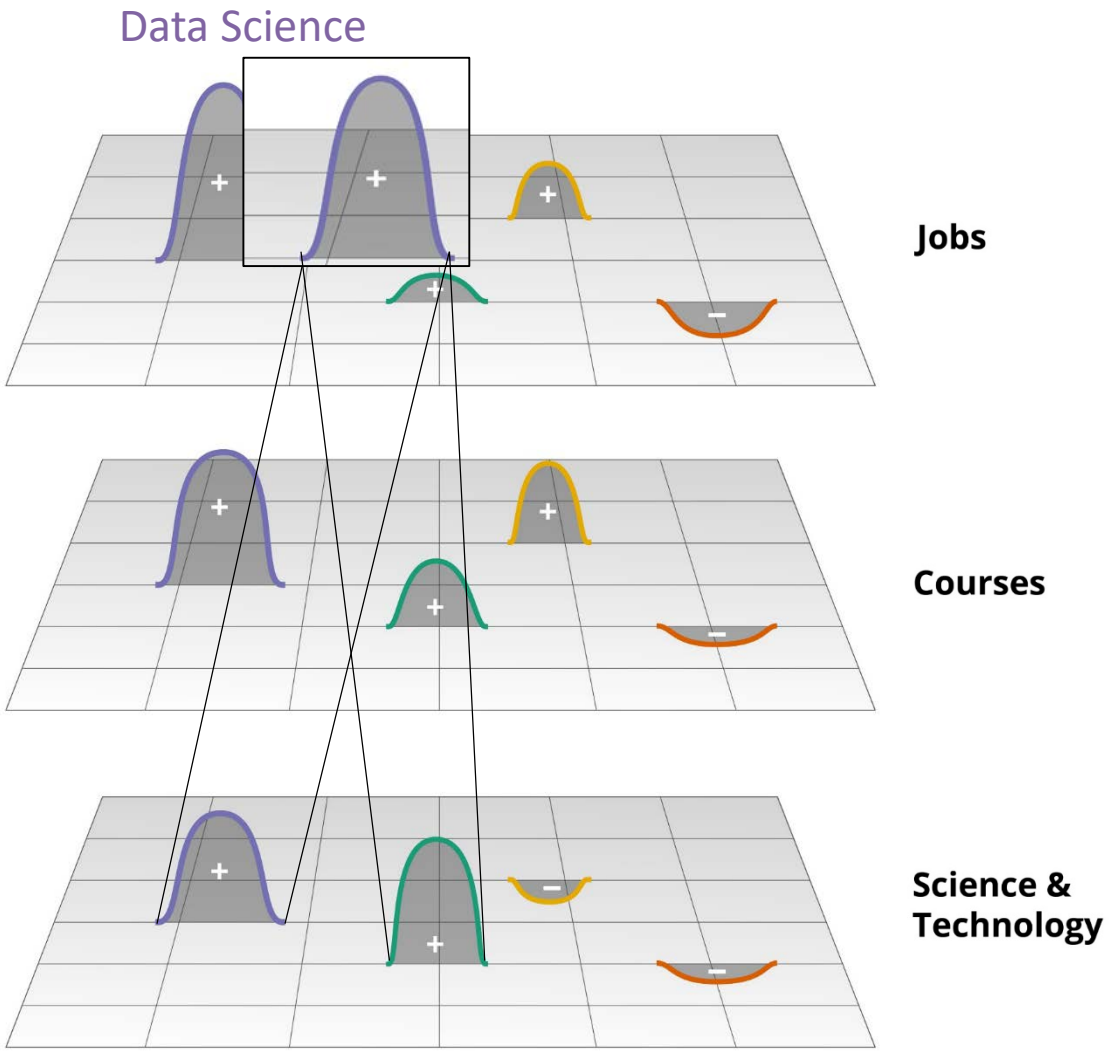
Science & Technology vs. Education/Training vs. Jobs

Katy Börner, Olga B. Scrivner, Xiaozhong Liu, Indiana University

Need to study the **(mis)match** and **temporal dynamics** of S&T progress, education and workforce development options, and job requirements.

Challenges:

- Rapid change of STEM knowledge
- Increase in tools, AI
- Social skills (project management, team leadership)
- Increasing team size

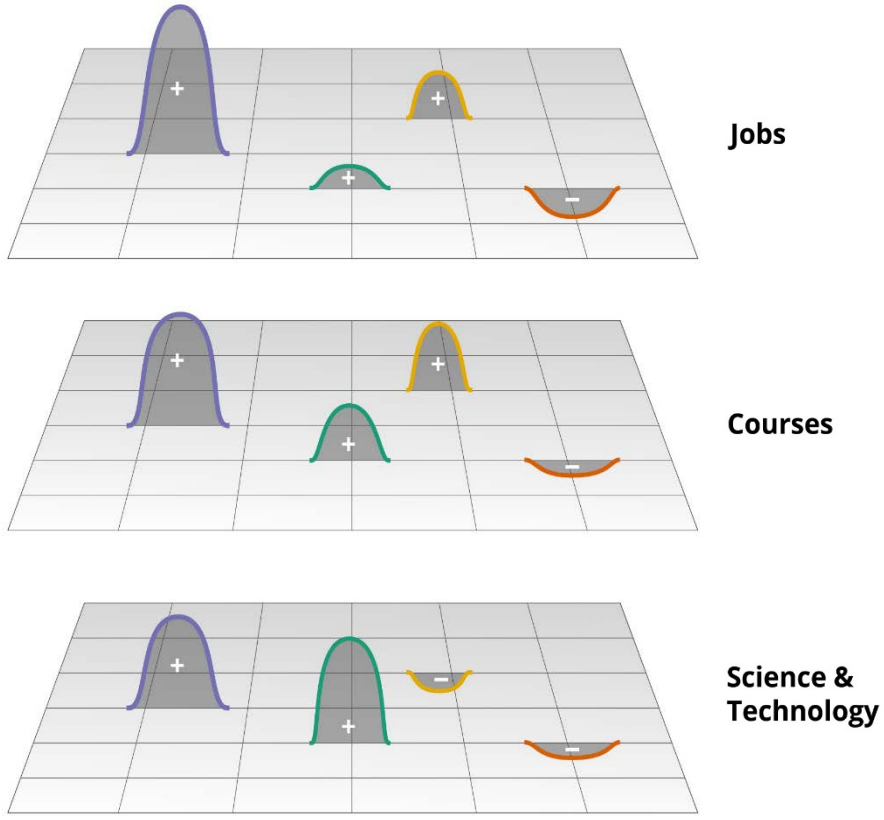


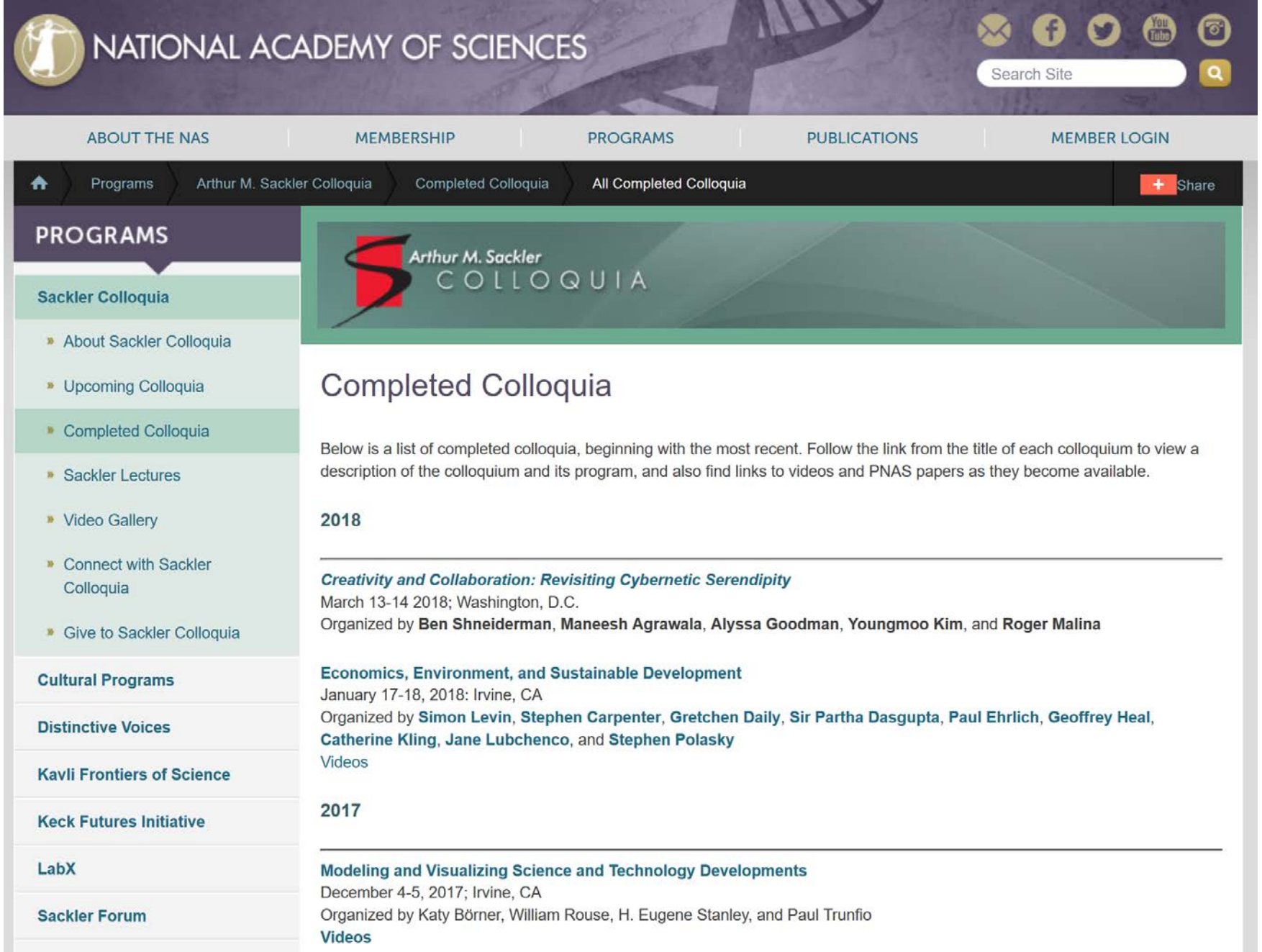
Science & Technology vs. Education/Training vs. Jobs

Study results are needed by:

- **Students:** What jobs will exist in 1-4 years? What program/learning trajectory is best to get/keep my dream job?
- **Teachers:** What course updates are needed? What curriculum design is best? What is my competition doing? How much timely knowledge (to get a job) vs. forever knowledge (to be prepared for 80 productive years) should I teach? How to innovate in teaching and get tenure?
- **Employers:** What skills are needed next year, in 5 years? Who trains the best? What skills does my competition list in job advertisements? How to hire/train productive teams?

What is ROI of my time, money, compassion?





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http://www.nasonline.org/programs/sackler-colloquia/completed_colloquia/modeling-and-visualizing.html

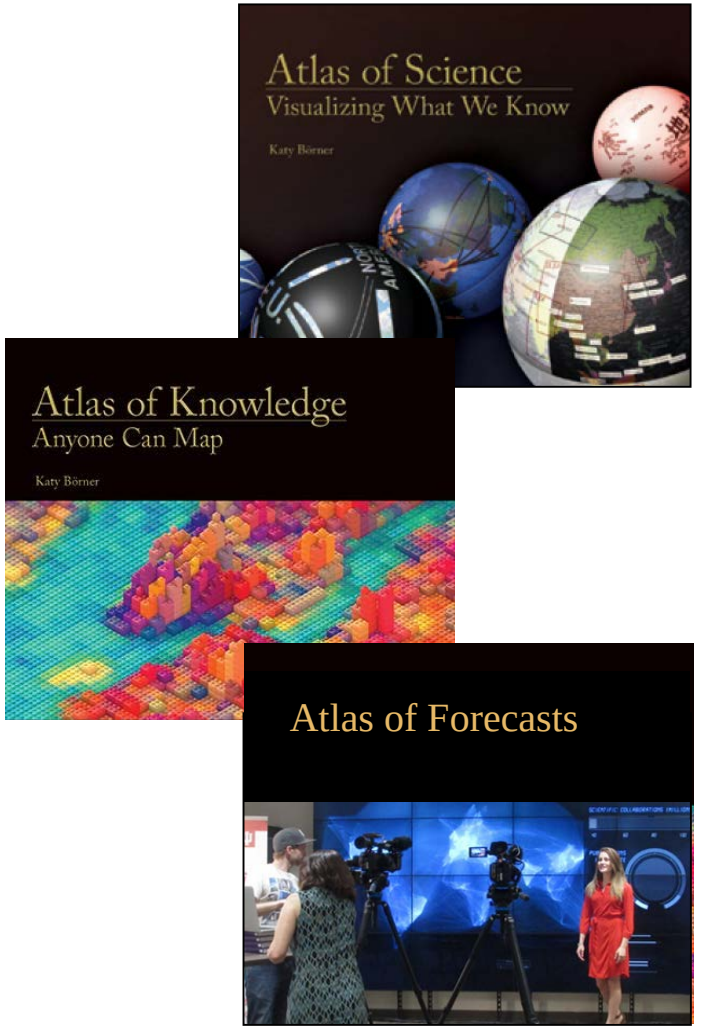
Atlas Trilogy

- 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.

- **ModSTI Conference** slides, recordings, and report are at modsti.cns.iu.edu/report



All papers, maps, tools, talks, press are linked from [cns.iu.edu](cns.iu.edu)

These slides are at cns.iu.edu/presentations

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Place & Spaces: Mapping Science Exhibit Facebook: facebook.com/mappingscience

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