Concentric Network Symmetry

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FAPESP
SÃO PAULO RESEARCH FOUNDATION

September 2017

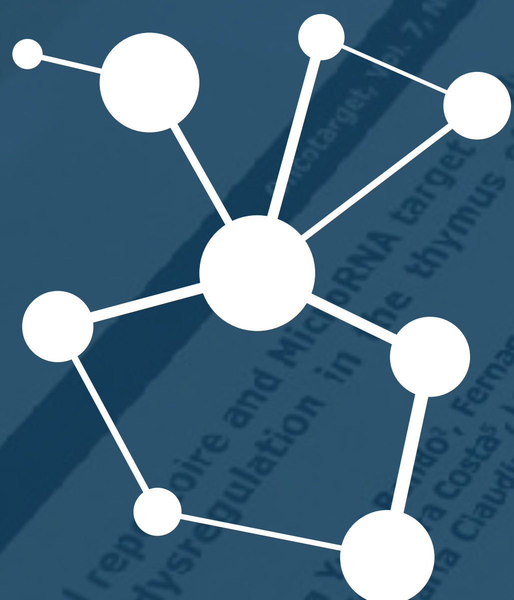
About me

Postdoctoral fellow 2015 - now
Computational Physics
São Carlos Institute of Physics Brazil
Advisor: Prof. Luciano da F. Costa

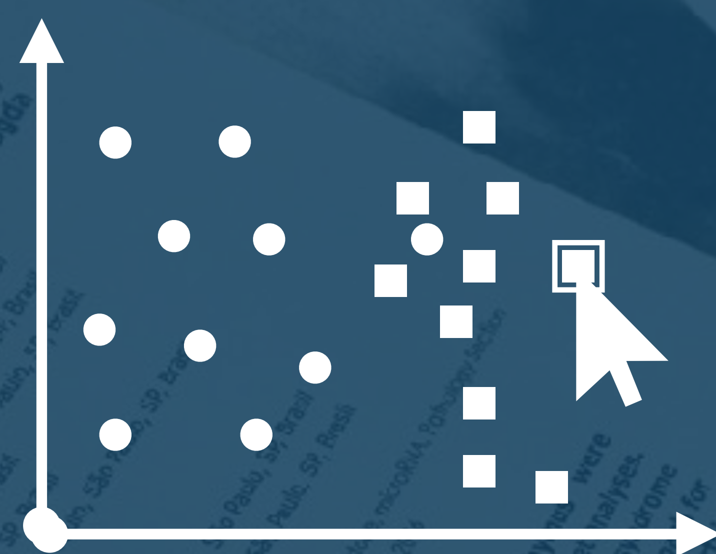
Visiting Scholar 2017 - now
Indiana University
Advisor: Prof. Filippo Menczer

São Carlos Institute of Physics - IFSC
University of São Paulo - USP

My research



Complex networks



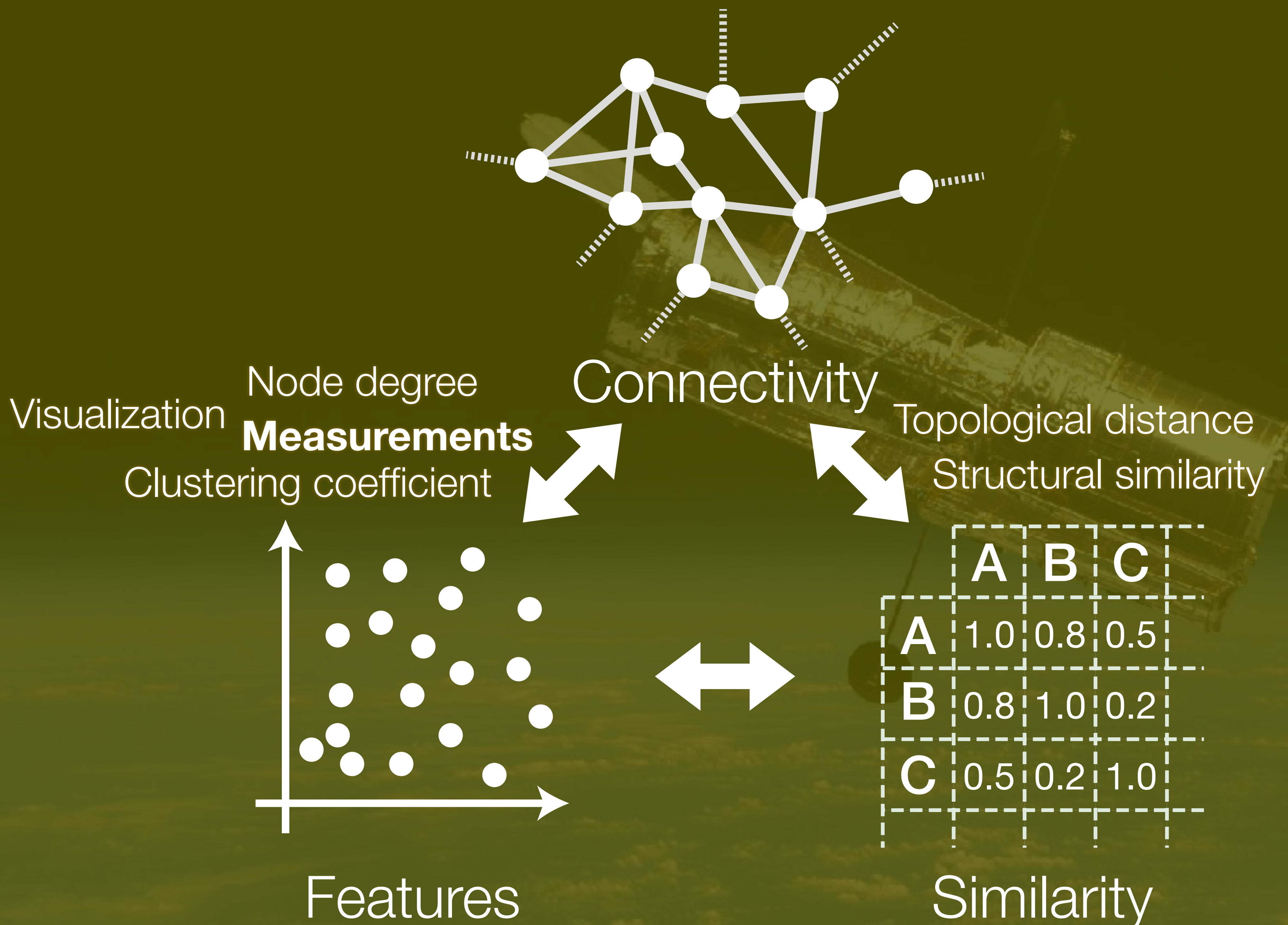
Interactive visualization

Data analysis

My research

Science of science
Urban network analysis
Network visualization
Text analysis
Biological networks
Transistors

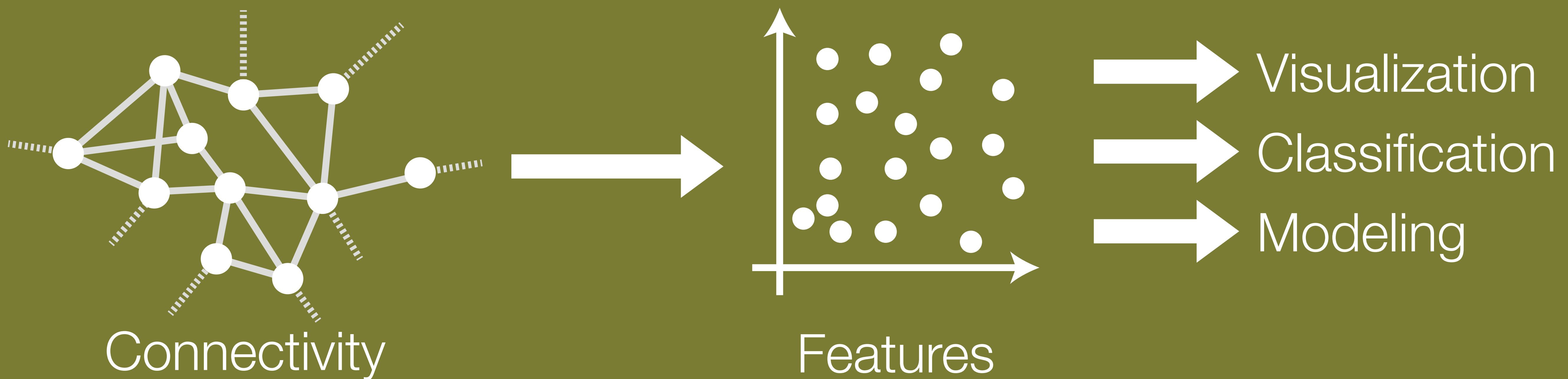
Representing and modeling complex systems



Comin, C. H.; Peron, T. K. DM.; Silva, F. N.; Amancio, D. R.; Rodrigues, F. A.; Costa, L. da F. Complex systems: features, similarity and connectivity (https://arxiv.org/abs/1606.05400)

Representing and modeling complex systems

Informative features for nodes?

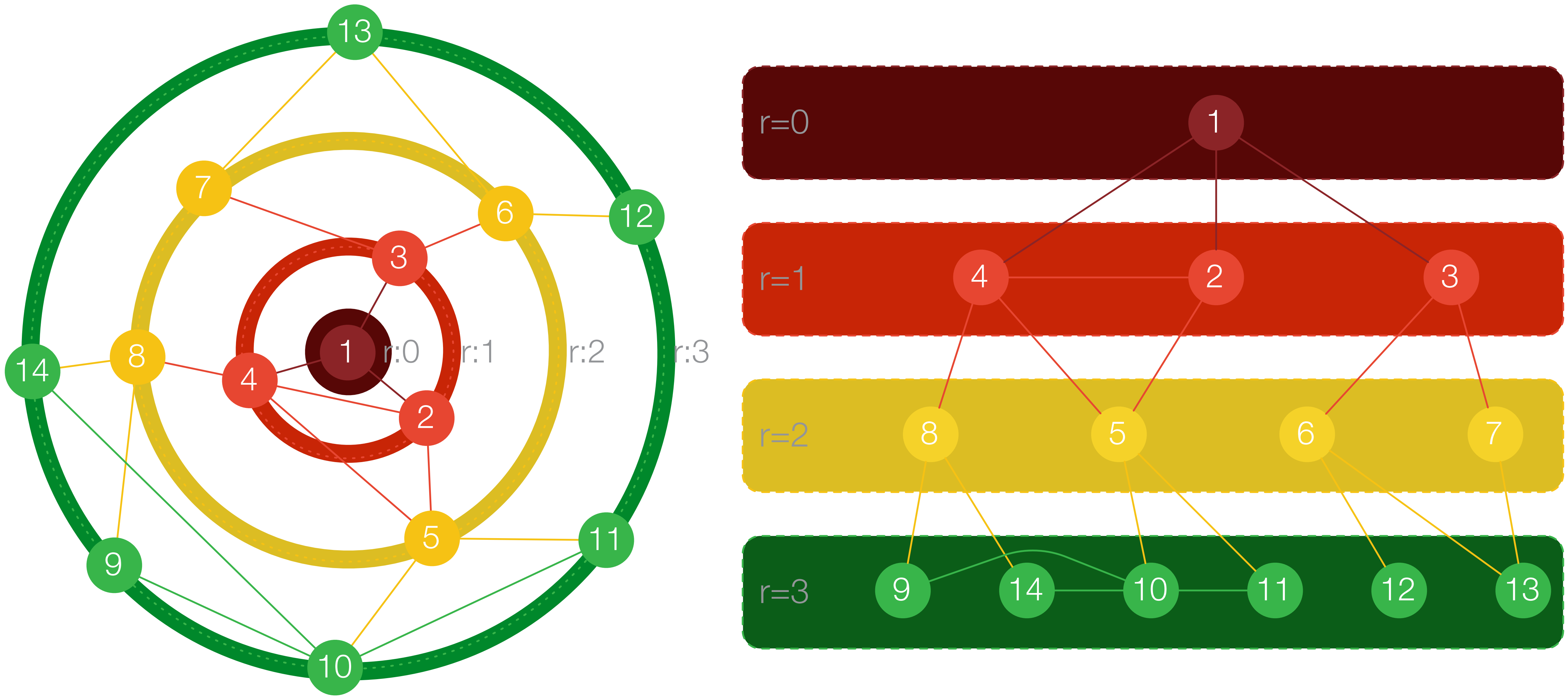


Global vs local measurements

Dependence with the size of networks is not desirable

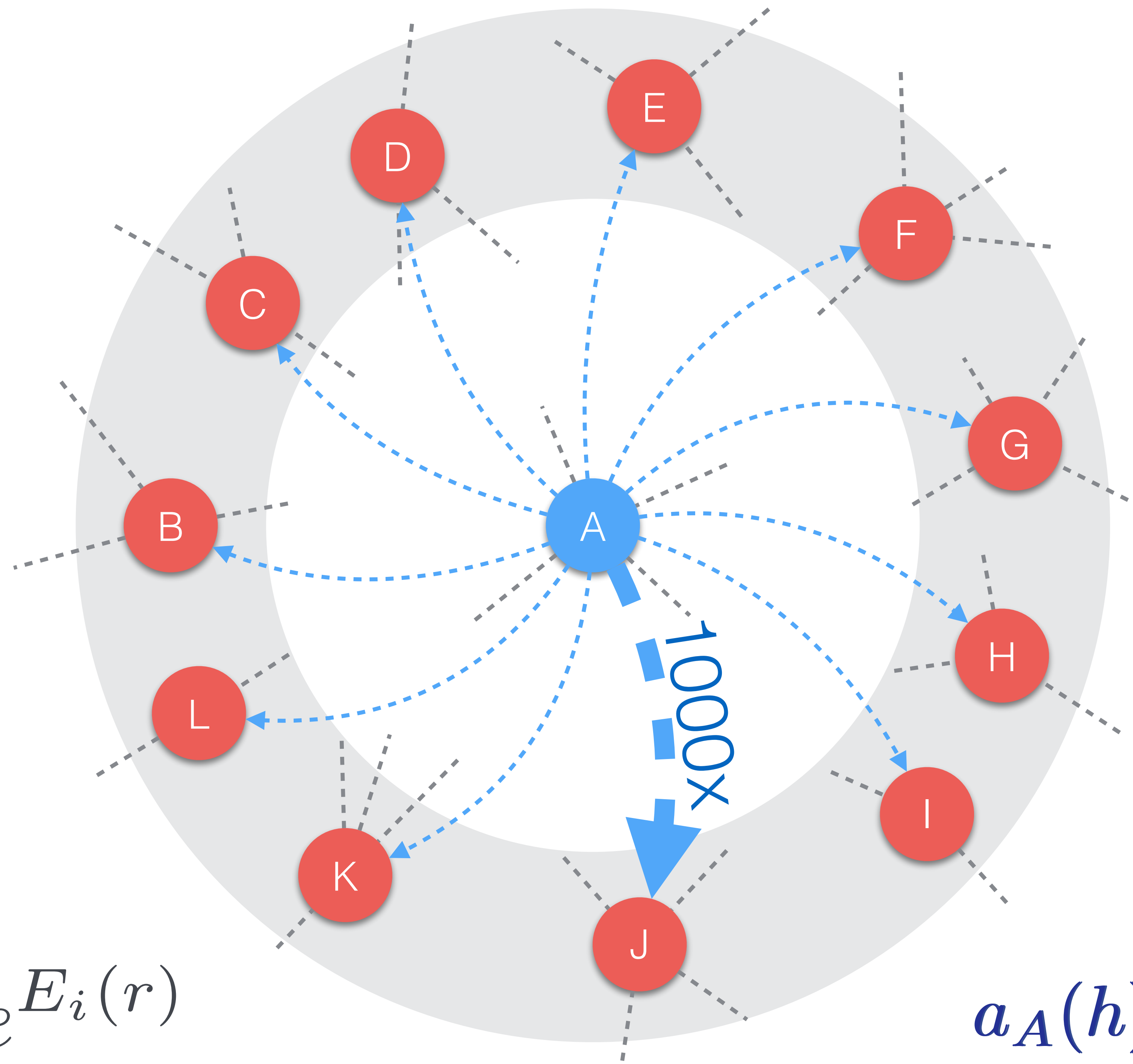
Concentric levels and properties

Balance between local and global measurements



COSTA, L. da F.; SILVA, F. N. Hierarchical characterization of complex networks. *Journal of Statistical Physics*, v. 125, n. 4, p. 845–876, 2006.

Accessibility

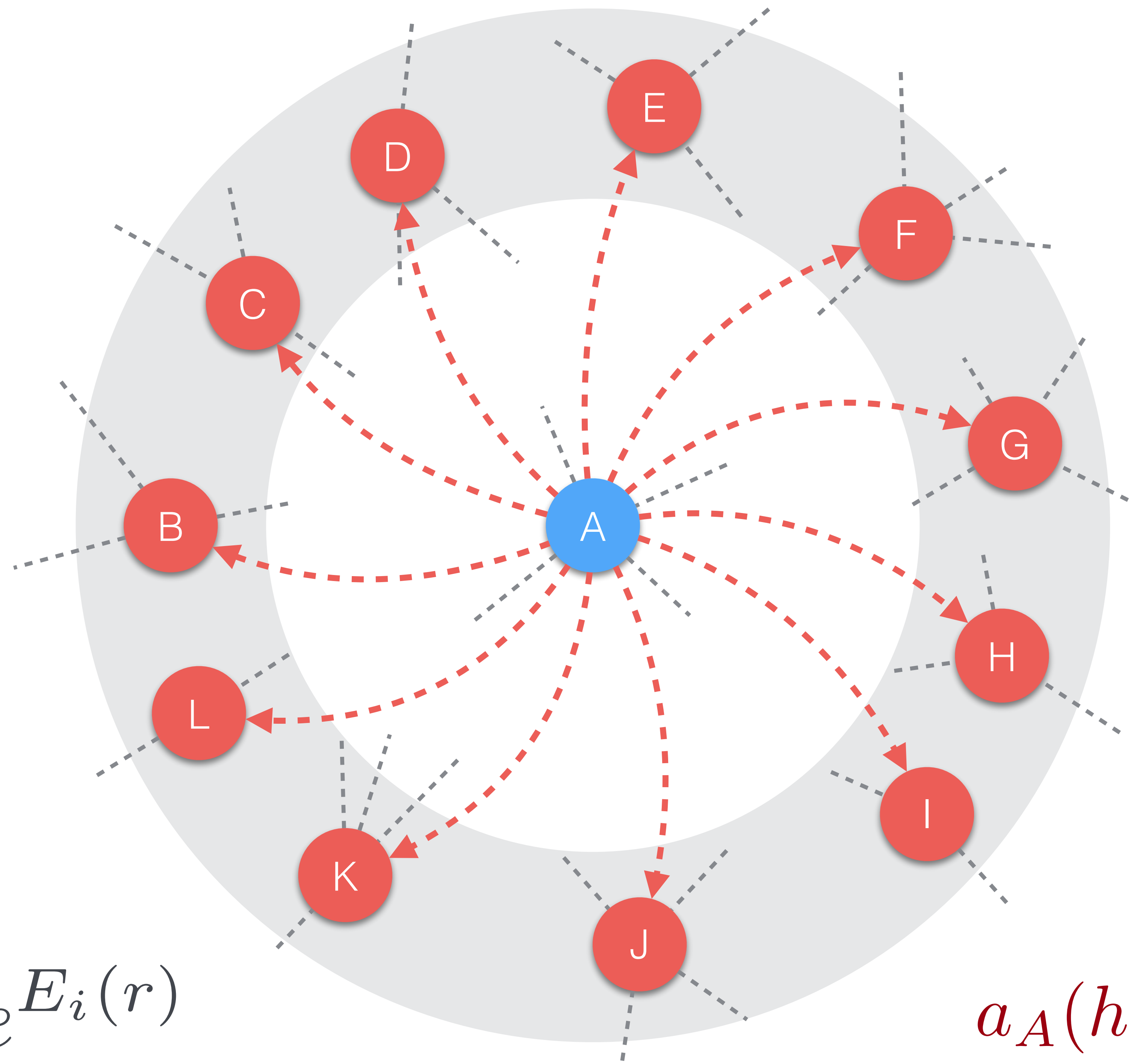


$$a_i(r) = e^{E_i(r)}$$

$$a_A(h) \approx 1.12$$

Viana, M. P.; Batista, J. a. L. B. and Costa, L. da F.
Effective number of accessed nodes in complex networks. *Phys. Rev. E*, v. 85, p. 036105, 2012.

Accessibility



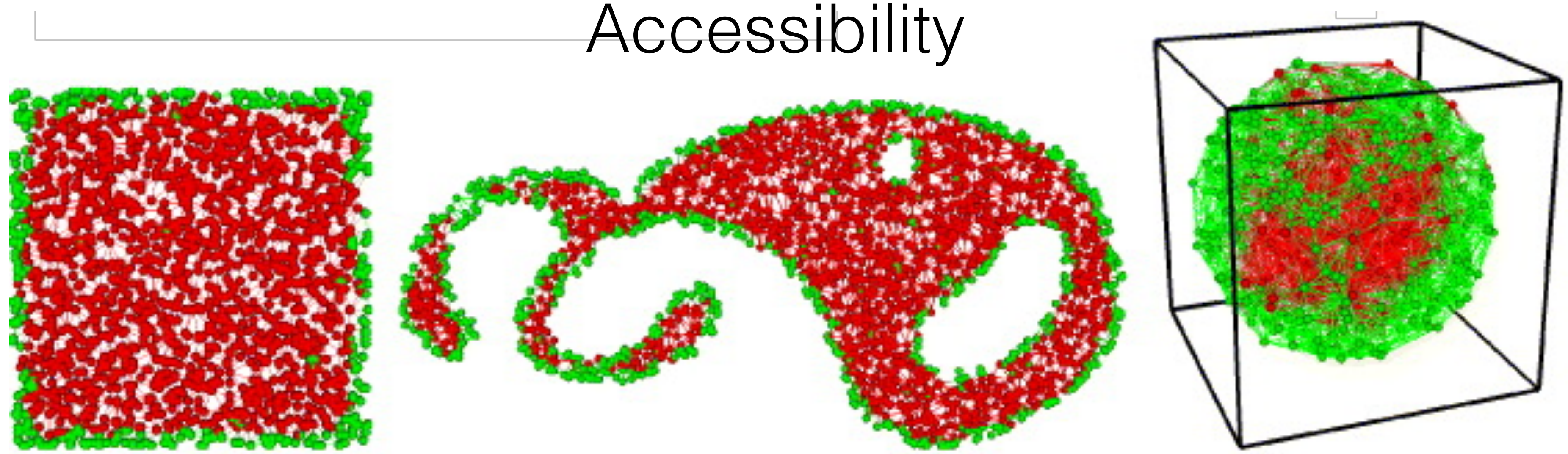
$$a_i(r) = e^{E_i(r)}$$

$$a_A(h) = 11$$

Viana, M. P.; Batista, J. a. L. B. and Costa, L. da F.
Effective number of accessed nodes in complex networks. *Phys. Rev. E*, v. 85, p. 036105, 2012.

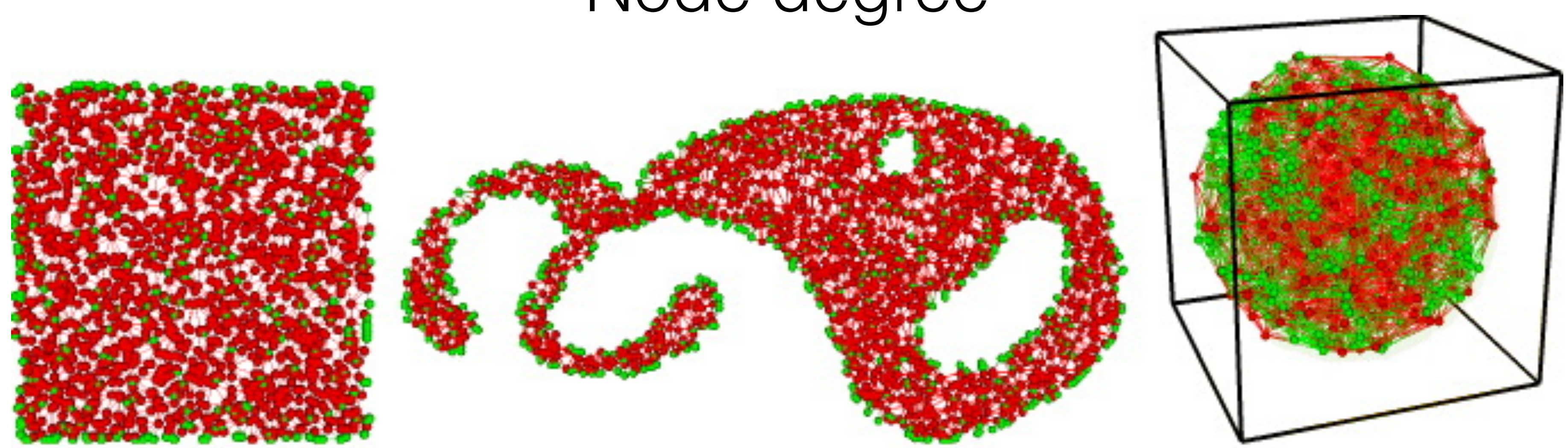
Accessibility

Accessibility



(d) (e) (f)

Node degree



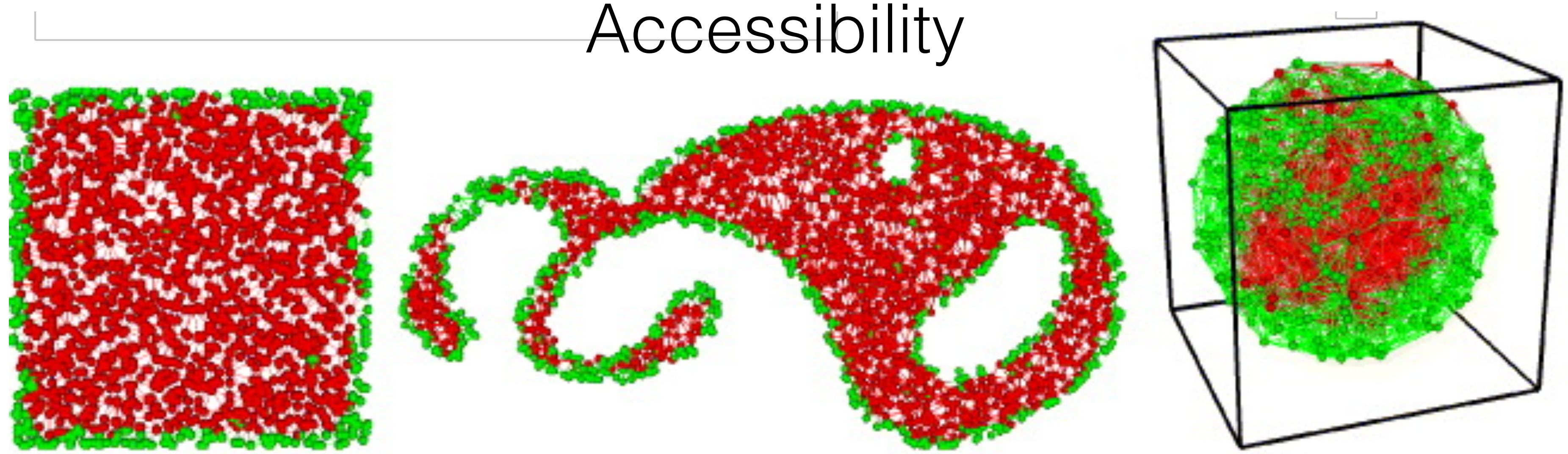
(a) (b) (c)

Good to detect borders on geographic networks

Figures from: Travençolo, B. A., Viana, M. P., & da Fontoura Costa, L. (2009) Border detection in complex networks. *New Journal of Physics*, *11*(6), 063019.

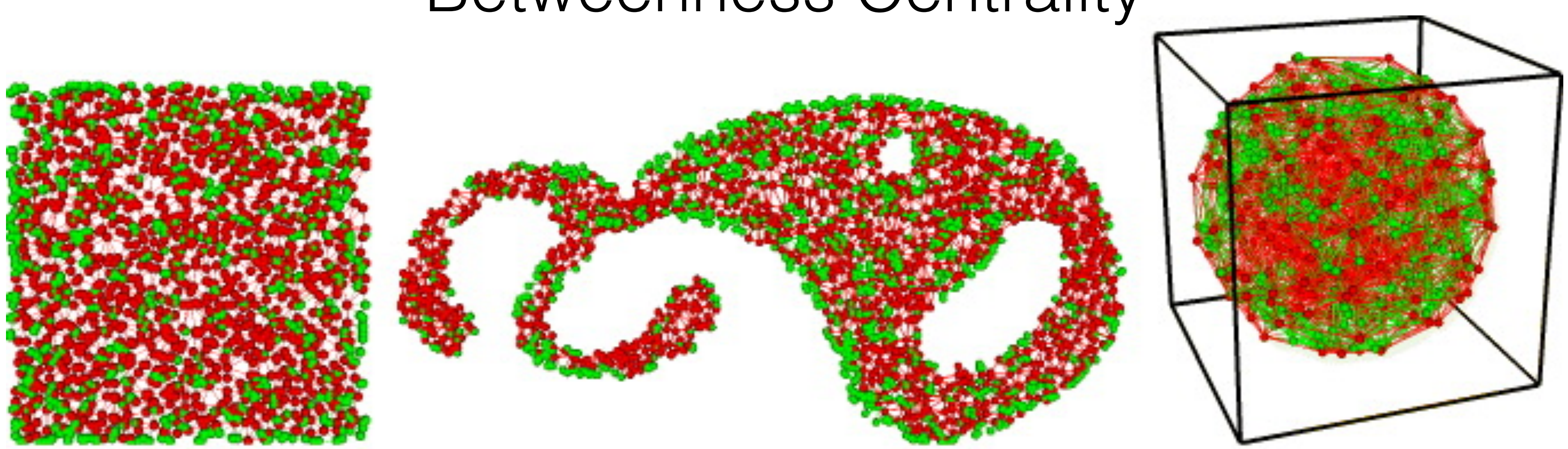
Accessibility

Accessibility



(d) (e) (f)

Betweenness Centrality



(a) (b) (c)

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Figures from: Travençolo, B. A., Viana, M. P., & da Fontoura Costa, L. (2009) Border detection in complex networks. *New Journal of Physics*, *11*(6), 063019.

Accessibility

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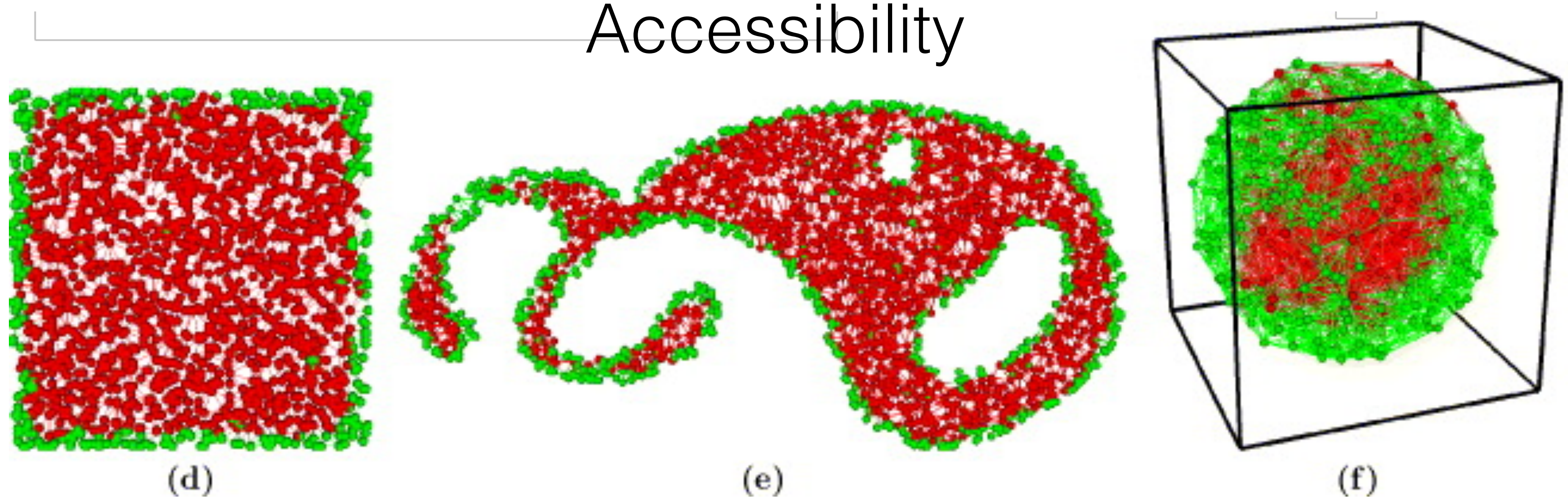
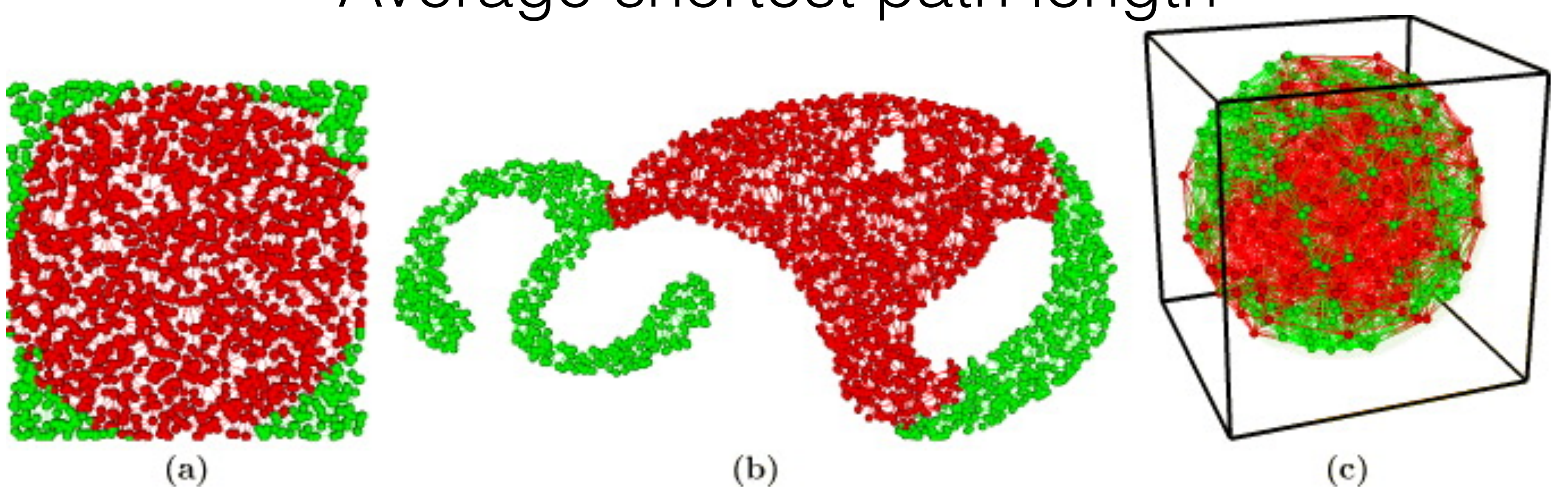


Average shortest path length



Good to detect borders on geographic networks

Figures from: Travençolo, B. A., Viana, M. P., & da Fontoura Costa, L. (2009) Border detection in complex networks. *New Journal of Physics*, *11*(6), 063019.

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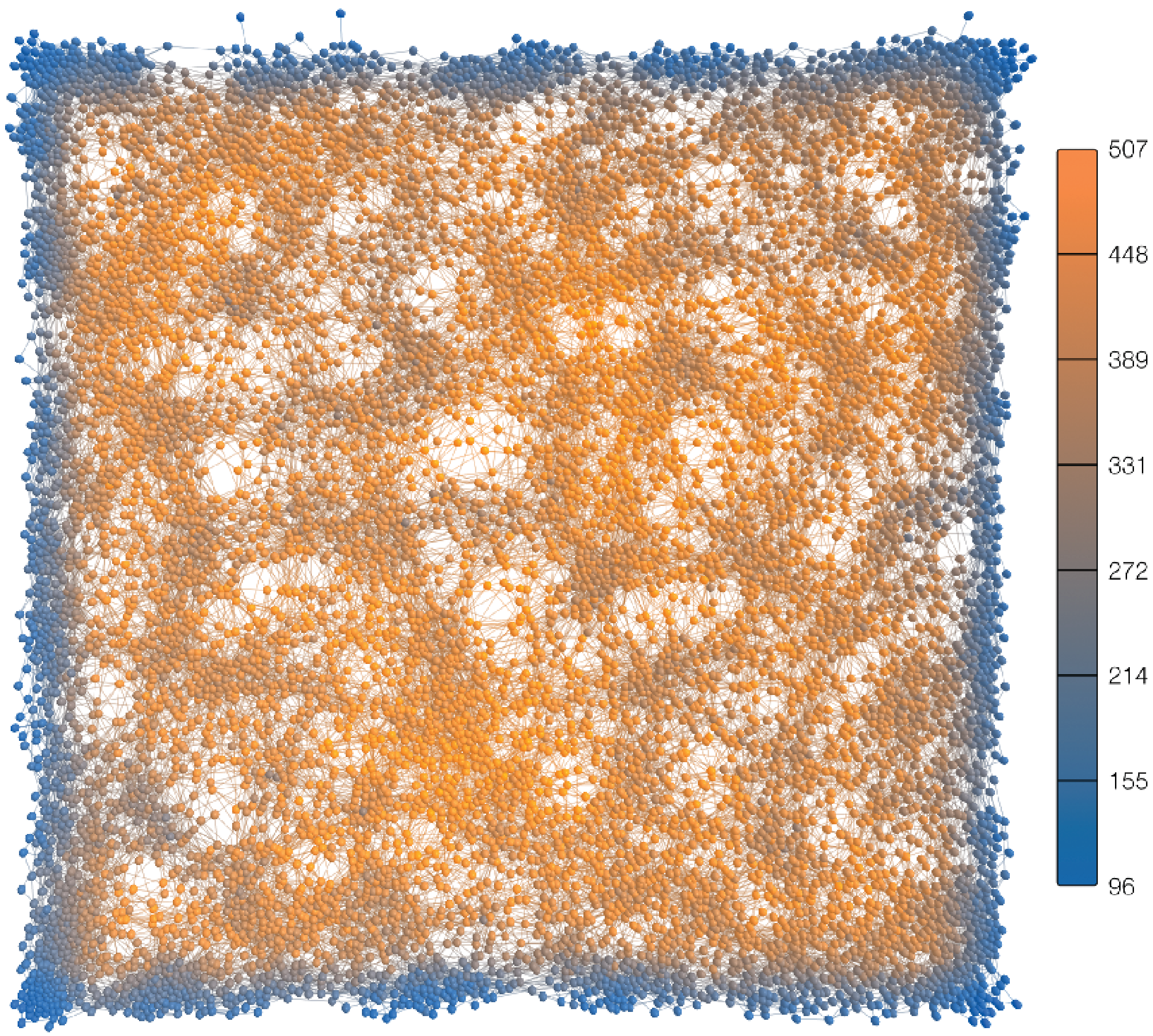
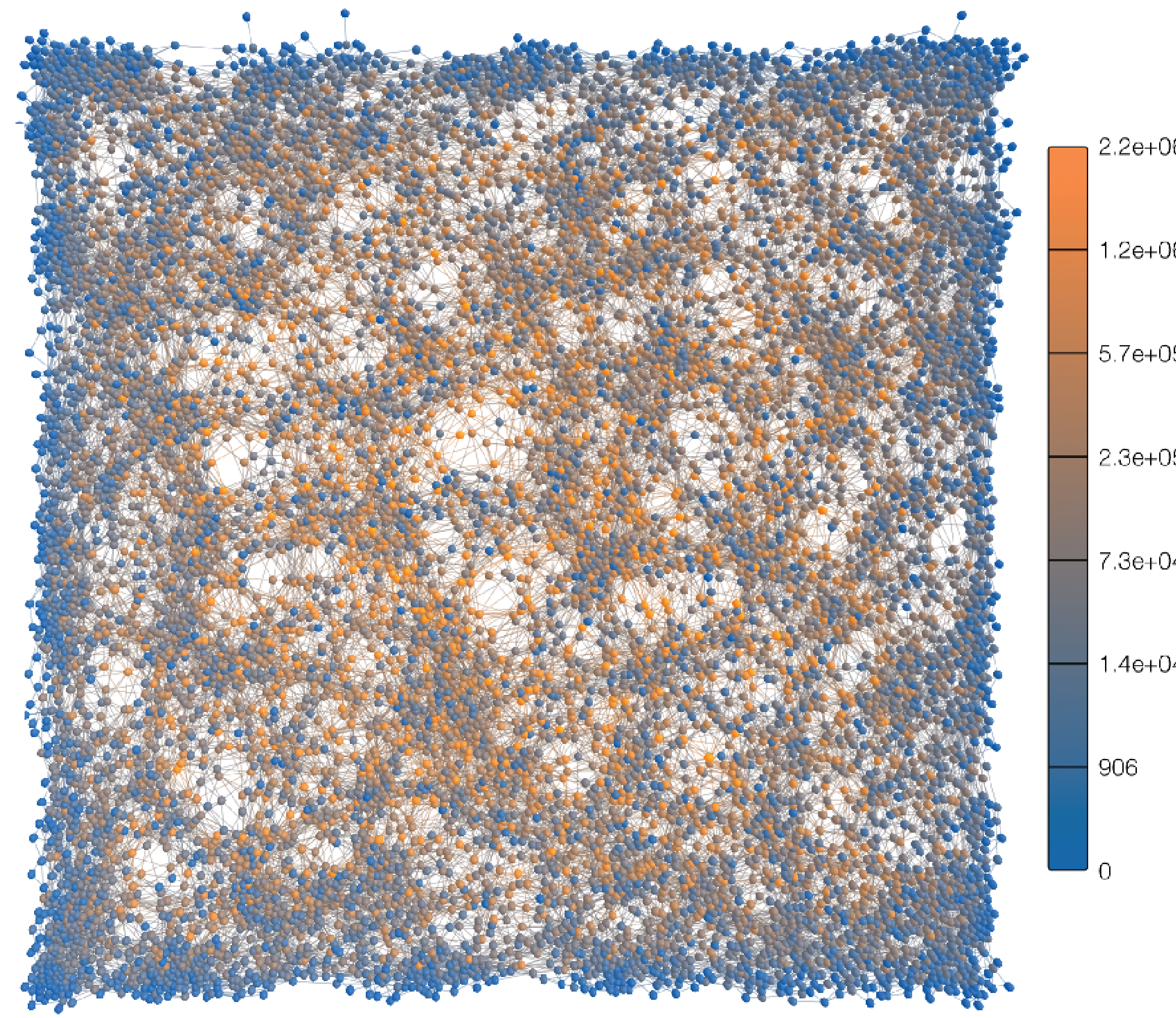


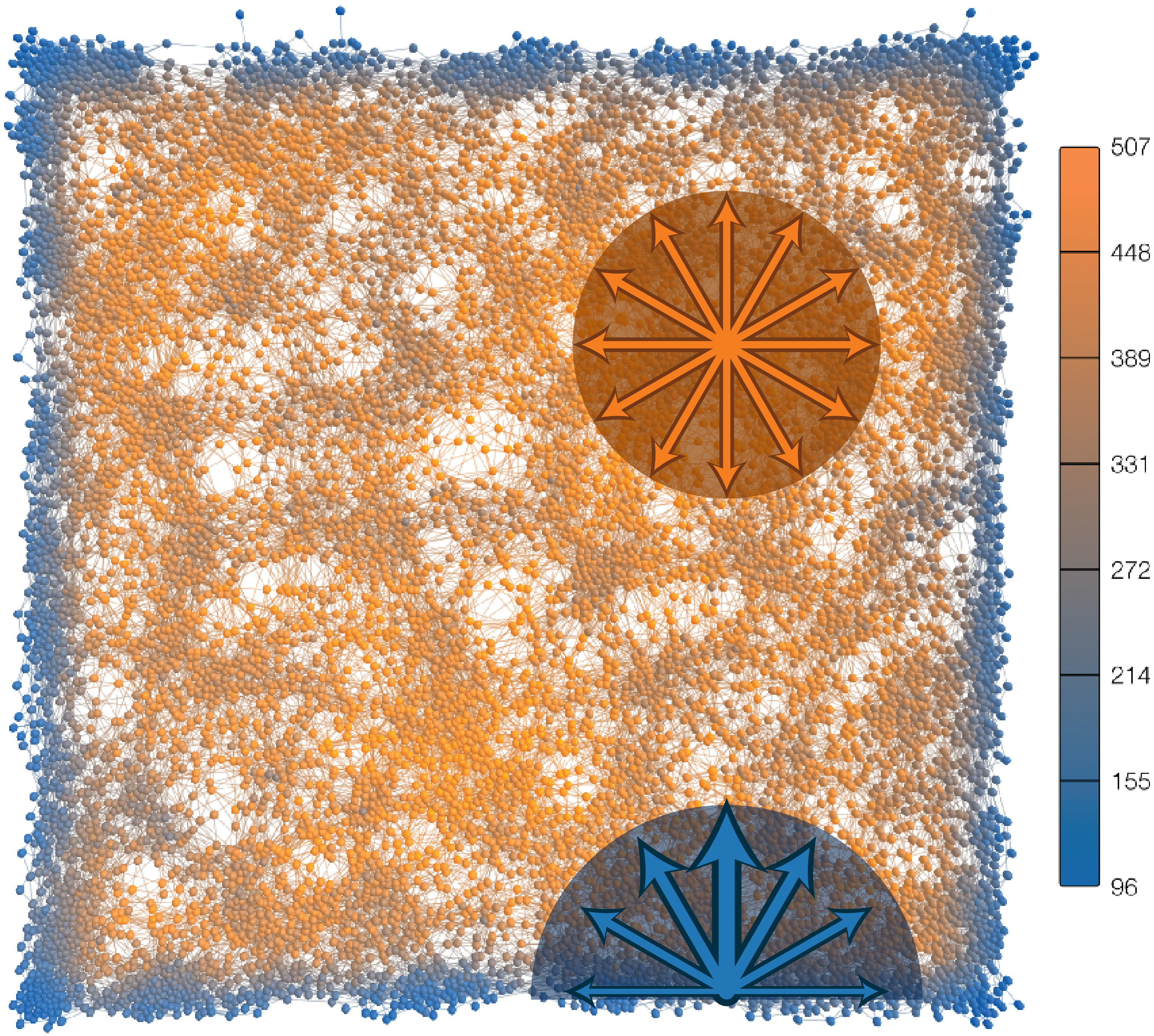
Accessibility (r=3)



Betweenness centrality

Good to detect borders on geographic networks

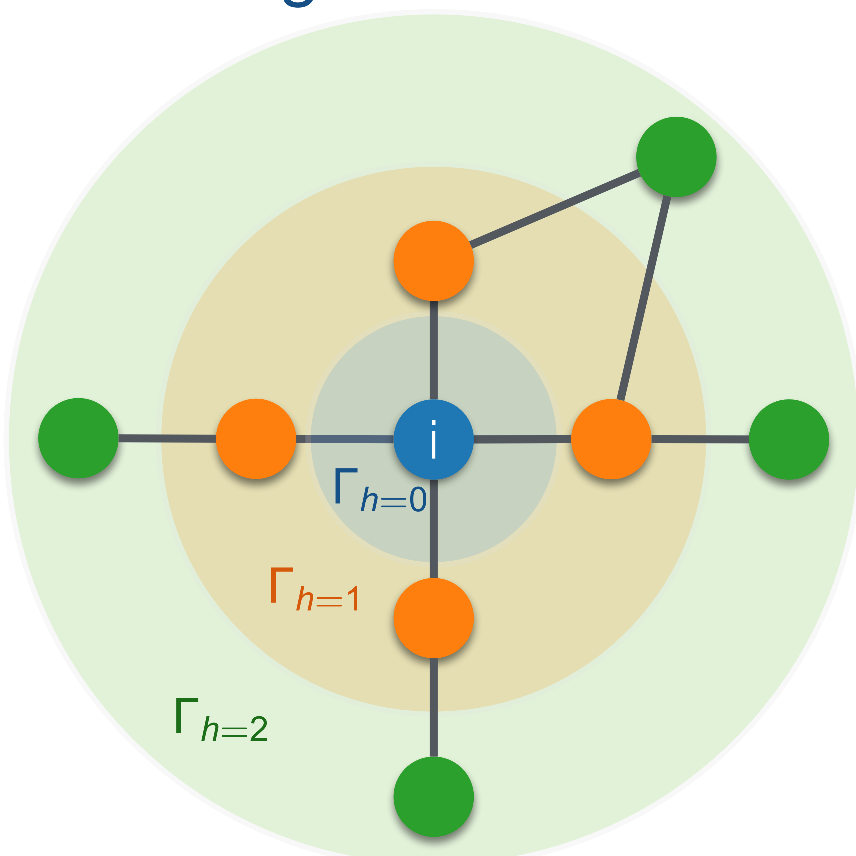
Accessibility



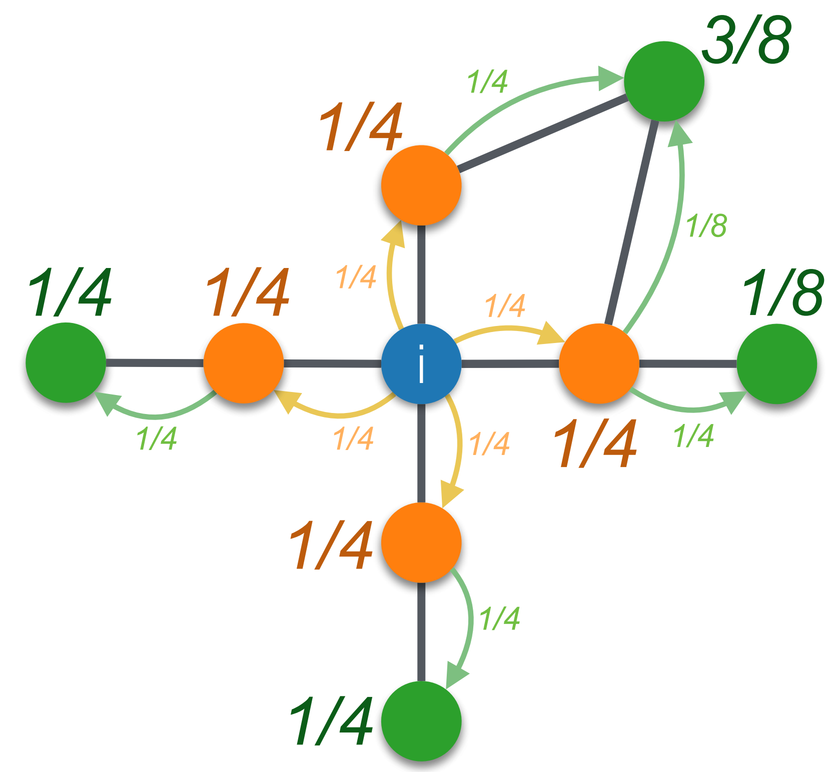
Accessibility (r=3)

Concentric symmetry

Original Pattern



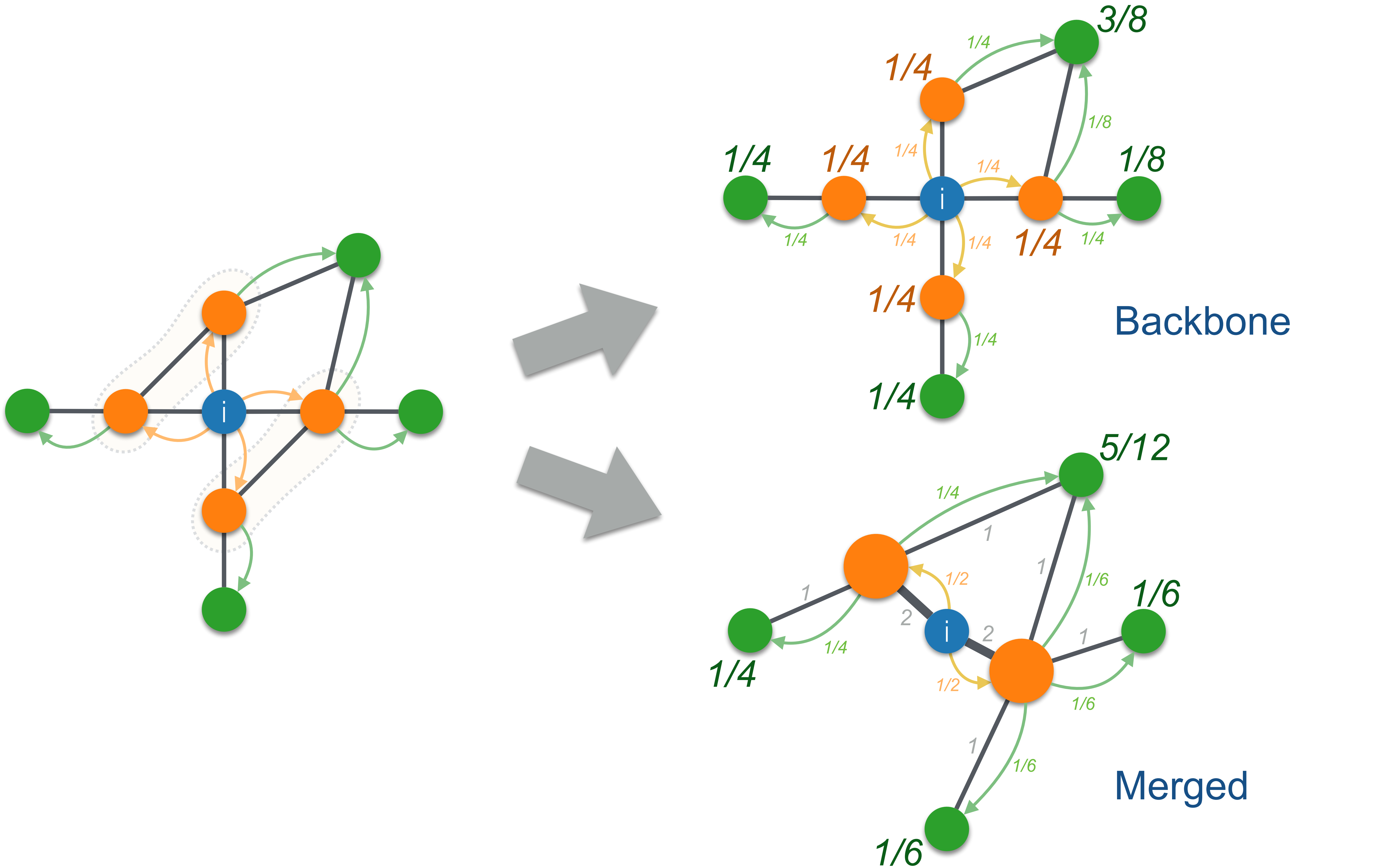
Transitions



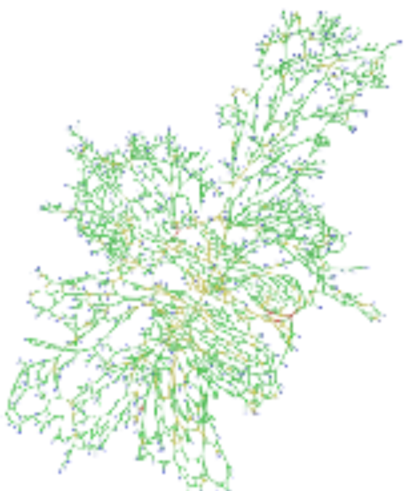
$$H_{h=3}(i) = \sum_{j \in \Gamma_{h=2}} P(i \rightarrow j) \ln(P(i \rightarrow j))$$

$$S_{h=3}(i) = \frac{e^{H_{h=3}(i)}}{|\Gamma_{h=2}|}$$

Concentric symmetry

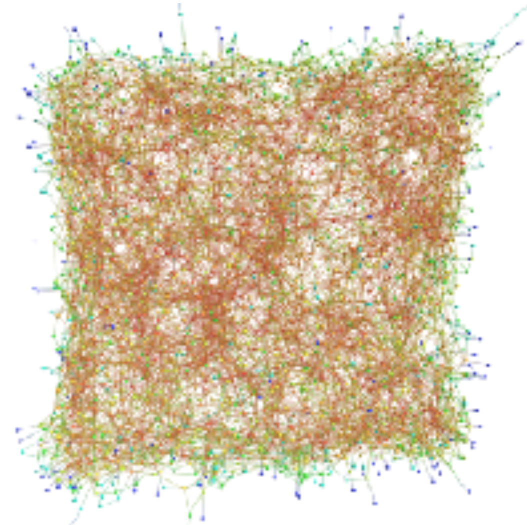


Results



Cities
(Oldenburg)

ER

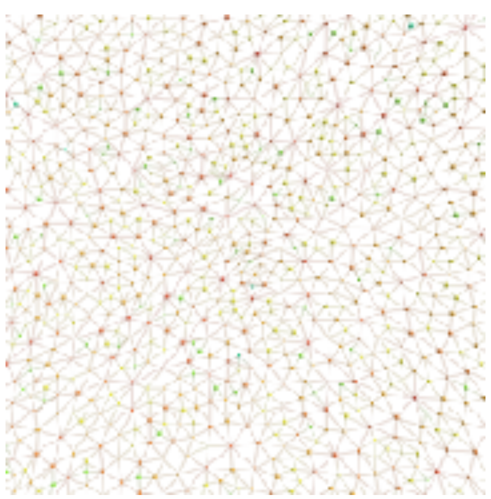


Random Geographic

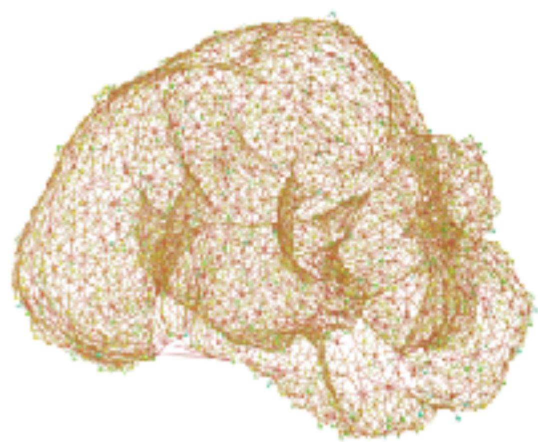
BA

Wikipedia

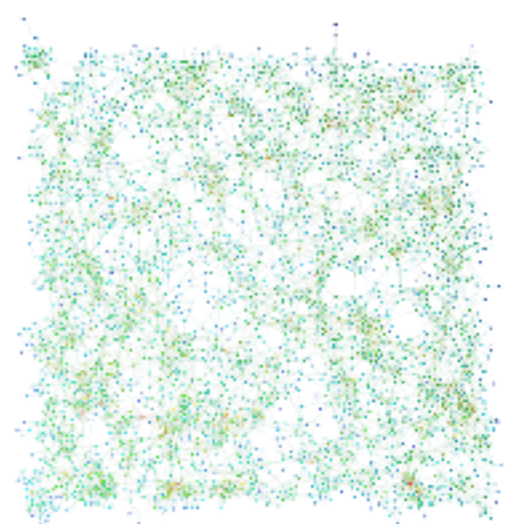
Voronoi



Rewired Voronoi



Waxman



Airports

http://cyvision.ifsc.usp.br/software/networks3d

Concentric Symmetry Results

ER (similar to BA)

	Backbone Symmetry h=2	Merged Symmetry h=2	Backbone Symmetry h=3	Merged Symmetry h=3	Backbone Symmetry h=4	Merged Symmetry h=4	Betweenness Centrality	Node Degree
Clustering Coefficient	0.00	0.00	-0.01	-0.00	-0.00	0.02	-0.02	-0.02
Node Degree	-0.04	-0.08	-0.09	-0.32	-0.16	-0.79	0.95	
Betweenness Centrality	-0.06	-0.10	-0.12	-0.36	-0.19	-0.70		
Merged Symmetry h=4	0.12	0.16	0.17	0.37	0.25			
Backbone Symmetry h=4	0.82	0.81	0.95	0.91				
Merged Symmetry h=3	0.80	0.80	0.93					
Backbone Symmetry h=3	0.87	0.86						
Merged Symmetry h=2	0.99							

Waxman (similar to other GEO models)

	Backbone Symmetry h=2	Merged Symmetry h=2	Backbone Symmetry h=3	Merged Symmetry h=3	Backbone Symmetry h=4	Merged Symmetry h=4	Betweenness Centrality	Node Degree
Clustering Coefficient	0.01	-0.04	-0.01	-0.05	-0.03	-0.02	0.01	0.03
Node Degree	-0.35	-0.64	-0.53	-0.36	-0.52	-0.18	0.29	
Betweenness Centrality	-0.06	-0.16	-0.12	-0.16	-0.14	-0.13		
Merged Symmetry h=4	0.07	0.21	0.12	0.35	0.13			
Backbone Symmetry h=4	0.44	0.53	0.72	0.35				
Merged Symmetry h=3	0.11	0.42	0.18					
Backbone Symmetry h=3	0.65	0.50						
Merged Symmetry h=2	0.30							

F.N. Silva, C.H. Comin, T.K.DM. Peron, F.A. Rodrigues, C.Ye, R.C. Wilson, E. Hancock, L. da F. Costa
Concentric network symmetry. *Information Sciences*, v. 333, p. 61 – 80, 2015. doi: 10.1016/j.ins.2015.11.014.

Concentric Symmetry Results

San Joaquin (matrix similar to Oldenburg)

	Backbone Symmetry h=2	Merged Symmetry h=2	Backbone Symmetry h=3	Merged Symmetry h=3	Backbone Symmetry h=4	Merged Symmetry h=4	Betweenness Centrality	Node Degree
Clustering Coefficient	0.01	0.02	0.00	0.01	-0.00	-0.02	0.10	0.03
Node Degree	-0.35	-0.40	-0.40	-0.41	-0.38	-0.35	0.24	
Betweenness Centrality	0.08	0.07	0.07	0.06	0.04	0.02		
Merged Symmetry h=4	0.30	0.32	0.60	0.62	0.92			
Backbone Symmetry h=4	0.29	0.31	0.63	0.64				
Merged Symmetry h=3	0.53	0.54	0.95					
Backbone Symmetry h=3	0.54	0.55						
Merged Symmetry h=2	0.96							

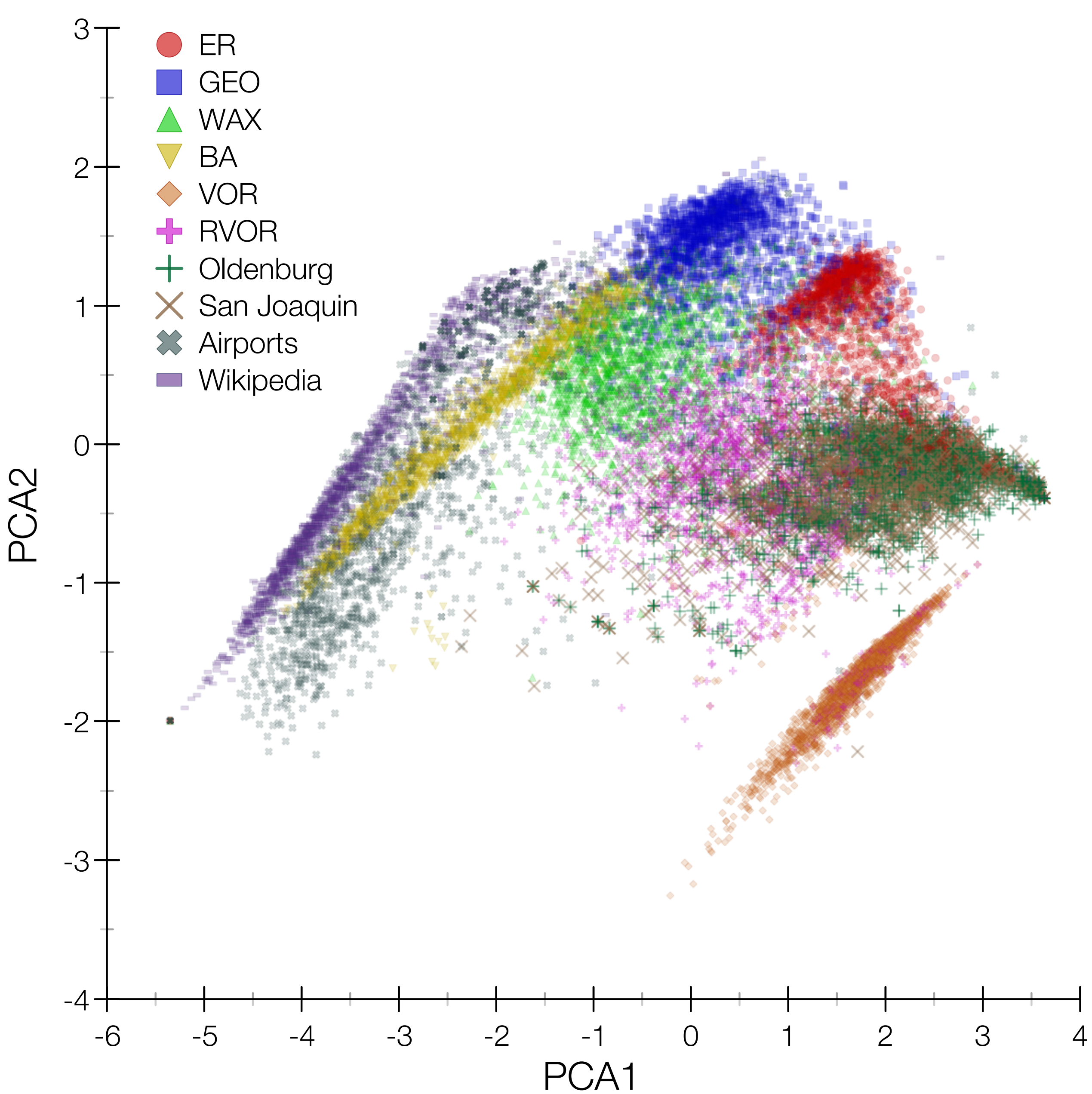
Wikipedia (matrix similar to airport)

	Backbone Symmetry h=2	Merged Symmetry h=2	Backbone Symmetry h=3	Merged Symmetry h=3	Backbone Symmetry h=4	Merged Symmetry h=4	Betweenness Centrality	Node Degree
Clustering Coefficient	-0.05	-0.10	-0.05	-0.05	-0.00	-0.02	0.00	0.02
Node Degree	-0.31	-0.27	-0.16	-0.11	-0.12	0.06	0.78	
Betweenness Centrality	-0.11	-0.09	-0.05	-0.03	-0.04	0.10		
Merged Symmetry h=4	0.10	0.21	0.29	0.57	0.46			
Backbone Symmetry h=4	0.46	0.31	0.72	0.51				
Merged Symmetry h=3	0.30	0.57	0.63					
Backbone Symmetry h=3	0.65	0.63						
Merged Symmetry h=2	0.63							

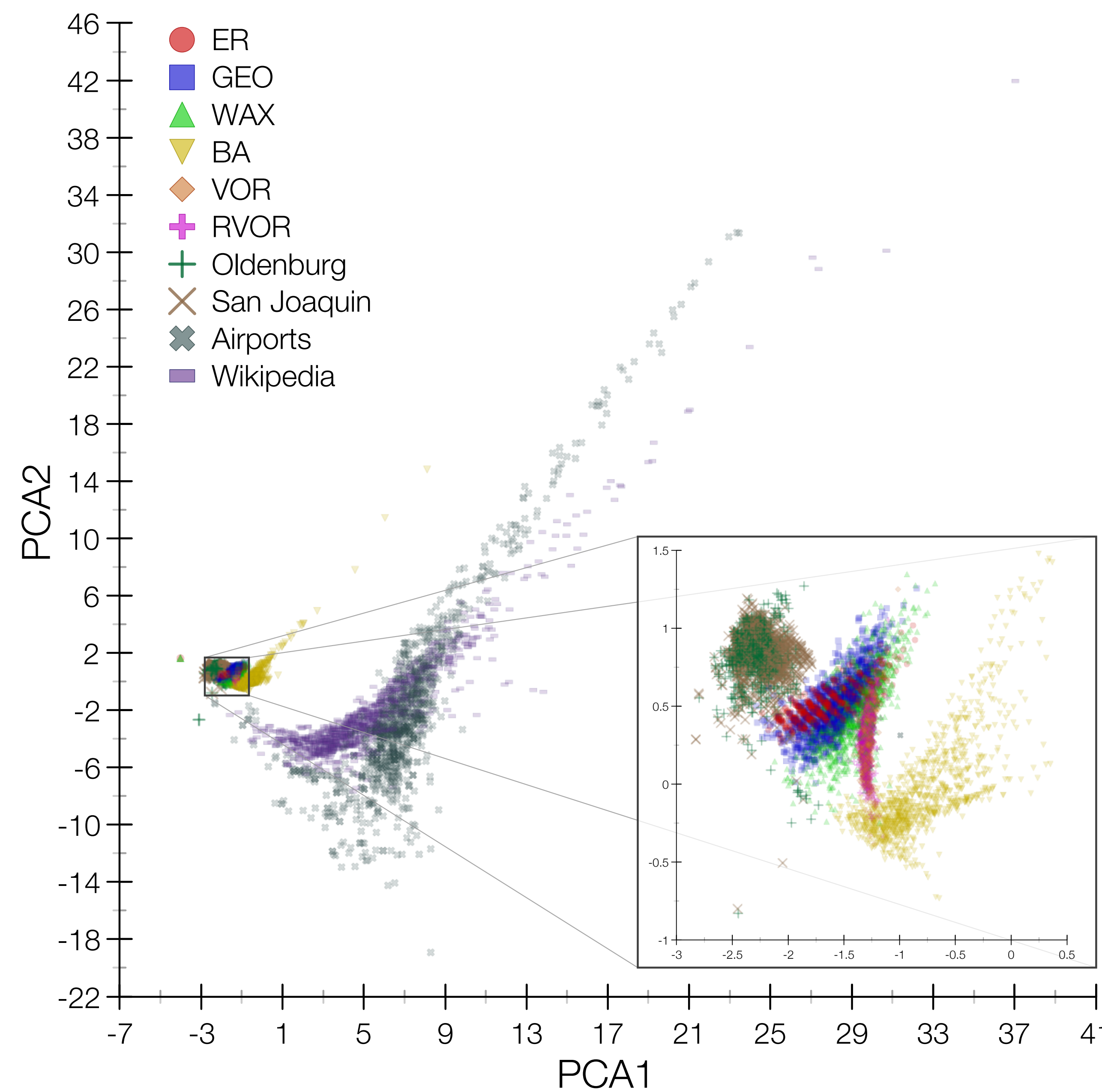
F.N. Silva, C.H. Comin, T.K.DM. Peron, F.A. Rodrigues, C.Ye, R.C. Wilson, E. Hancock, L. da F. Costa
Concentric network symmetry. *Information Sciences*, v. 333, p. 61 – 80, 2015. doi: 10.1016/j.ins.2015.11.014.

Concentric Symmetry Results

Concentric symmetry



Traditional measurements



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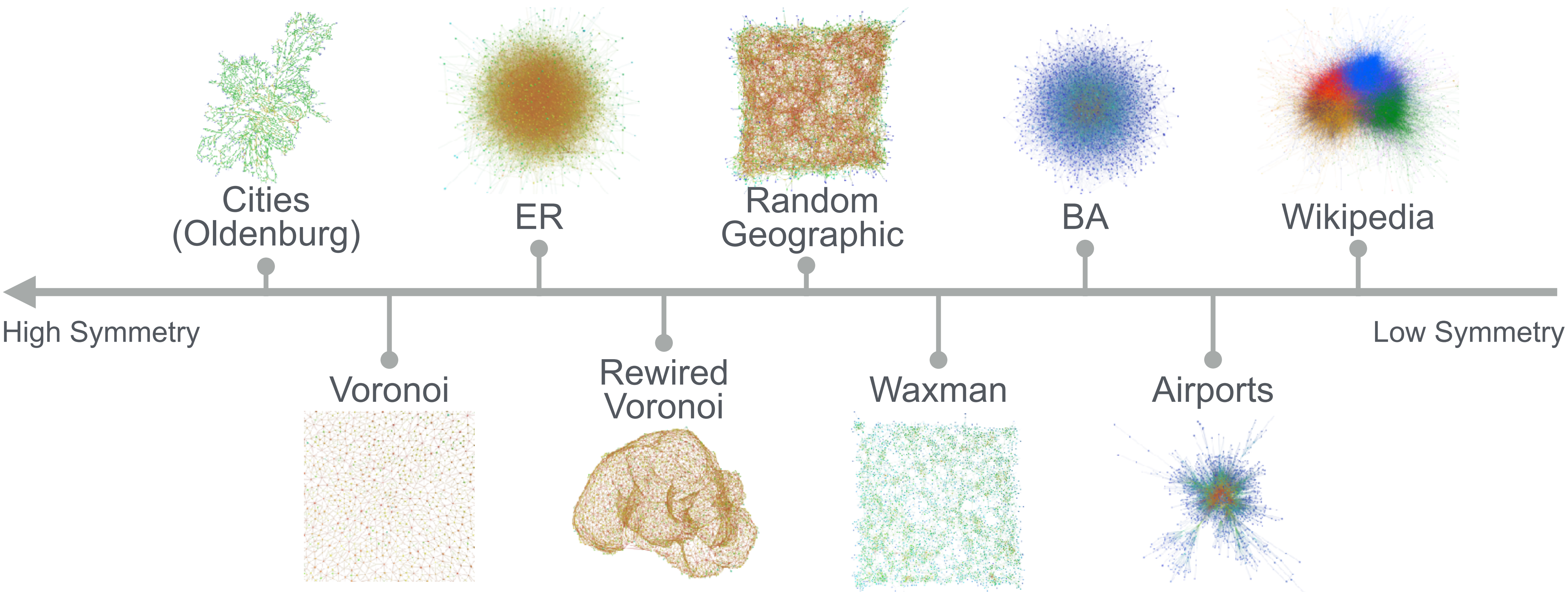
Concentric network symmetry. *Information Sciences*, v. 333, p. 61 – 80, 2015. doi: 10.1016/j.ins.2015.11.014.

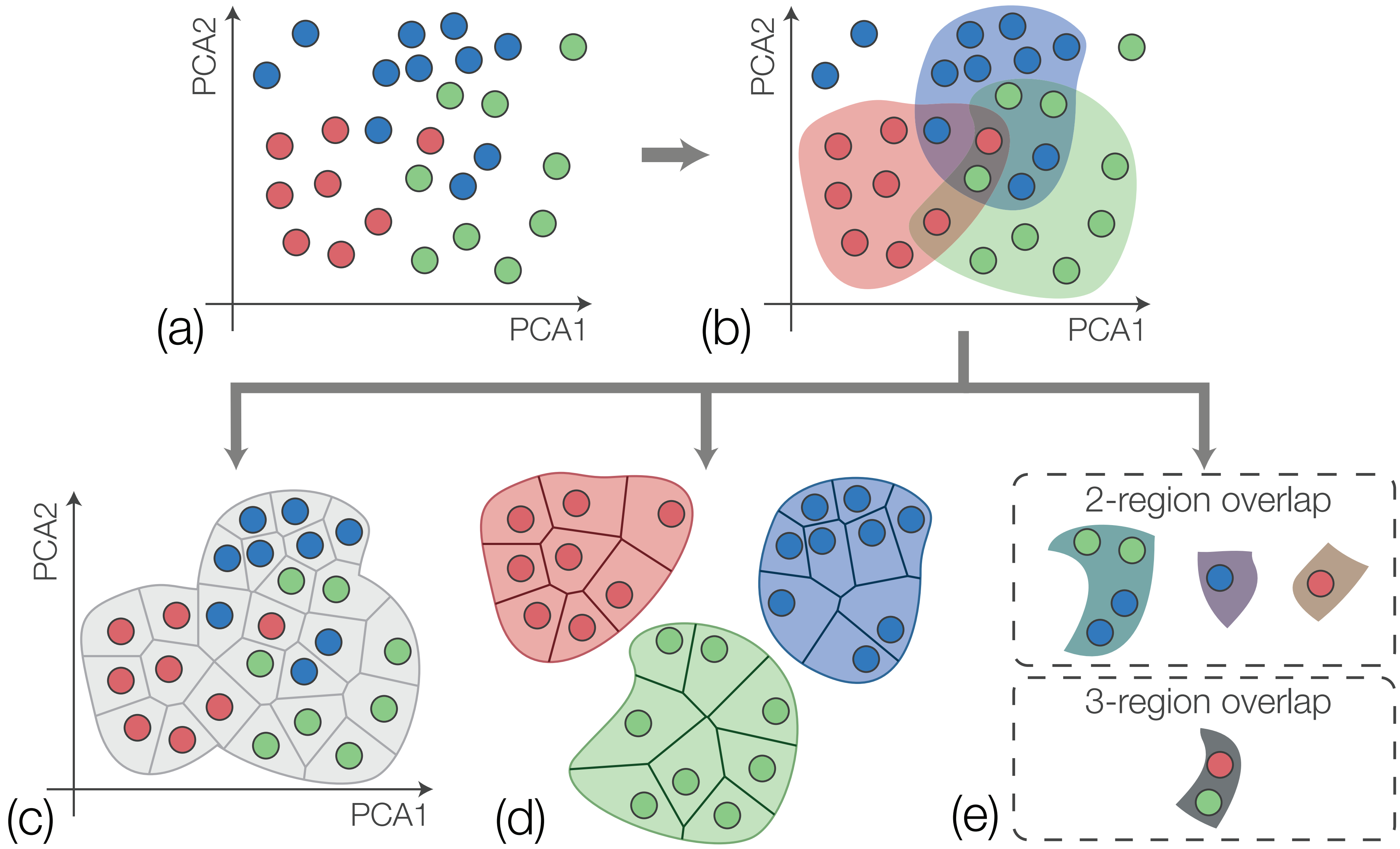
Concentric Symmetry Results

- Concentric symmetries
  - Do not correlate with traditional network measurements.
  - Discriminate between a diverse range of models and real networks.
  - Can be used to rank networks by their "average" symmetry.



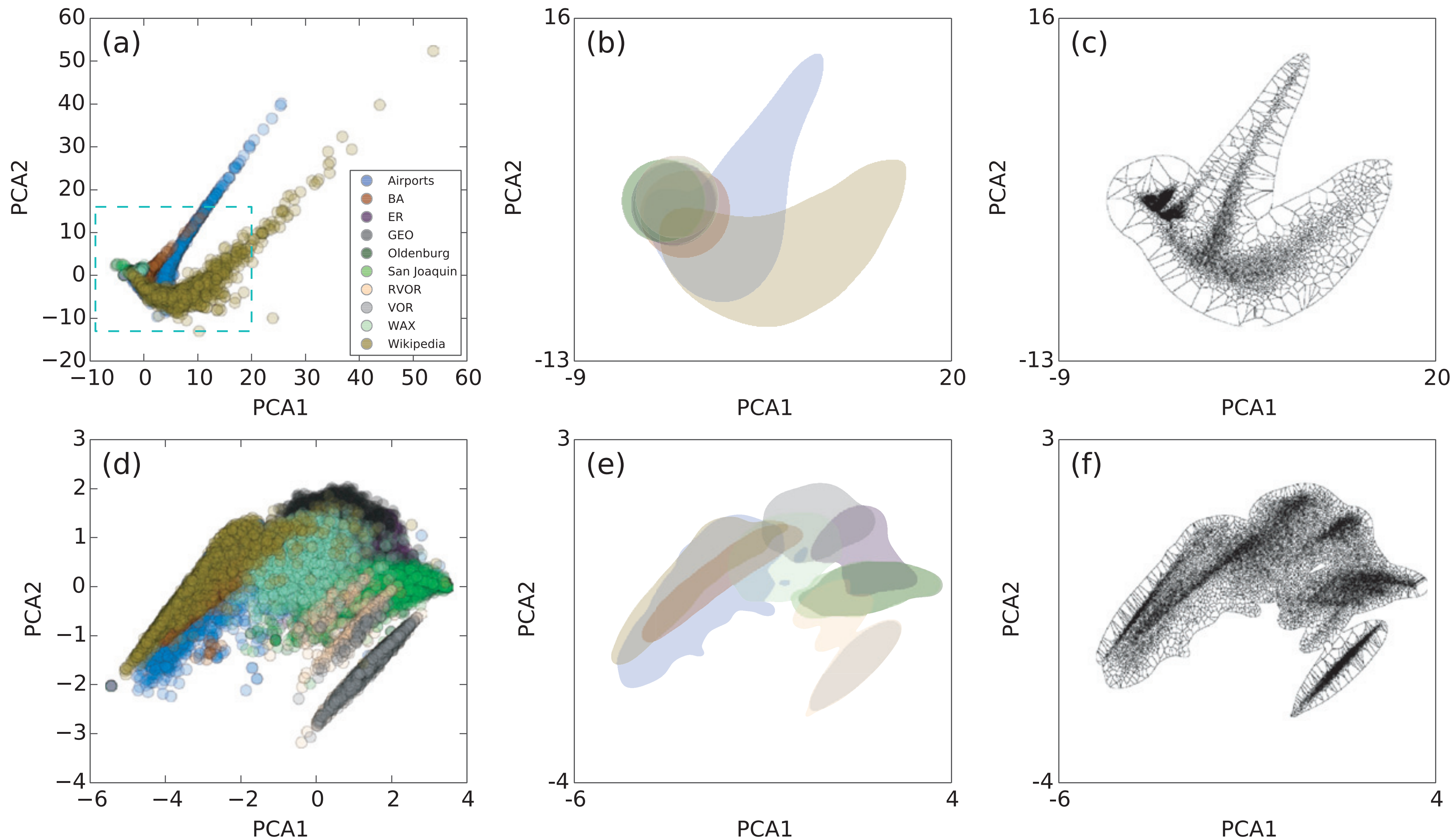
F.N. Silva, C.H. Comin, T.K.DM. Peron, F.A. Rodrigues, C.Ye, R.C. Wilson, E. Hancock, L. da F. Costa
Concentric network symmetry. *Information Sciences*, v. 333, p. 61 – 80, 2015. doi: 10.1016/j.ins.2015.11.014.

Evaluating symmetry



Comin, C. H., Silva, F. N., & Costa, L. D. F. (2015).
A framework for evaluating complex networks measurements. *EPL (Europhysics Letters)*, *110*(6), 68002.

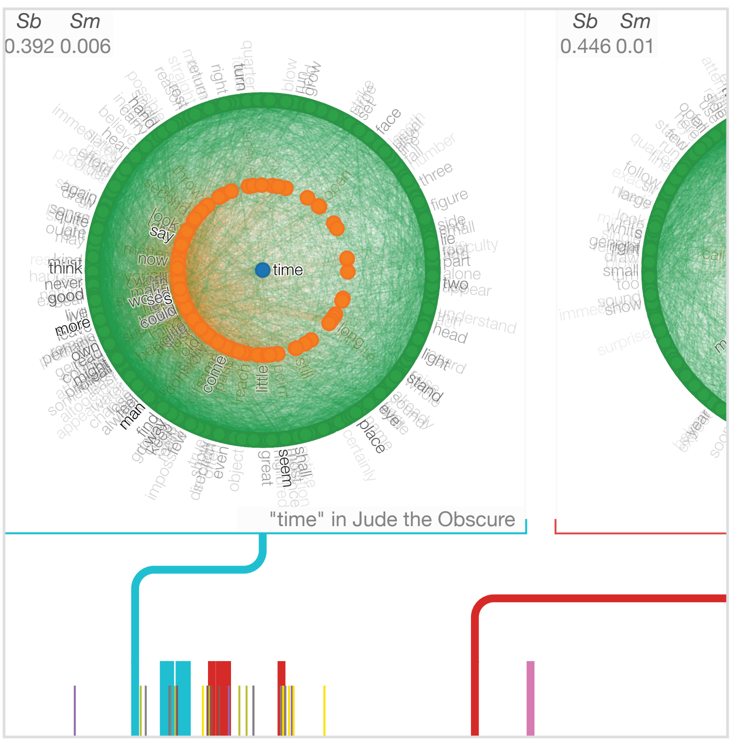
Evaluating symmetry



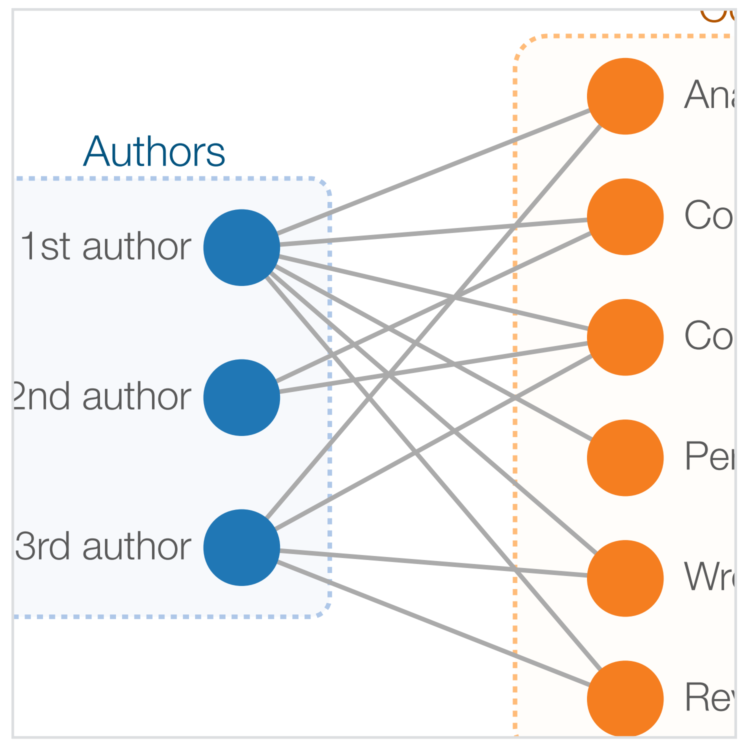
	Traditional	Symmetry
Exclusion	0.24 ± 0.05	0.848 ± 0.002
Global evenness	0.05 ± 0.01	0.387 ± 0.005
Average evenness	0.05 ± 0.01	0.447 ± 0.003

Comin, C. H., Silva, F. N., & Costa, L. D. F. (2015).
A framework for evaluating complex networks measurements. *EPL (Europhysics Letters)*, *110*(6), 68002.

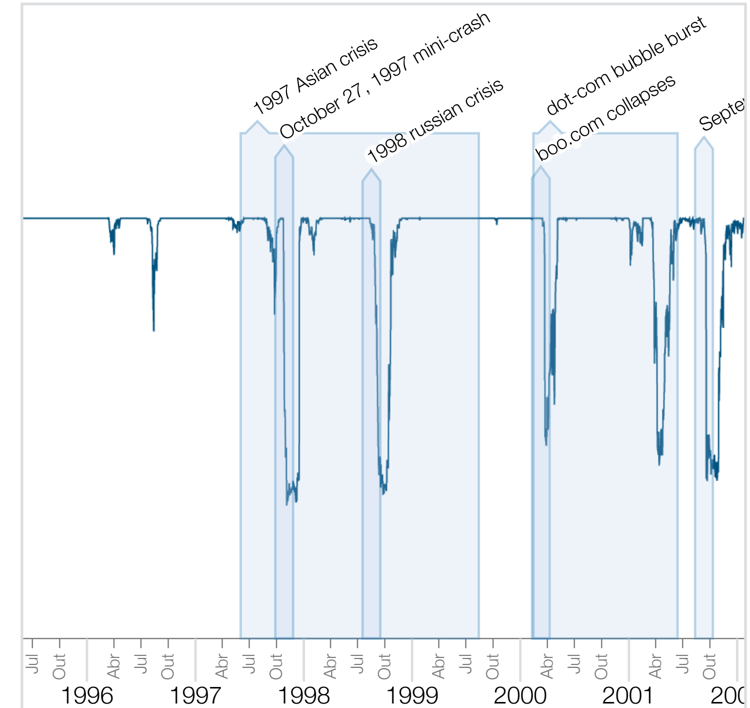
Applications



Authorship detection of books



Characterizing authors contributions



Detecting anomalies in networks generated from time series

Other uses of concentric symmetry performed by collaborators

Amancio DR (2015) A Complex Network Approach to Stylometry. PLOS ONE 10(8): e0136076. https://doi.org/10.1371/journal.pone.0136076

Arruda, H. F., Costa, L.da F. and Amancio, D.R., (2016) Using complex networks for text classification: Discriminating informative and imaginative documents. EPL (Europhysics Letters), 113(2), p.28007. https://doi.org/10.1209/0295-5075/113/28007

Current interests

References

COSTA, L. da F. et al.
Analyzing and modeling real-world phenomena with complex networks: a survey of applications
Advances in Physics, v. 60, n. 3, p. 329--412, 2011.

COSTA, L. da F.; SILVA, F. N.
Hierarchical characterization of complex networks
Journal of Statistical Physics, v. 125, n. 4, p. 845–876, 2006.

COSTA, L. da F.; TOGNETTI, M. A. R.; SILVA, F. N.
Concentric characterization and classification of complex network nodes: Application to an institutional collaboration network
Physica A, v. 387, n. 24, p. 6201--6214, 2008.

SILVA, F.N.; COMIN, C.H.; PERON, T.K.DM.; RODRIGUES, F.A.; Ye, C.; WILSON, R.C.; HANCOCK, E.; COSTA, L. da F.
Concentric network symmetry
Information Sciences, v. 333, p. 61 – 80, 2015.

COMIN, C. H.; SILVA, F. N.; COSTA, L. da F.
A framework for evaluating complex networks measurements.
EPL (Europhysics Letters), 110(6), 68002, 2015.

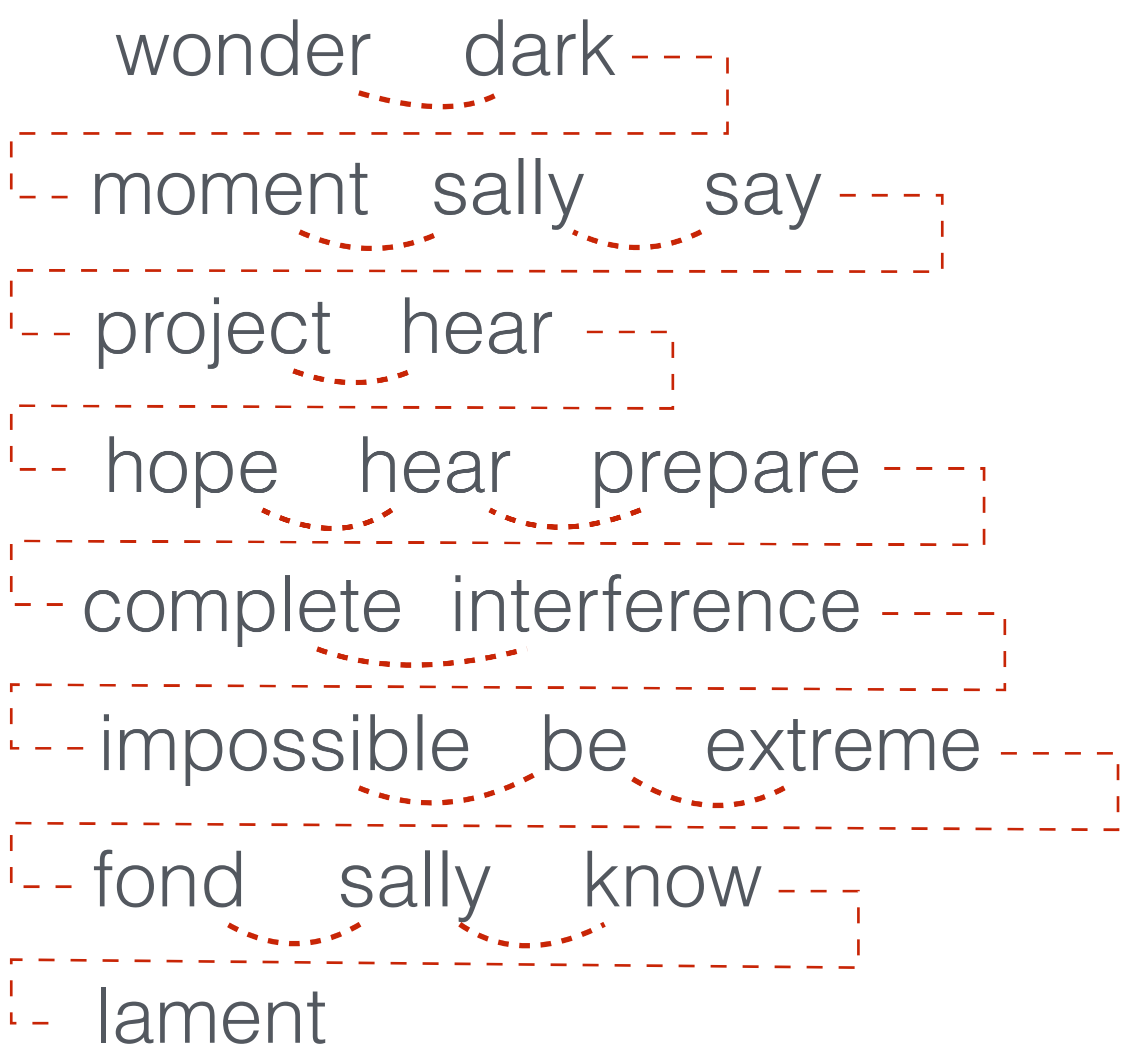
AMANCIO, D. R.; SILVA, F. N.; COSTA, L. da F.
Concentric network symmetry grasps authors' styles in word adjacency networks
EPL (Europhysics Letters). Volume 110, Issue 6, 68001, 2015.

http://cyvision.ifsc.usp.br/software/networks3d

Thanks!

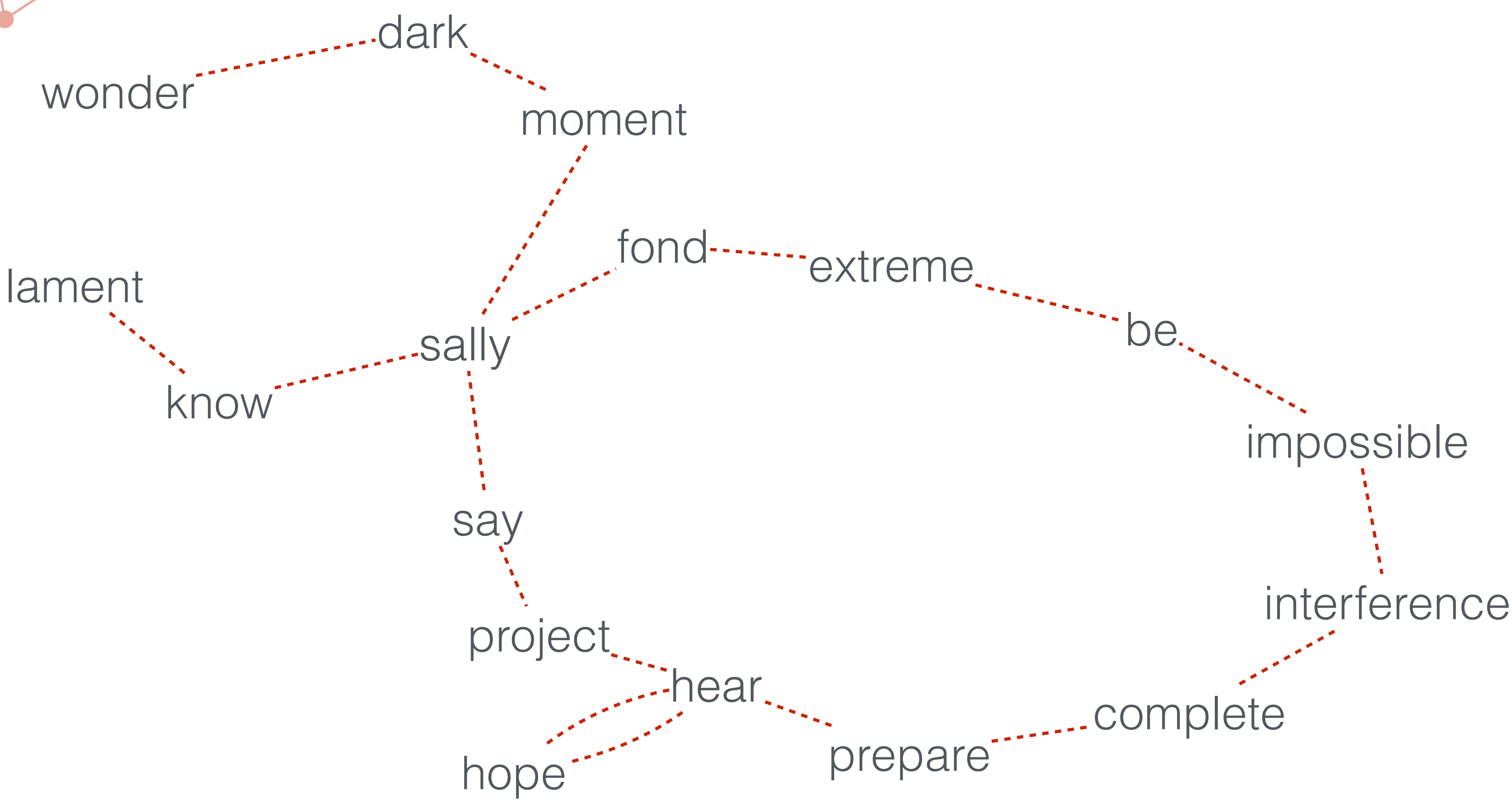
filipinascimento@gmail.com

Symmetry of adjacency networks



Concentric network symmetry grasps authors' styles in word adjacency networks
D.R. Amancio and F.N. Silva and L. da F. Costa
Europhysics Letters. Volume 110, Issue 6, 68001 (2015)

Symmetry of adjacency networks



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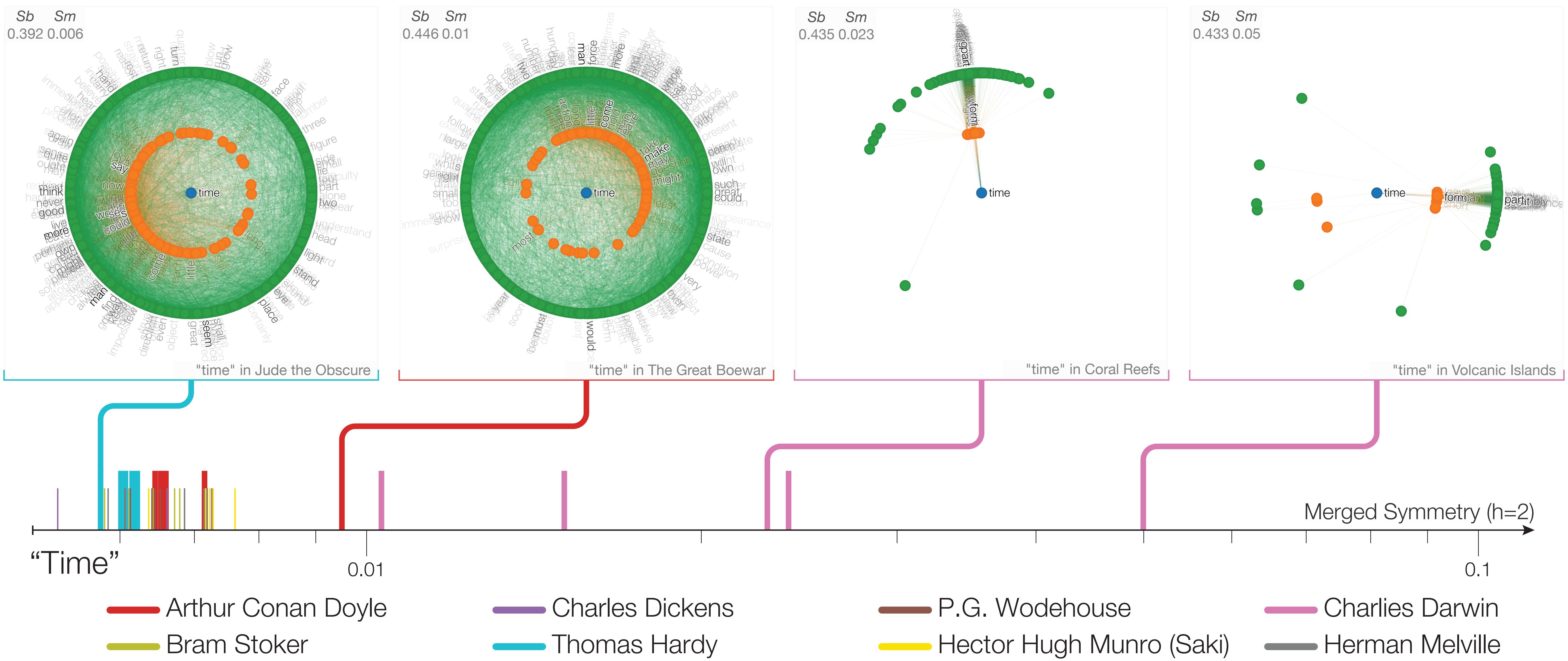
Symmetry of adjacency networks



8 authors

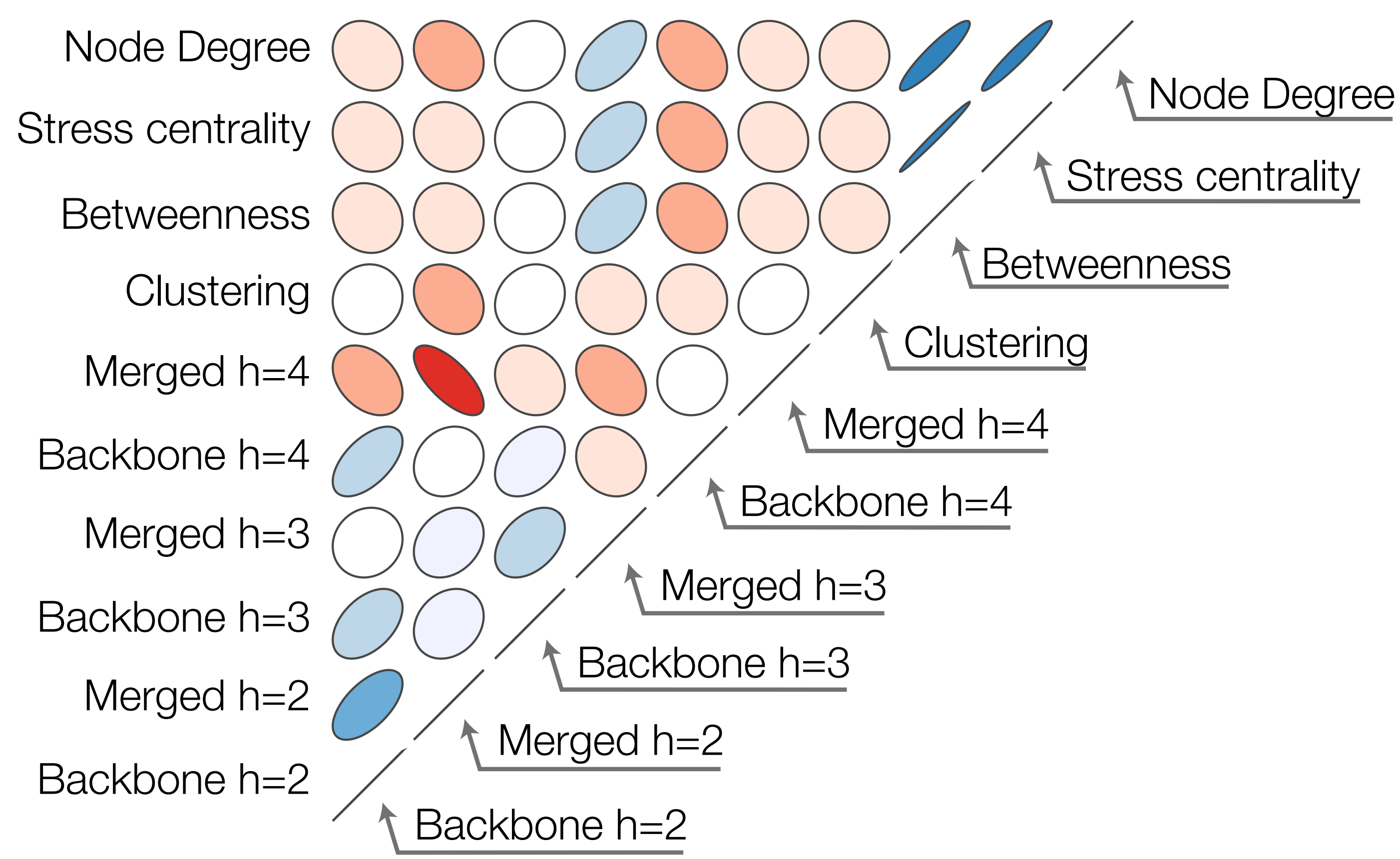
Concentric network symmetry grasps authors' styles in word adjacency networks
D.R. Amancio and F.N. Silva and L. da F. Costa
Europhysics Letters. Volume 110, Issue 6, 68001 (2015)

Symmetry of adjacency networks

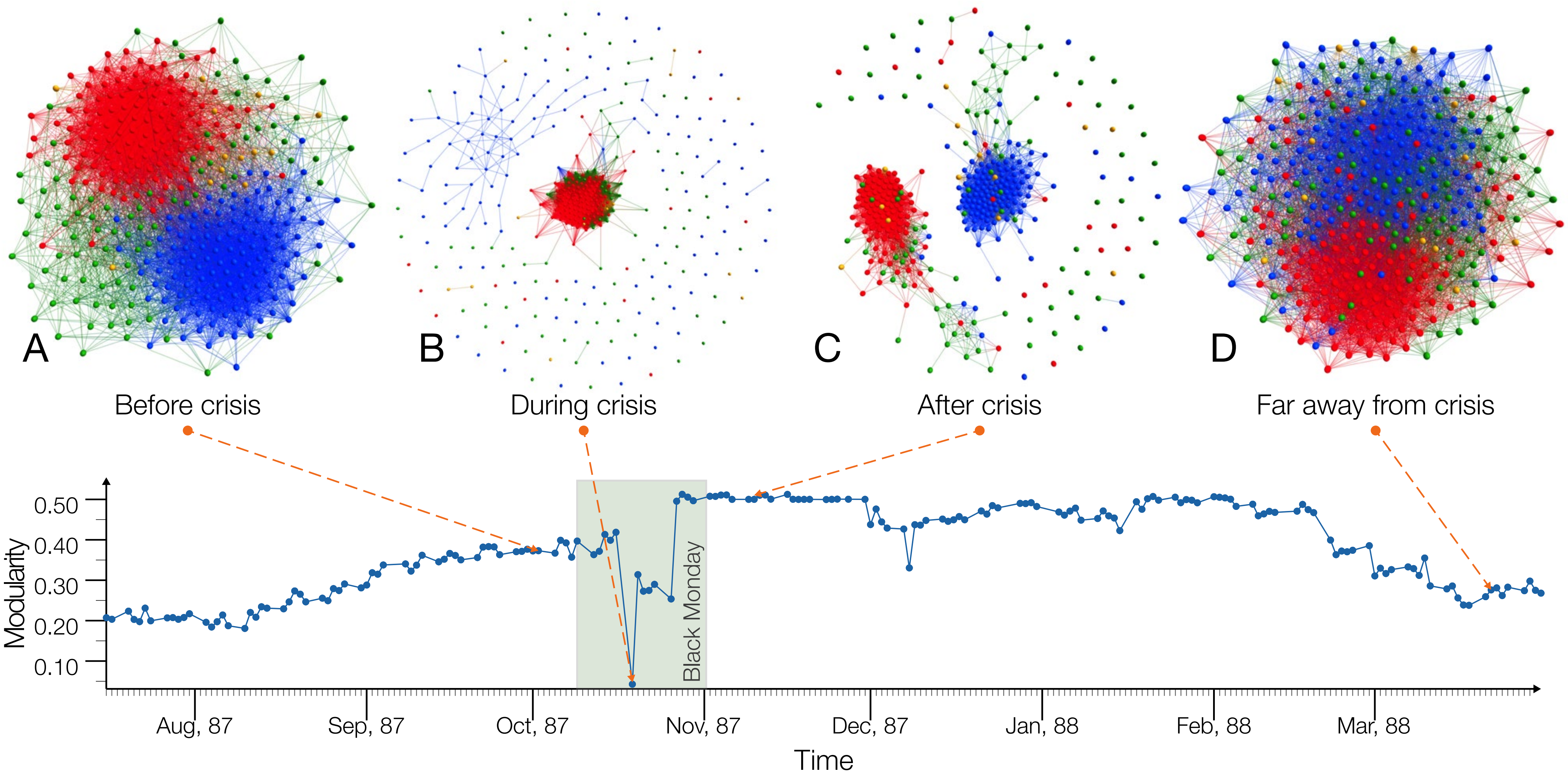
Symmetry	SVM	MLP	KNN	NBY
Merged $h = 2$	75.0%	72.5%	55.0%	42.5%
Merged $h = 3$	70.0%	62.5%	65.0%	40.0%
Merged $h = 4$	82.5%	82.5%	57.5%	42.5%
Backbone $h = 2$	32.5%	32.5%	20.0%	20.0%
Backbone $h = 3$	70.0%	72.5%	57.5%	27.5%
Backbone $h = 4$	70.0%	82.5%	57.5%	42.5%

Accuracy rates found for the authorship detection task.

Pearson correlation coefficients between symmetry and other traditional network measurements

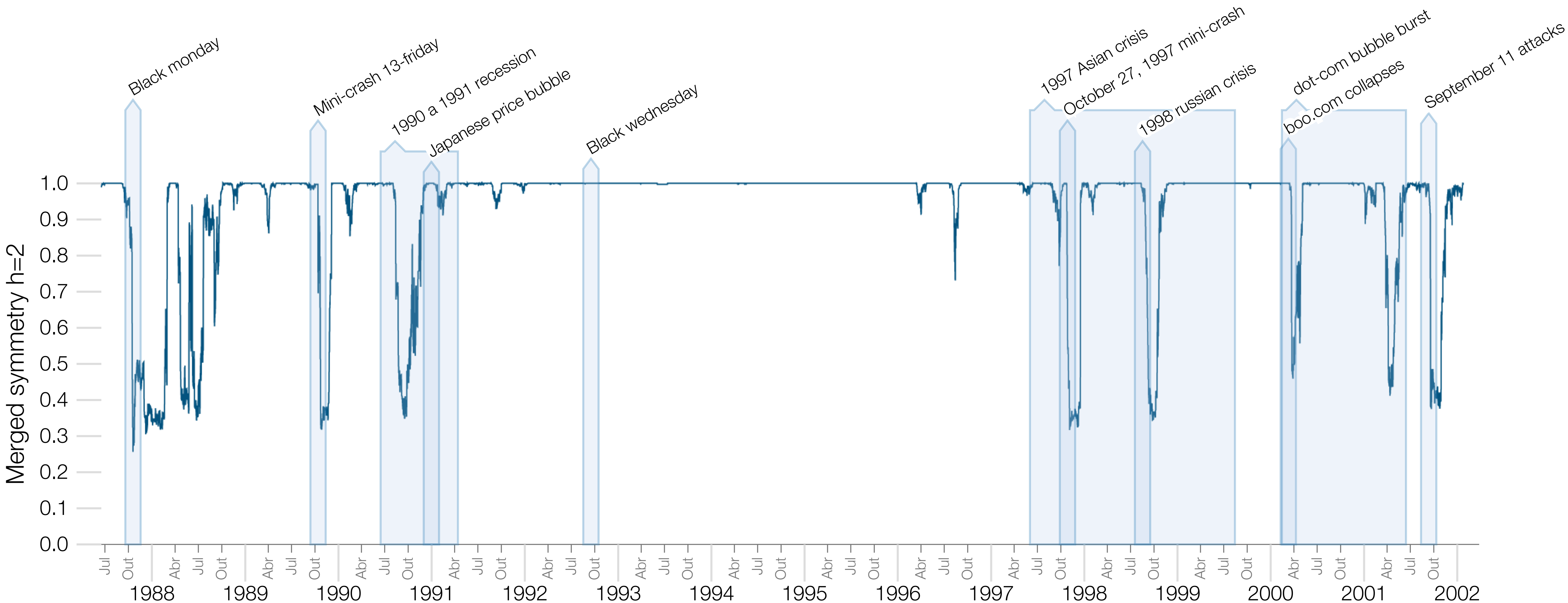


Financial market networks

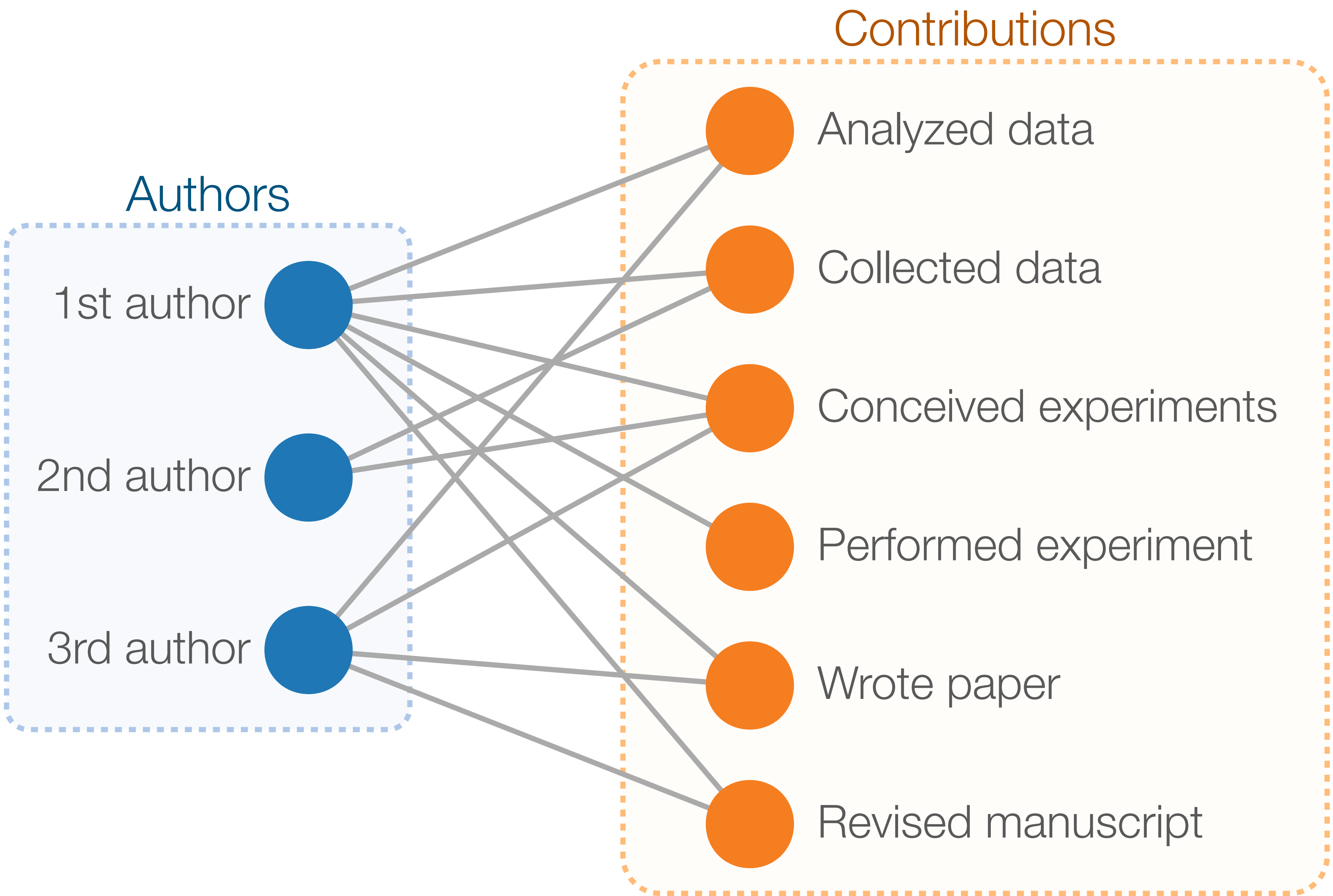


SILVA, F. N.; COMIN, C. H.; PERON, T. K. D.; RODRIGUES, F. A.; YE, C.; WILSON, R. C.; HANCOCK, E.; COSTA, L. da F. On the modular dynamics of financial market networks. 2015 <http://arxiv.org/abs/1501.05040>

Financial market networks



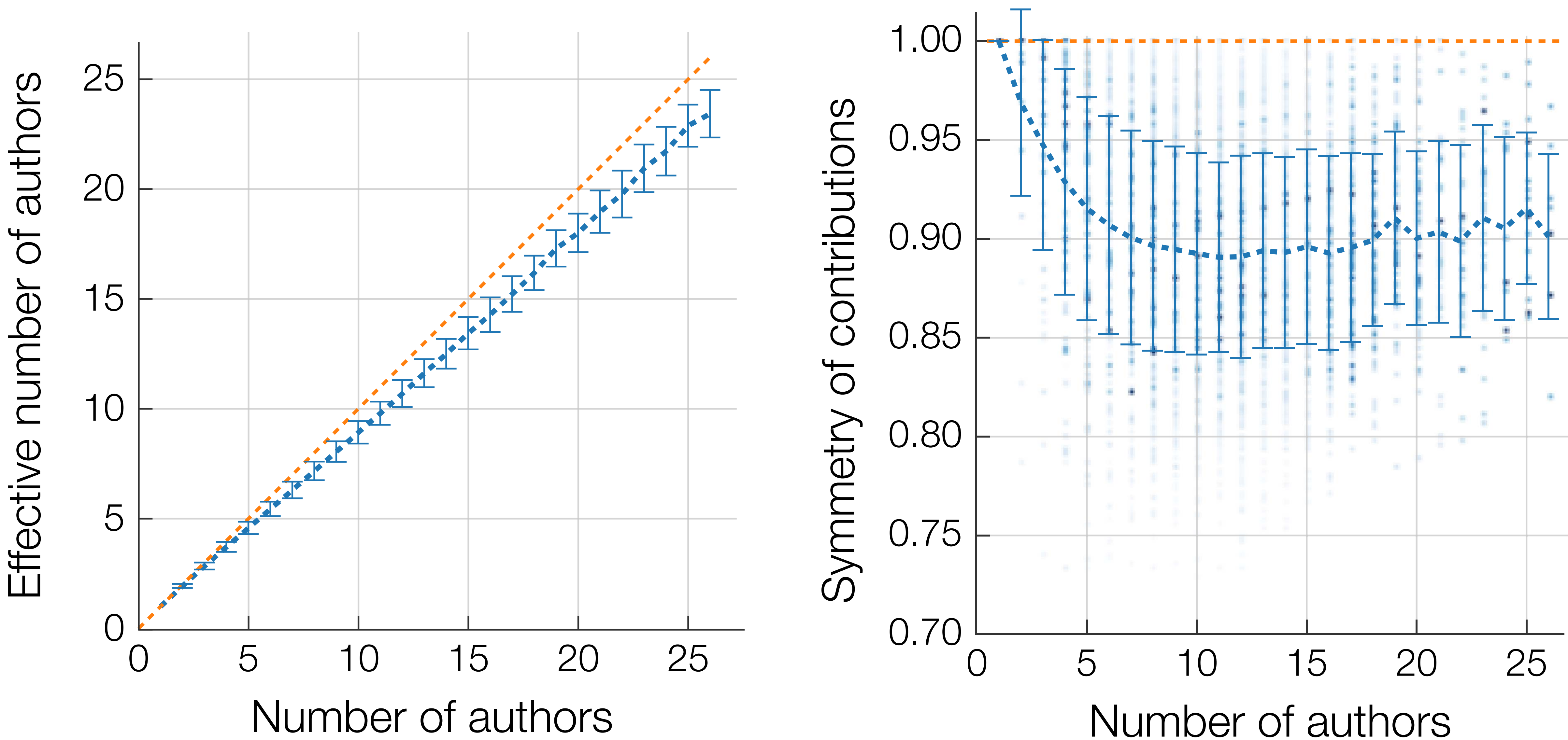
Patterns of authors contribution in scientific manuscripts



Dataset: http://cyvision.ifsc.usp.br/patternsauthors

E. A. Corrêa Jr., F. N. Silva, L. da F. Costa, D. R. Amancio.
Patterns of authors contribution in scientific manuscripts. *Journal of Informetrics* v.11, n. 2, 2017.

Patterns of authors contribution in scientific manuscripts



Dataset: http://cyvision.ifsc.usp.br/patternsauthors

E. A. Corrêa Jr., F. N. Silva, L. da F. Costa, D. R. Amancio.
Patterns of authors contribution in scientific manuscripts. *Journal of Informetrics* v.11, n. 2, 2017.

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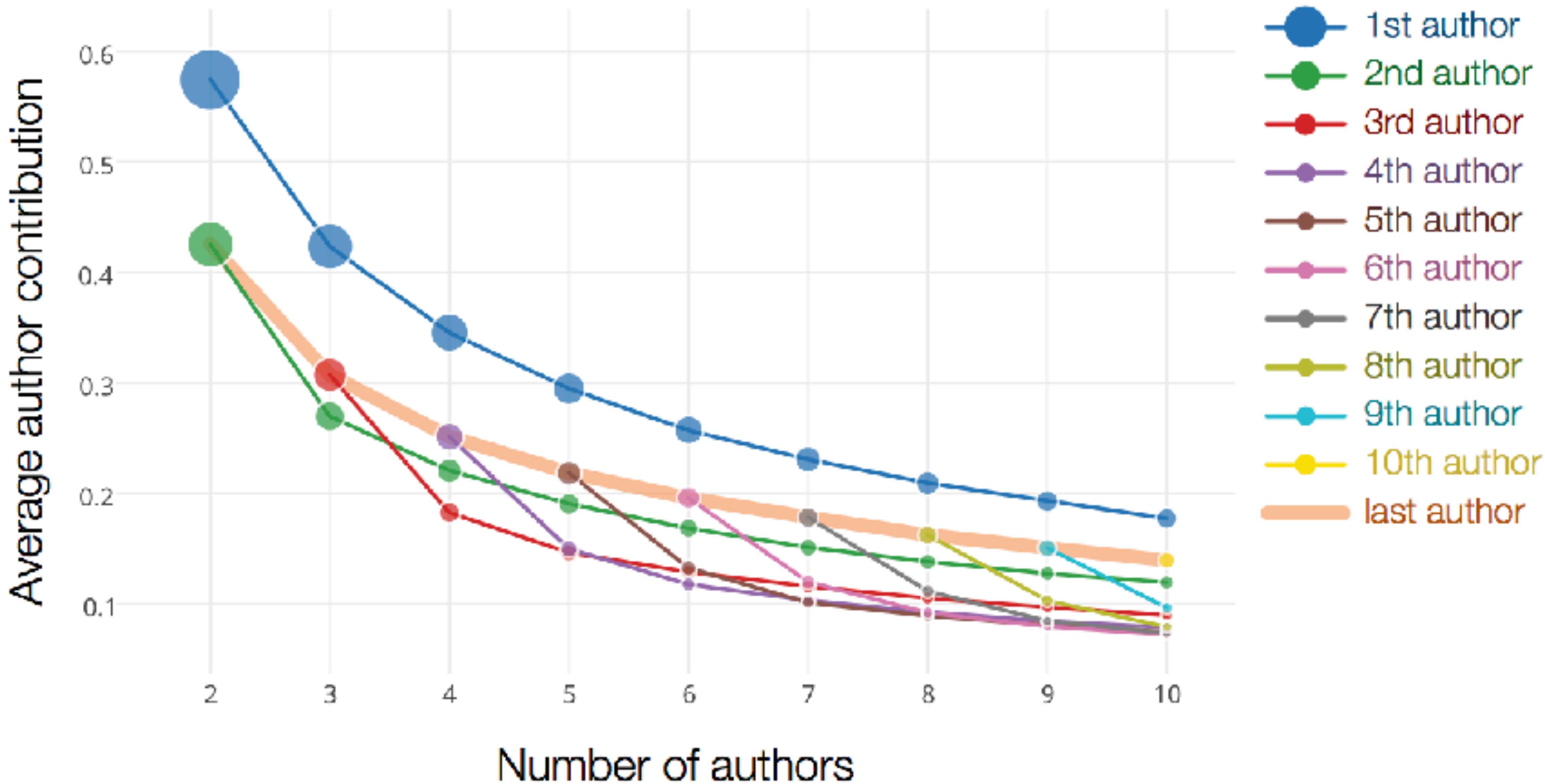

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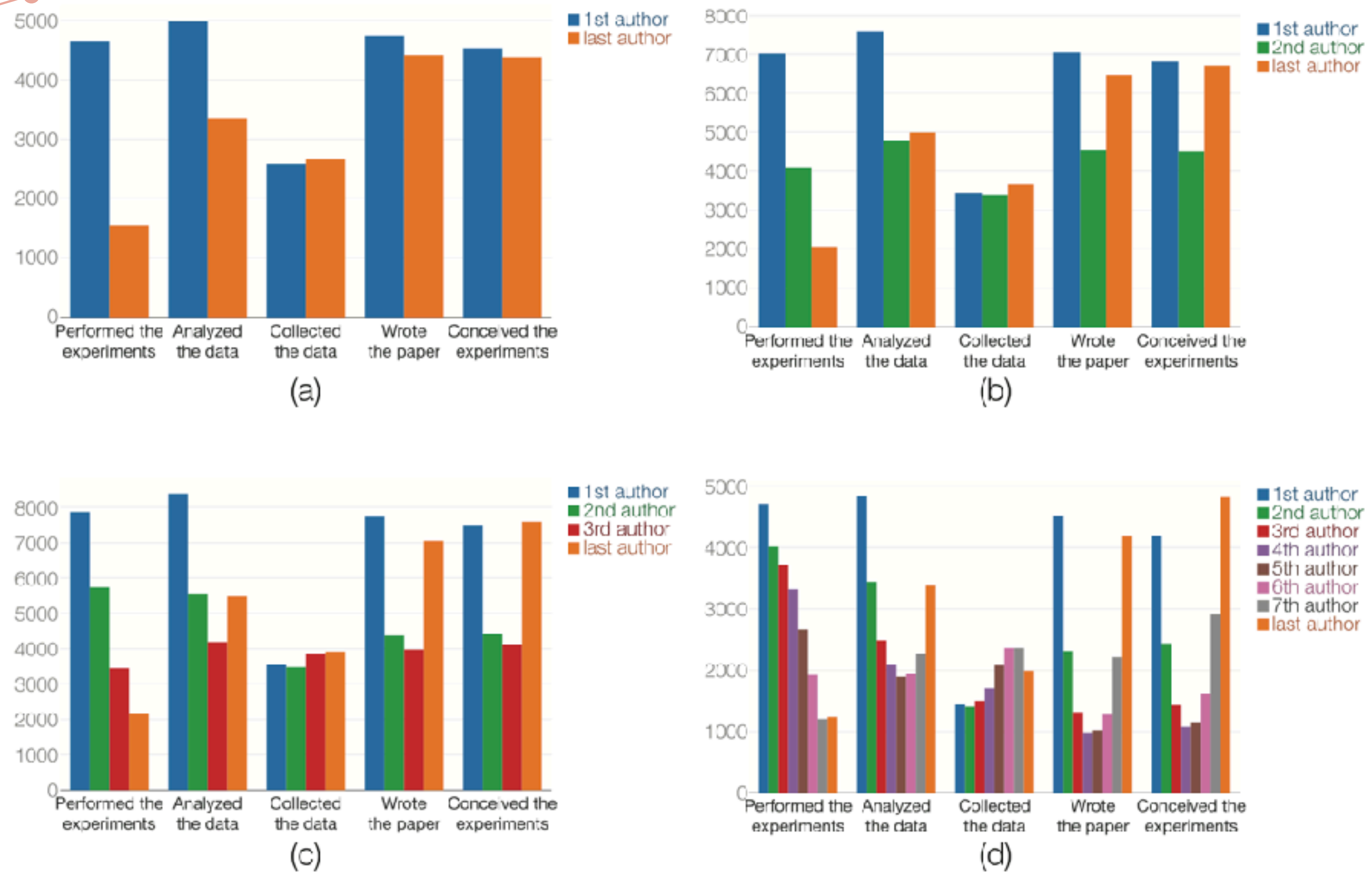
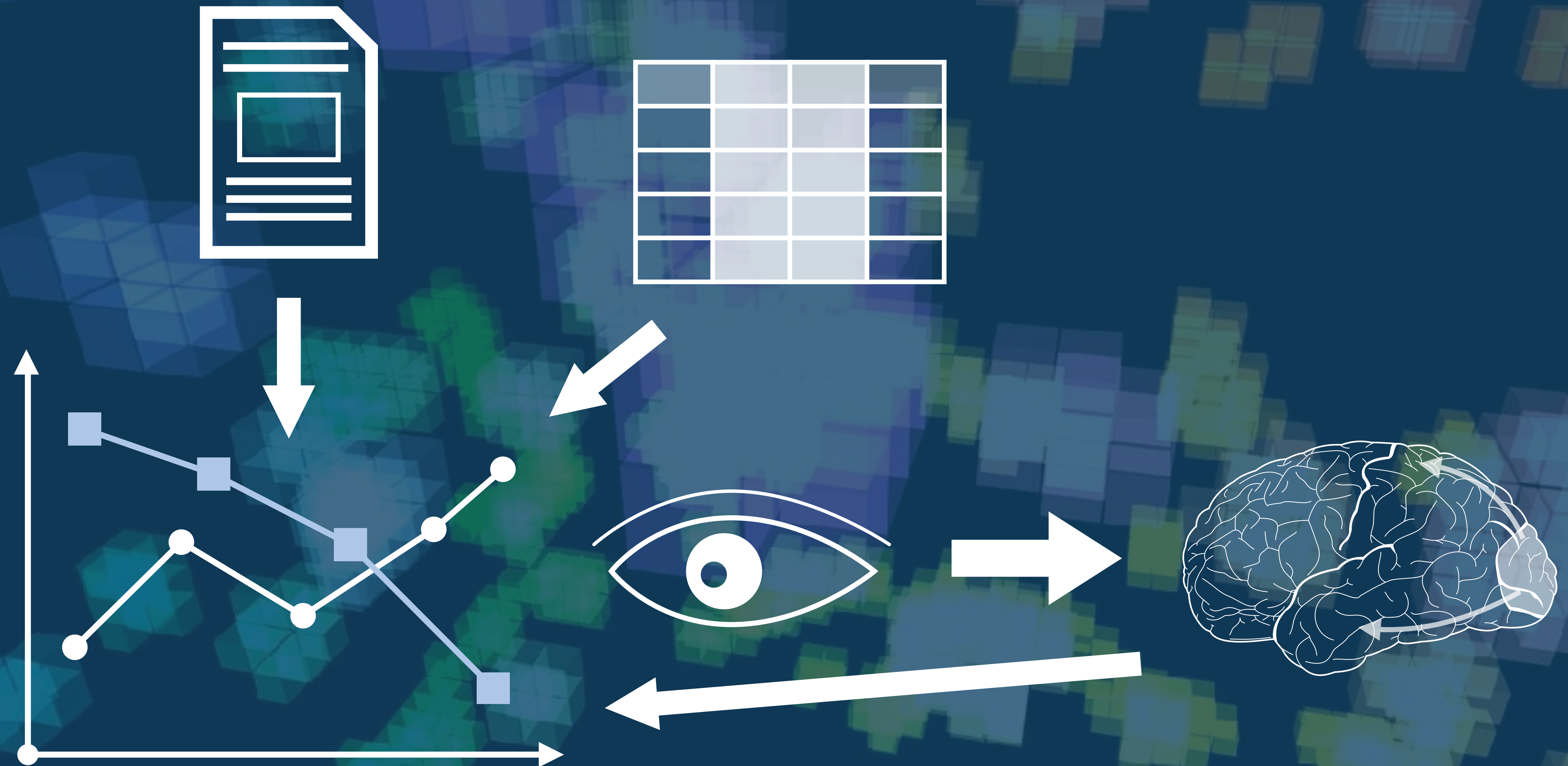
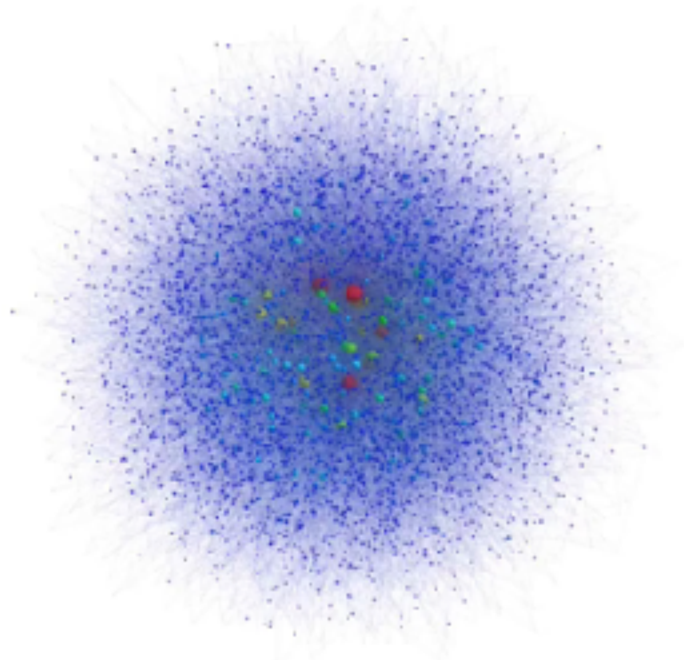
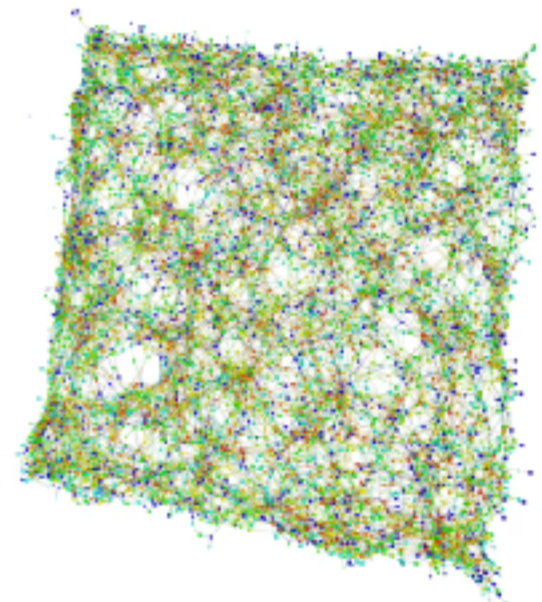
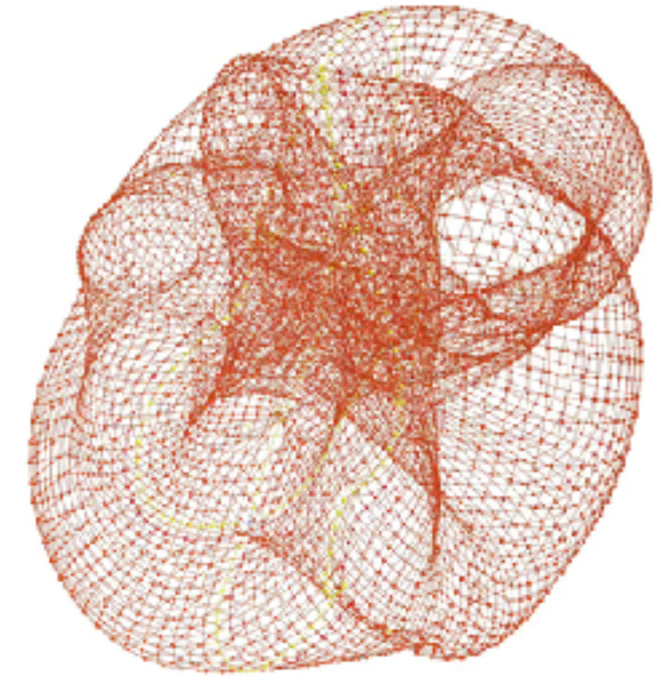
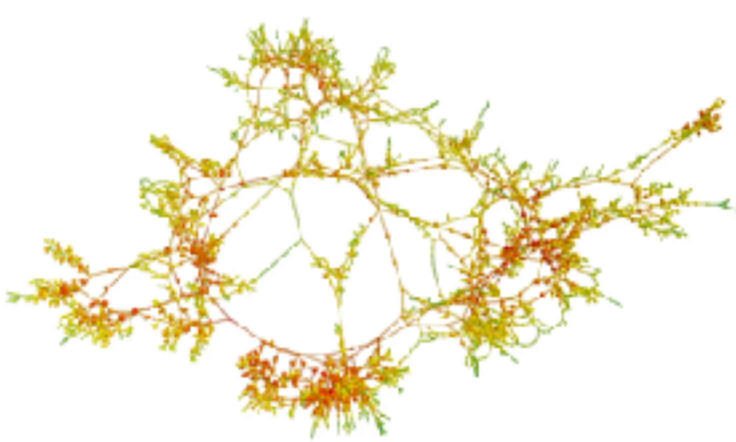
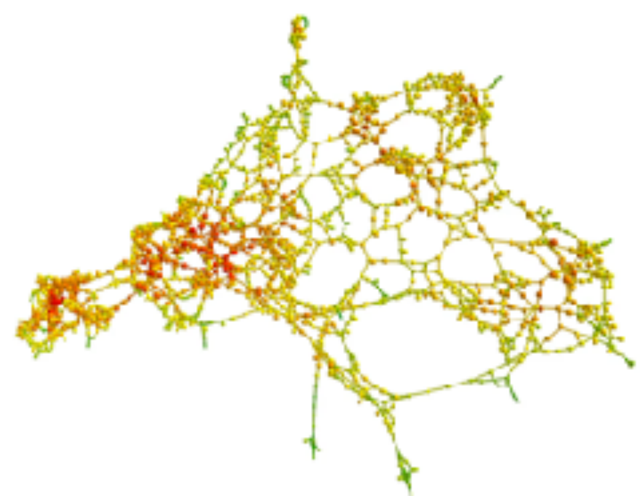
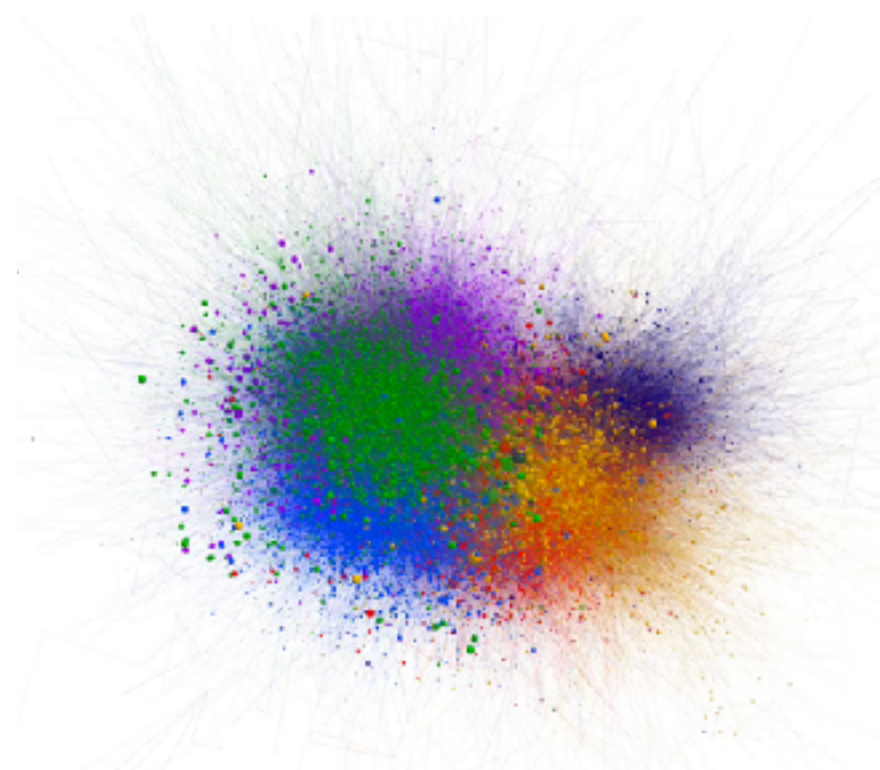


E. A. Corrêa Jr., F. N. Silva, L. da F. Costa, D. R. Amancio.
Patterns of authors contribution in scientific manuscripts. *Journal of Informetrics* v.11, n. 2, 2017.

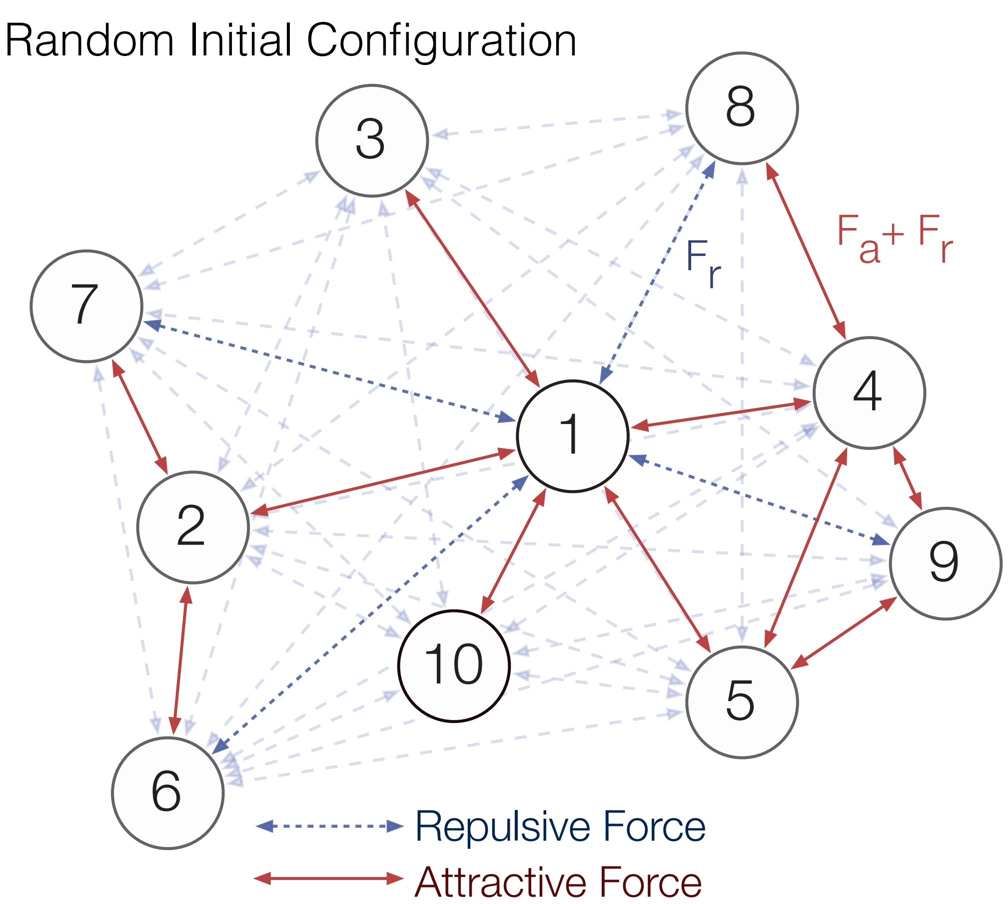
Visualization



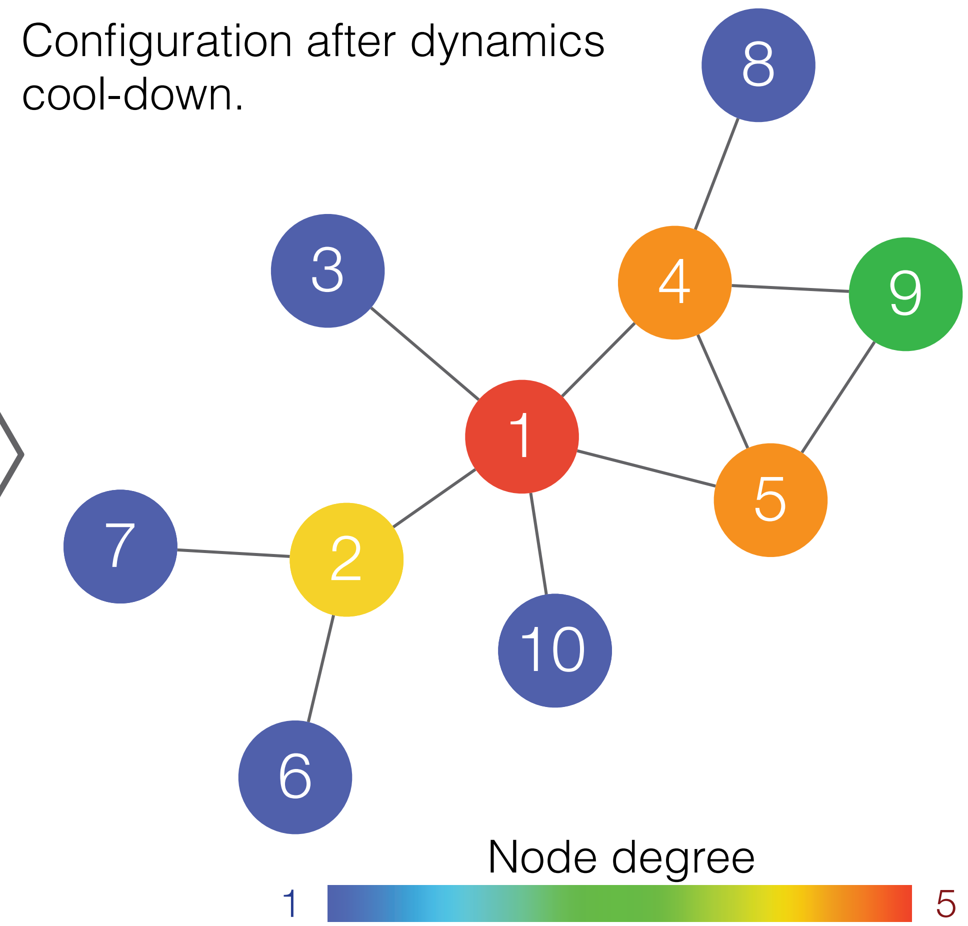
Complex networks + visualization

Force directed method



Molecular Dynamics Simulation



Attractive Force

$$\vec{F}_{(a)j} = \sum_{(i,j)\in\mathcal{E}} a_{ij}(\vec{R}_i - \vec{R}_j)^2 \hat{r}_{ij}$$

Repulsive Force

$$\vec{F}_{(r)j} = \sum_{i\in\mathcal{V}} \frac{-b}{(\vec{R}_i - \vec{R}_j)^2}\hat{r}_{ij}$$

Viscosity is used for cooling the system

$$\frac{d^2\vec{R}_j}{d^2t} = \vec{F}_{(a)i} + \vec{F}_{(r)j} - \mu\frac{d\vec{R}_j}{dt}$$

We use **Runge-Kutta** iterative method.

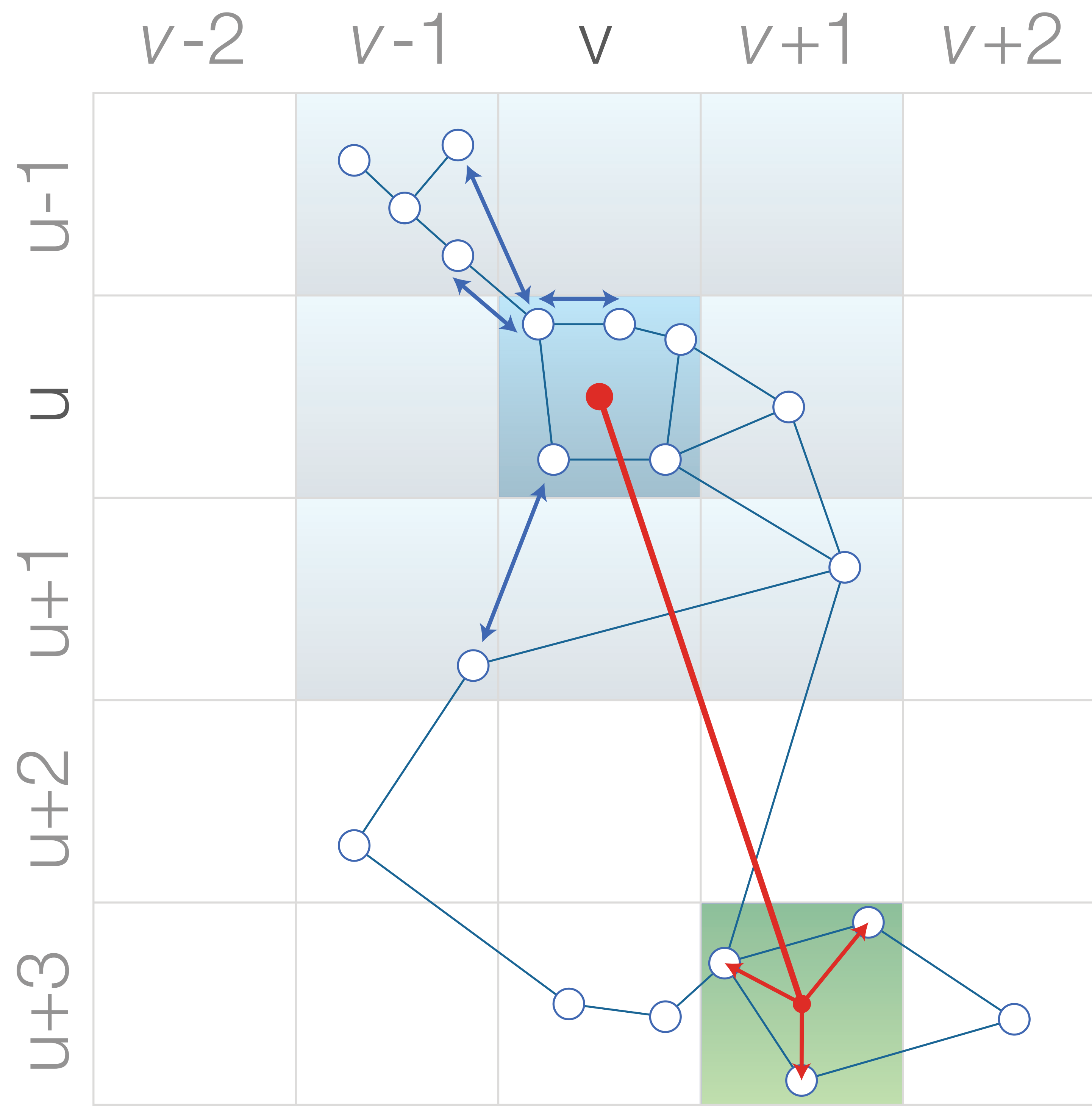
Optimizations

- Molecular dynamics simulation is **O(N²)** .
- We can use multipole expansion:

$$\sum_{i\in\mathcal{V}} \frac{\hat{r}_{ij}}{(\vec{R}_i-\vec{R}_j)^2} = -\vec{\nabla}\sum_{i\in\mathcal{V}}\frac{1}{|\vec{R}_i-\vec{R}_j|} = -\vec{\nabla}\phi(\vec{R}_j)$$

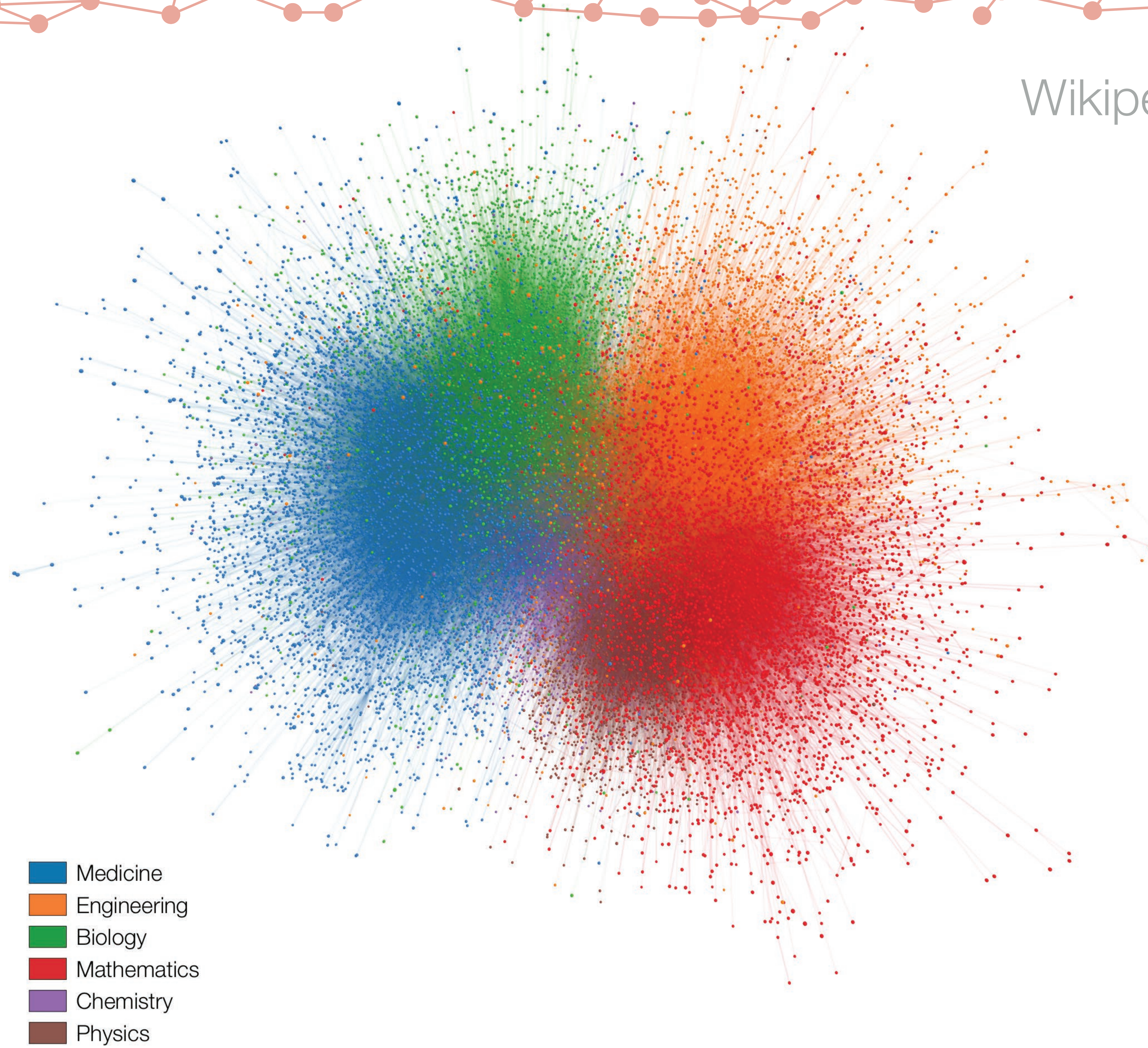
$$\phi(\vec{R}_j) \propto \frac{N_{u,v}}{|\vec{R}_j|} + \frac{\vec{p}_{u,v}\cdot\vec{R}_j}{|\vec{R}_j|^3} + \frac{1}{2}\sum_{m}^{3}\sum_{n}^{3} \frac{(Q_{u,v})_{mn}(R_j)_m(R_j)_n}{|\vec{R}_j|^5} + \dots$$

- Where $N_{u,v}$, $\mathbf{p}_{u,v}$ e $Q_{u,v}$ are **monopole**, **dipole** e **quadrupole** moments on **box** (u,v).
- Quadrupole is OK for most of networks.



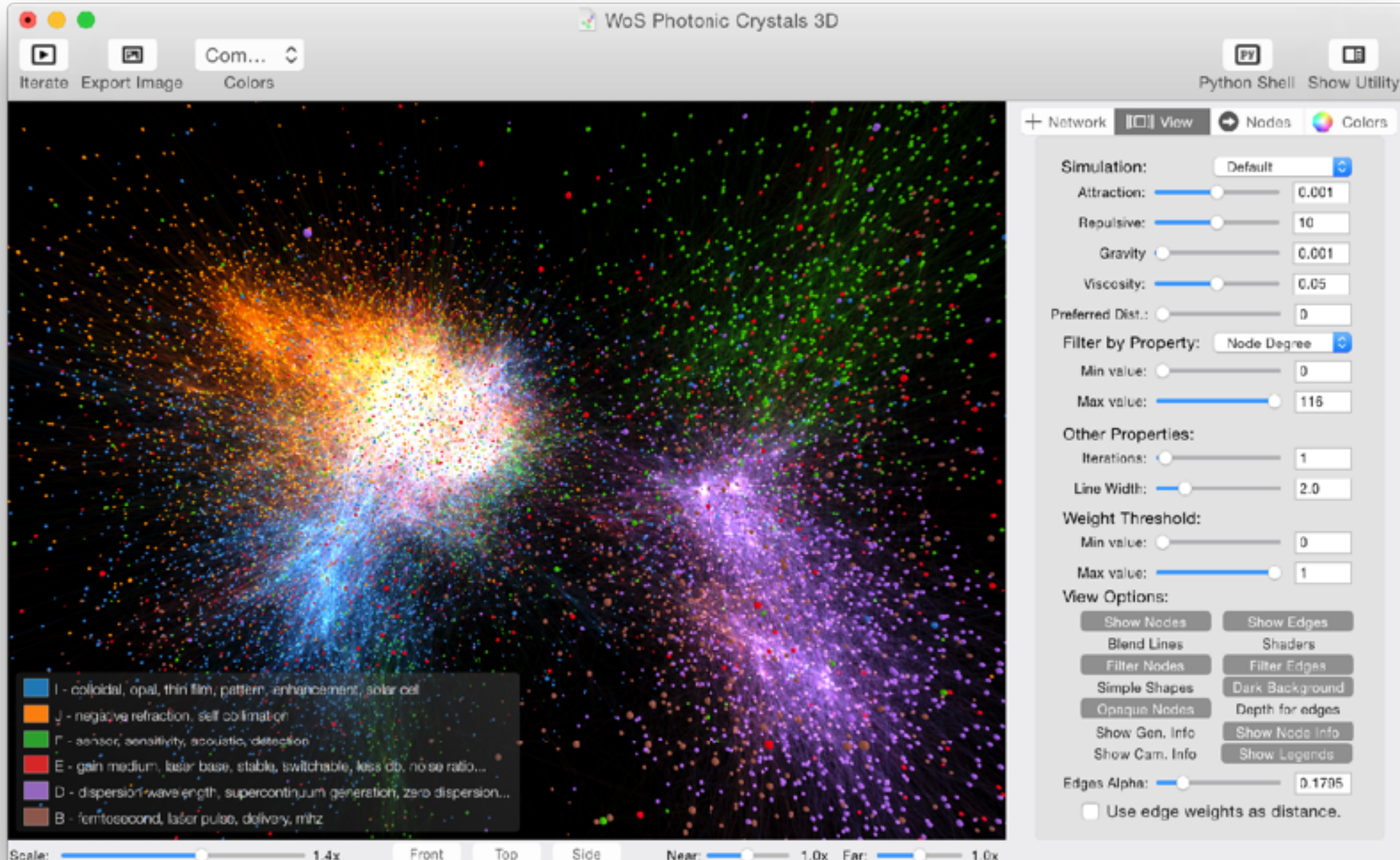
Examples

Wikipedia Network



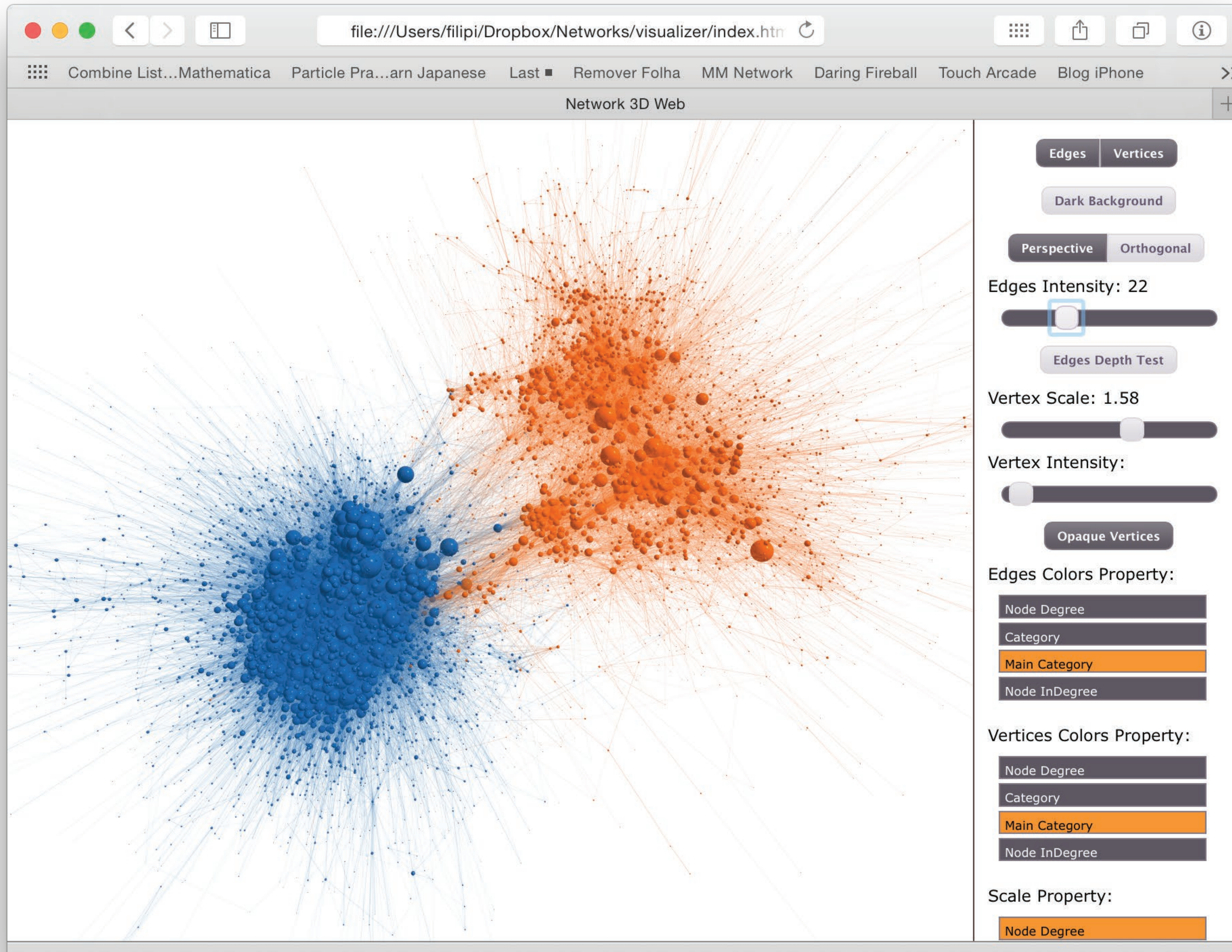
Network Visualization

Examples



Software Interface

Examples

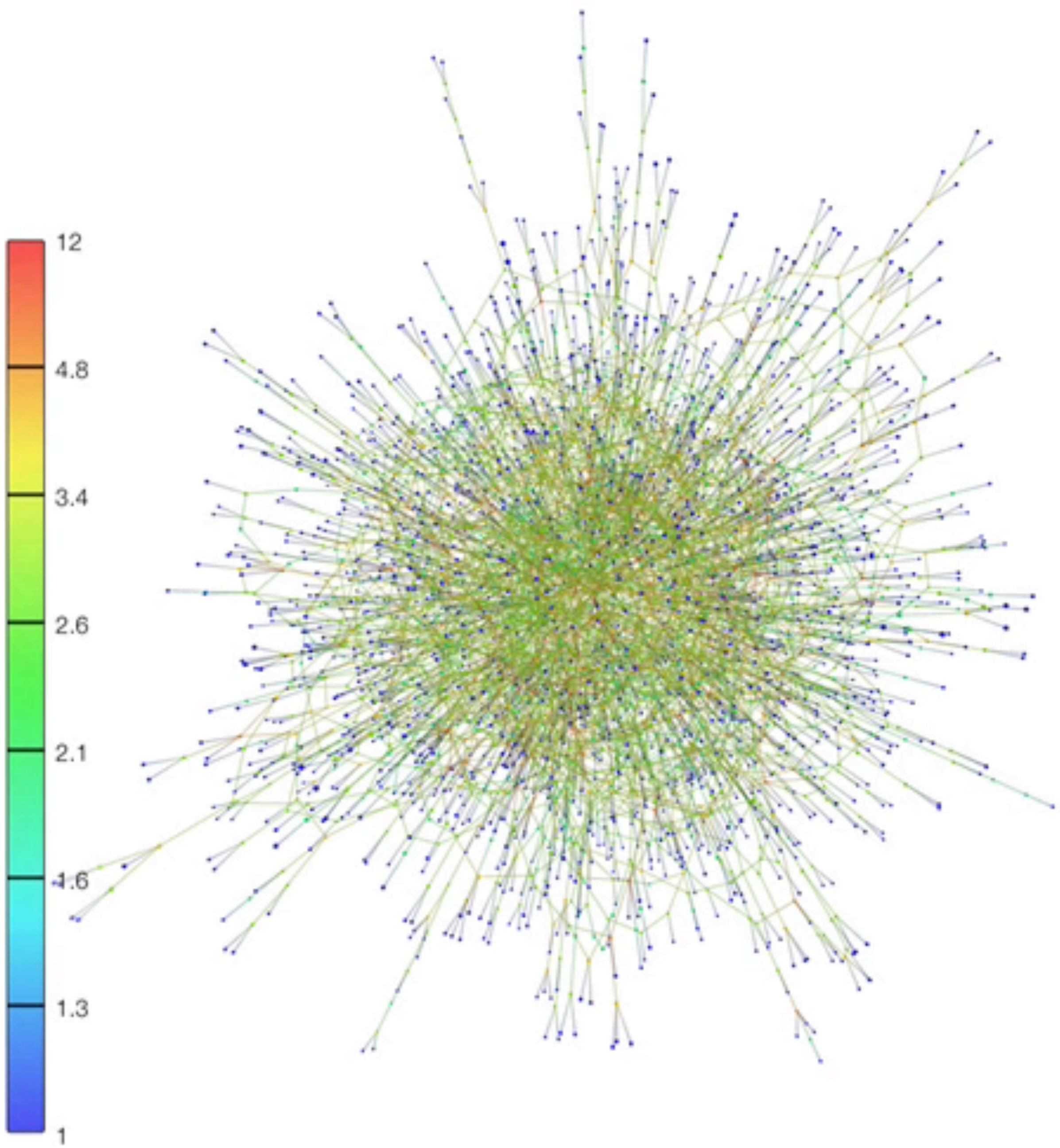


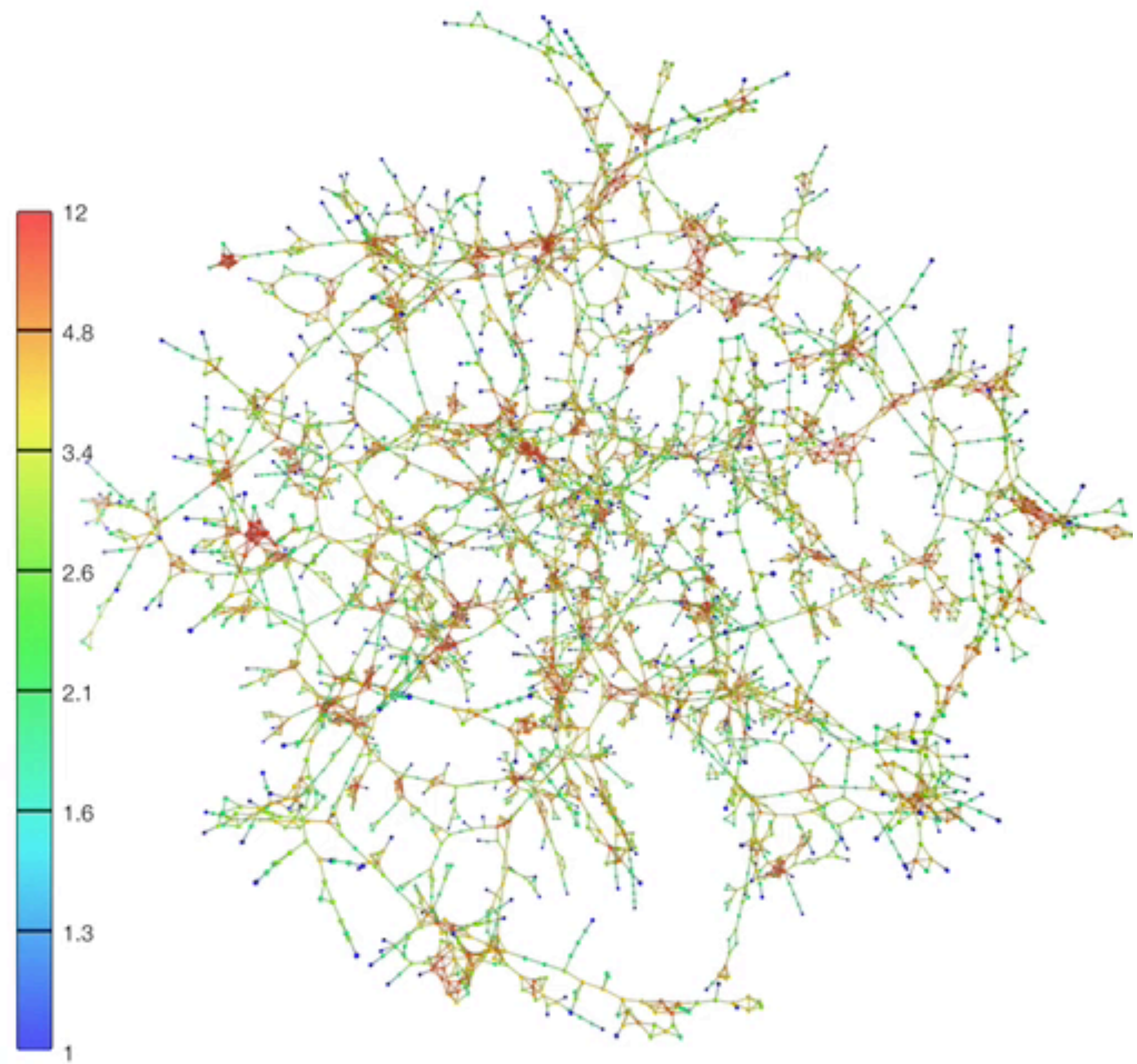
Web interface

Examples

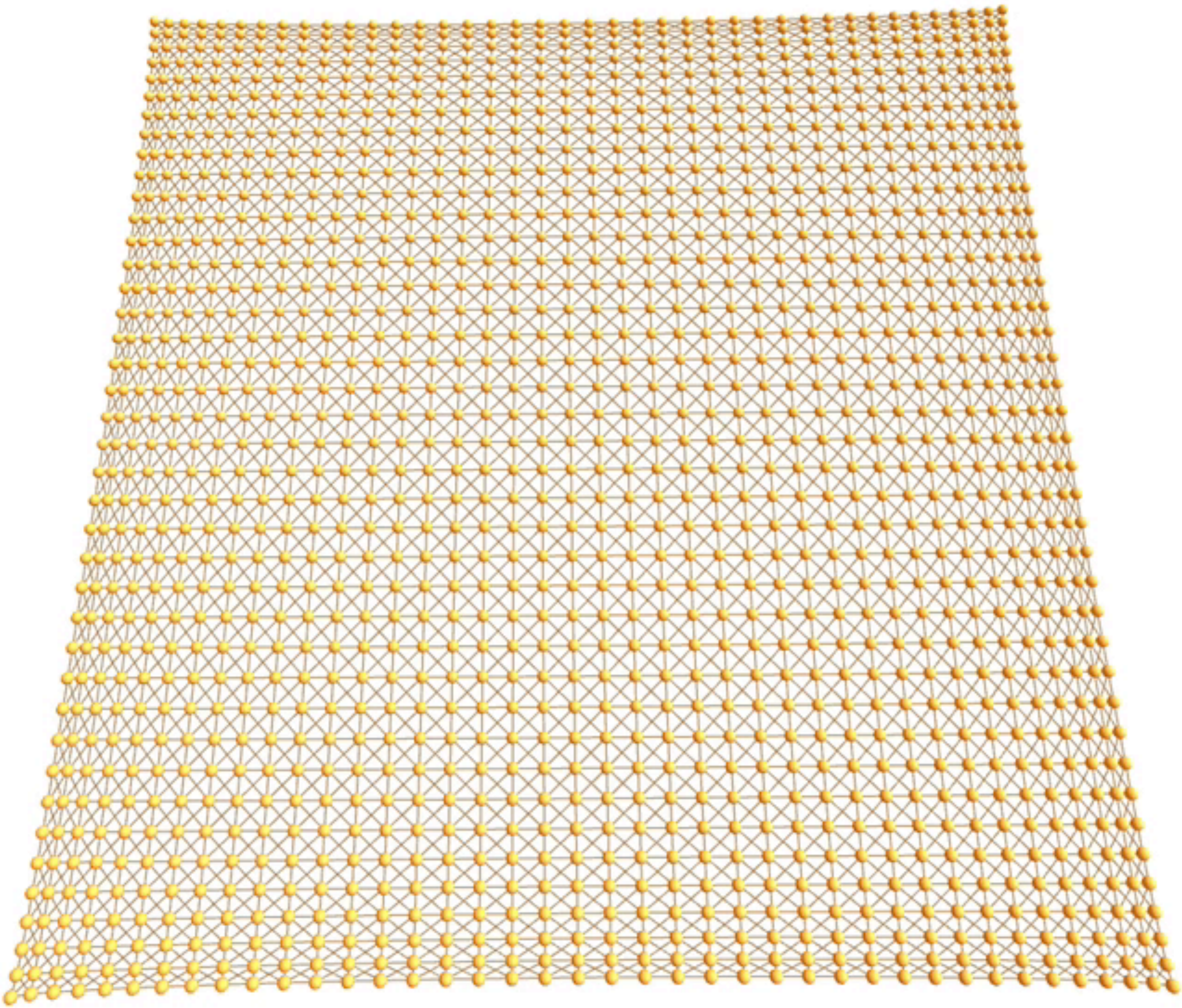

Chemistry
Physics
Medicine
Engineering
Biology
Mathematics

Examples



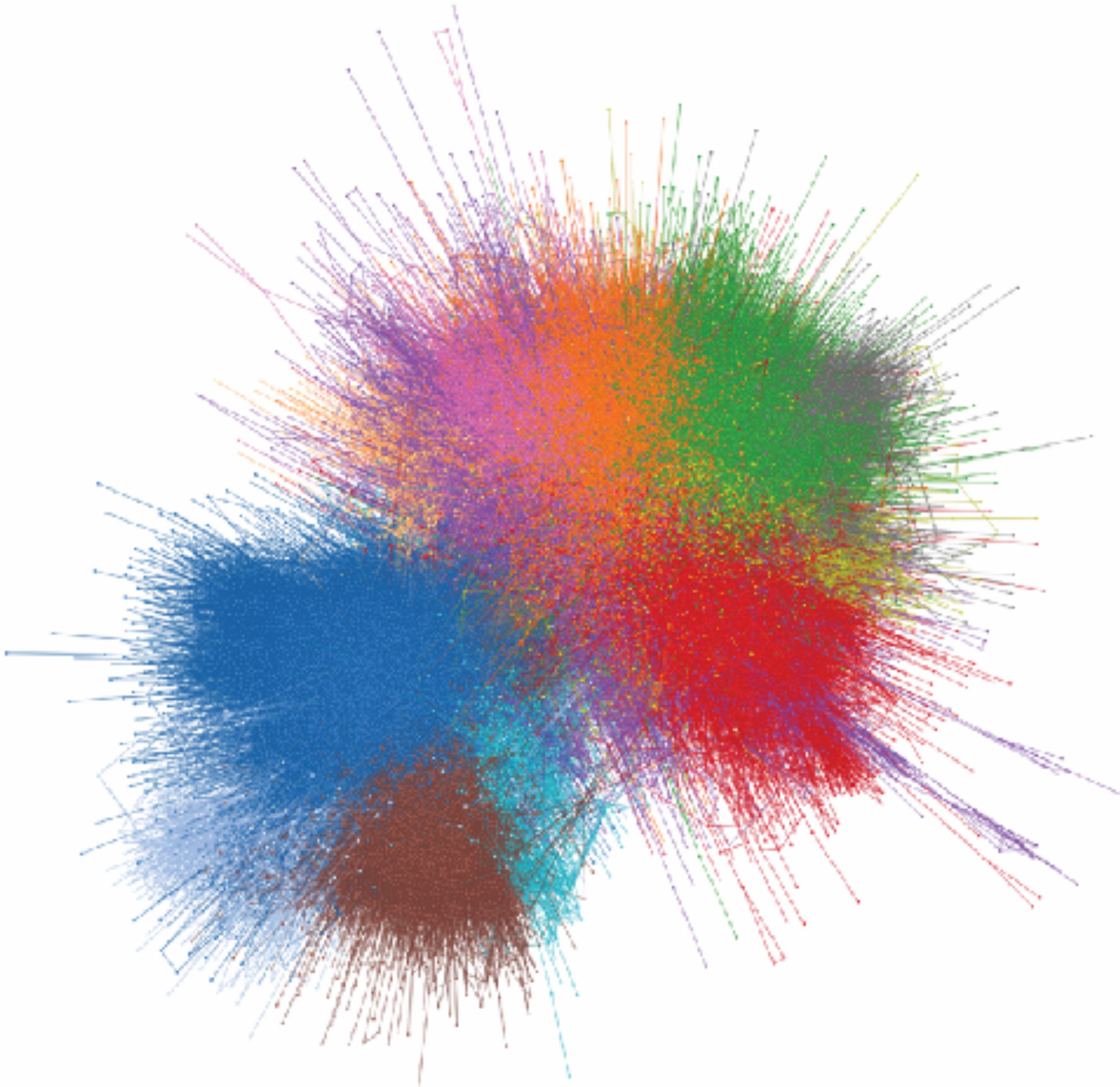


Examples

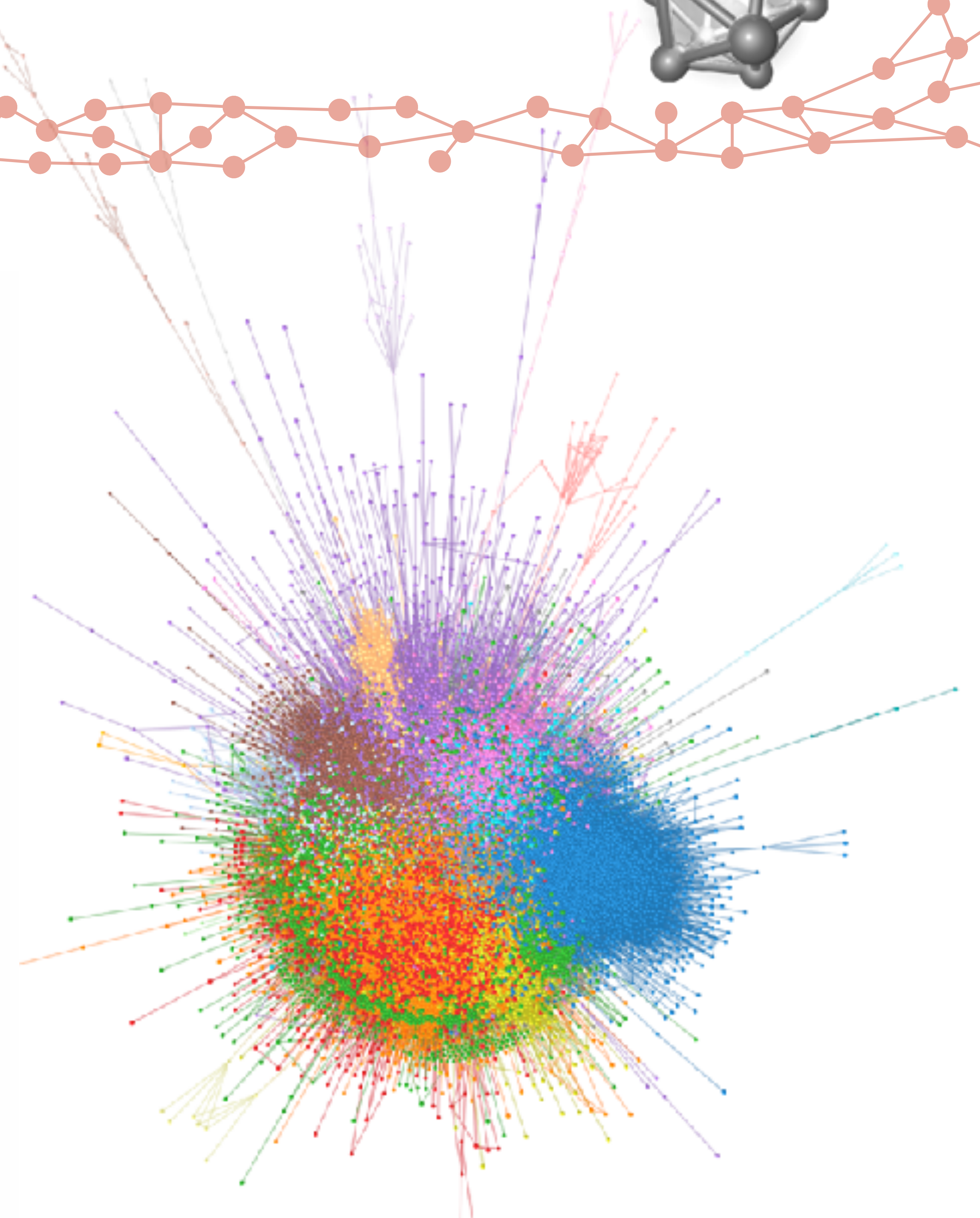


Examples

Examples



Photonic crystals



Complex networks

Filipi N. Silva, Diego R. Amancio, Maria Bardosova, Luciano da F. Costa, Osvaldo N. Oliveira Jr., **Using network science and text analytics to produce surveys in a scientific topic**, Journal of Informetrics, v. 10, 2, May 2016