Networks & Economic Development

Reporter：Jin-Hu Liu

Date： 2014.11.6

Outline

- Network and Graph
- Economic Network
- Social Network
- Coupled Network

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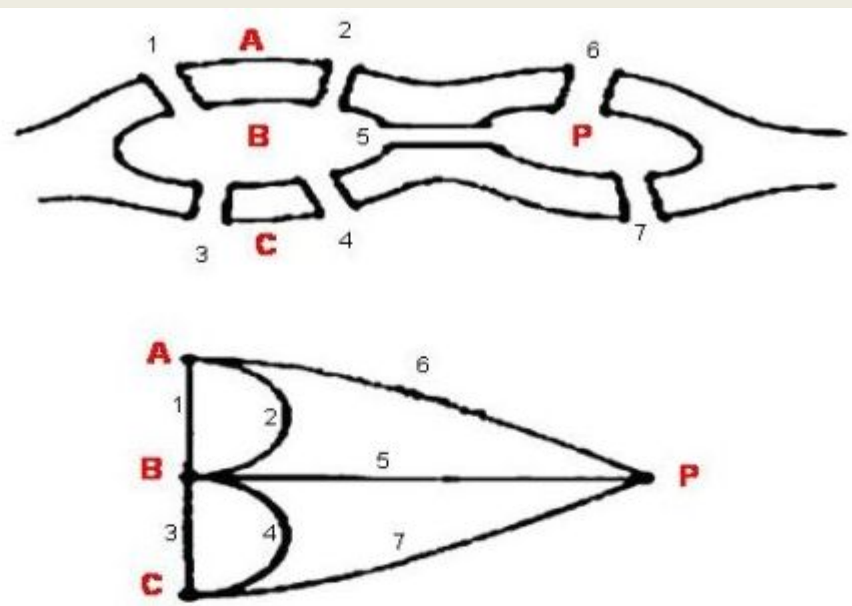
Network and Graph

- In mathematics, a network is a special graph which is a representation of a set of objects where some pairs of objects are connected by links.
  - (1) weighted or unweighted, directed or undirected
  - **(2)** Adjacency Matrix



0	1	0	1
1	0	1	1
0	1	0	1
1	1	1	0

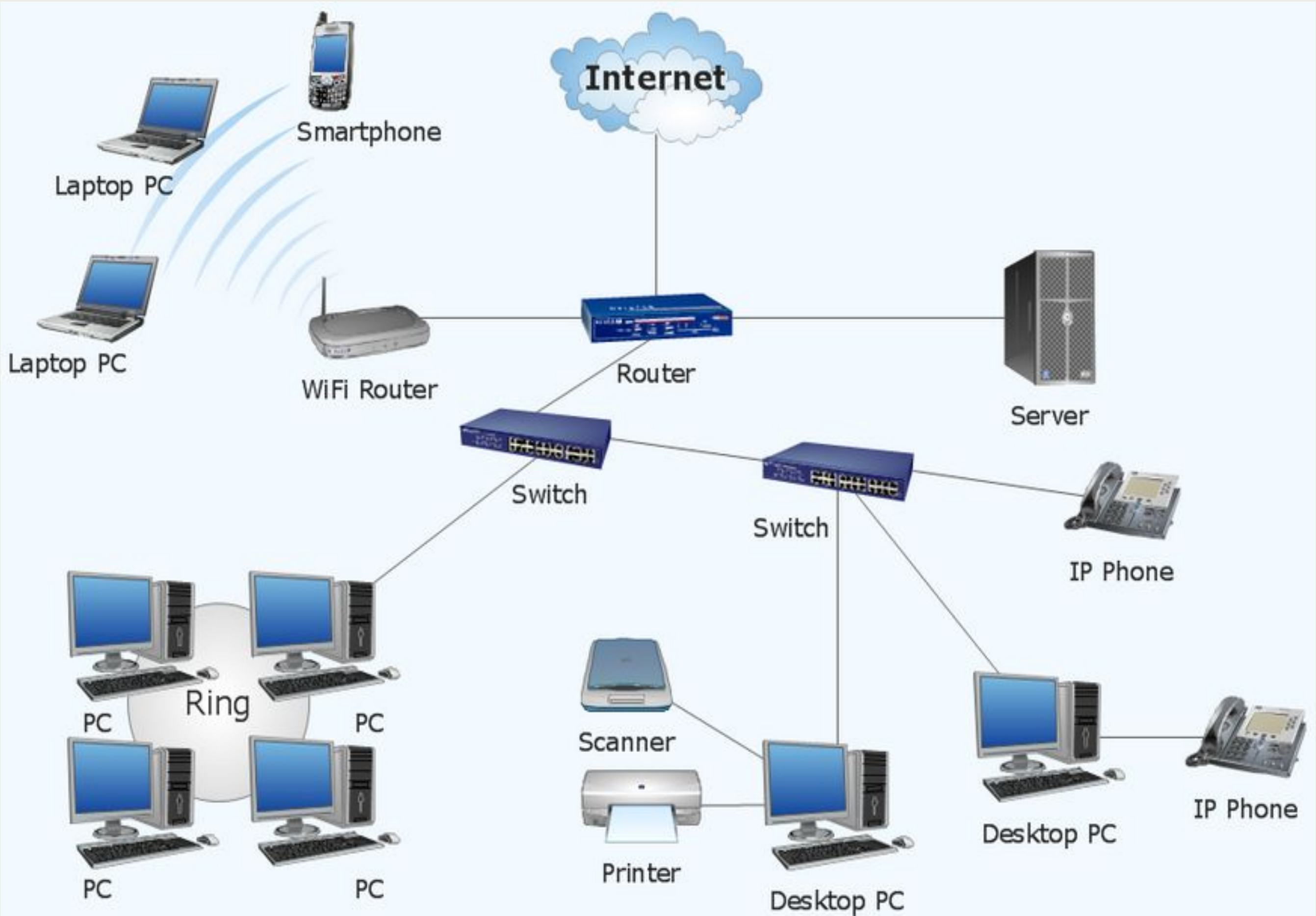
Vertexes

0	1	1	1	1	1	0
1	0	1	1	1	1	0
1	1	0	1	1	0	1
1	1	1	0	1	0	1
1	1	1	1	0	1	1
1	1	0	0	1	0	1
0	0	1	1	1	1	0

Edges

Network

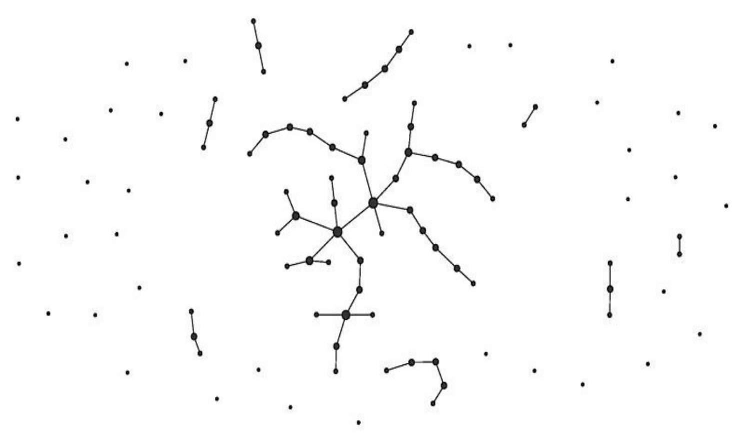
- In the computer world, networked computing devices pass data to each other along data connections. Data is transferred in the form of packets…

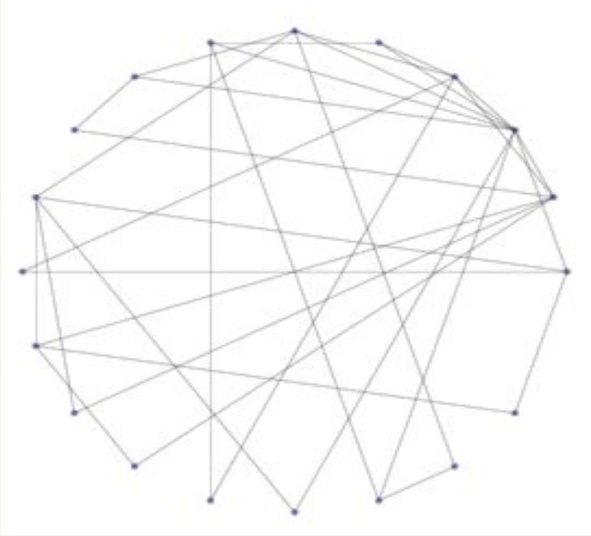


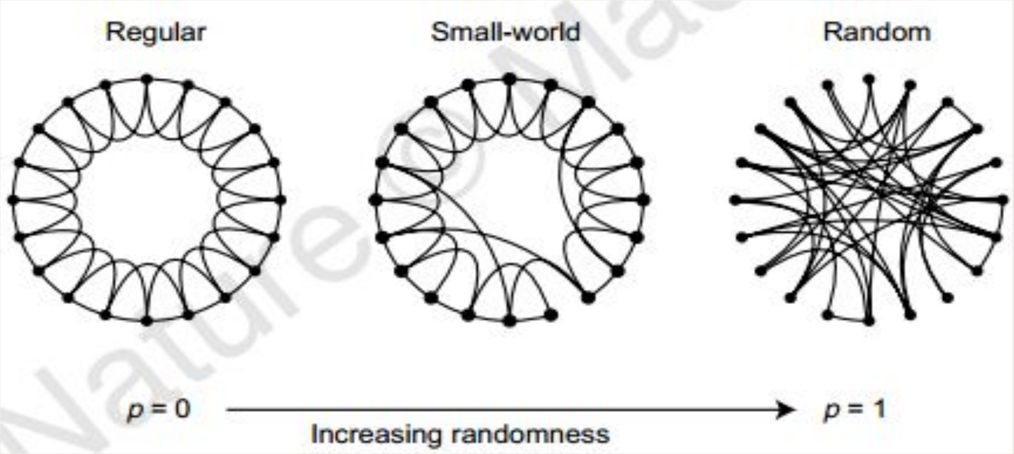
Network

- In physics, a network is a model.

computer networks
biological networks
social networks
…
Erdős–Rényi (ER) model
Barabási–Albert model
Watts–Strogatz (WS) model







Network

Albert-Lászlò Barabási

P Erdos, A Rényi, Bull. Inst. Internat. Statist 38 (4), 343-347
D Watts, S Strogatz, Nature 393, 440-442
AL Barabási, R Albert, Science 286 (5439), 509-512

Network Topology Structure

- Connectivity (Giant component)

- Degree and Average degree (in and out)

  Density: $\rho = \frac{2M}{N(N-1)}$

- Shortest path and Average path length(Diameter)

  Dijkstra algorithm

  Floyd algorithm

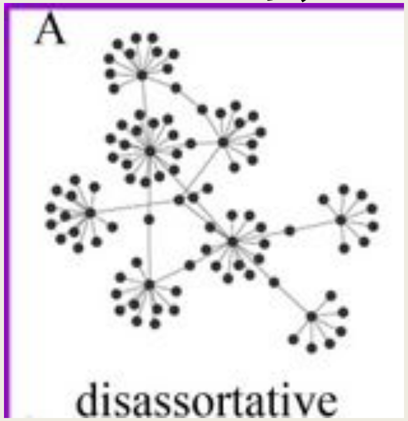
- Clustering coefficient

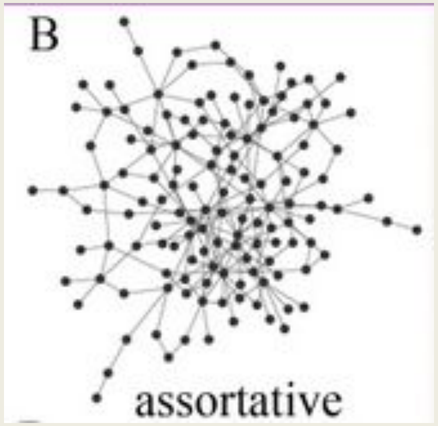
- Degree distribution

Network Structure

- Degree correlations(Assortativity or Disassortativity)

	network	n	r
real-world networks	physics coauthorship[a]	52 909	0.363
	biology coauthorship[a]	1 520 251	0.127
	mathematics coauthorship[b]	253 339	0.120
	film actor collaborations[c]	449 913	0.208
	company directors[d]	7 673	0.276
	Internet[e]	10 697	−0.189
	World-Wide Web[f]	269 504	−0.065
	protein interactions[g]	2 115	−0.156
	neural network[h]	307	−0.163
	food web[i]	92	−0.276
models	random graph[u]		0
	Callaway *et al.*[v]		$\delta/(1+2\delta)$
	Barabási and Albert[w]		0

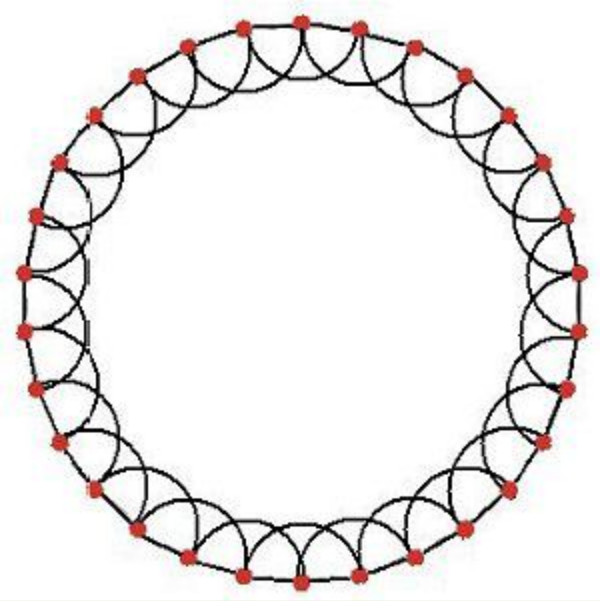


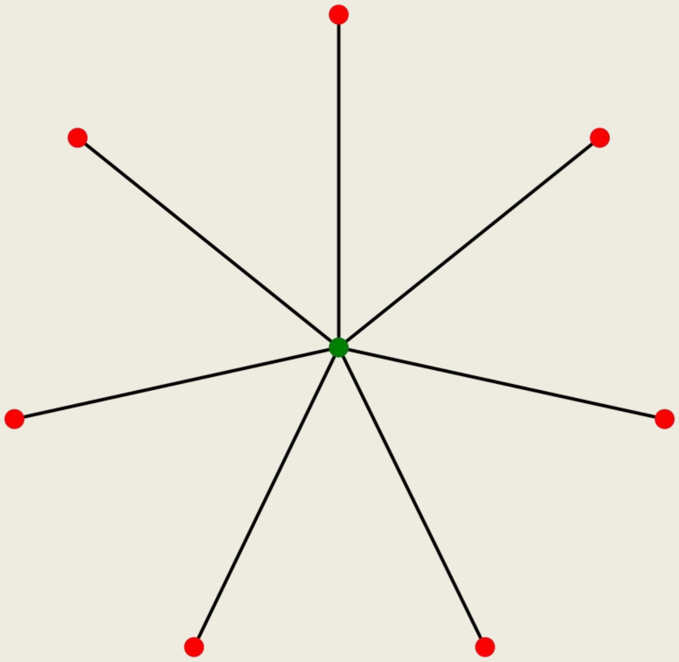


Newman, Mark EJ. "Assortative mixing in networks." *Physical review letters*89.20 (2002): 208701.
Newman, Mark EJ. "Mixing patterns in networks." *Physical Review E* 67.2 (2003): 026126.

Network Structure

- Homogeneity (Heterogenous)

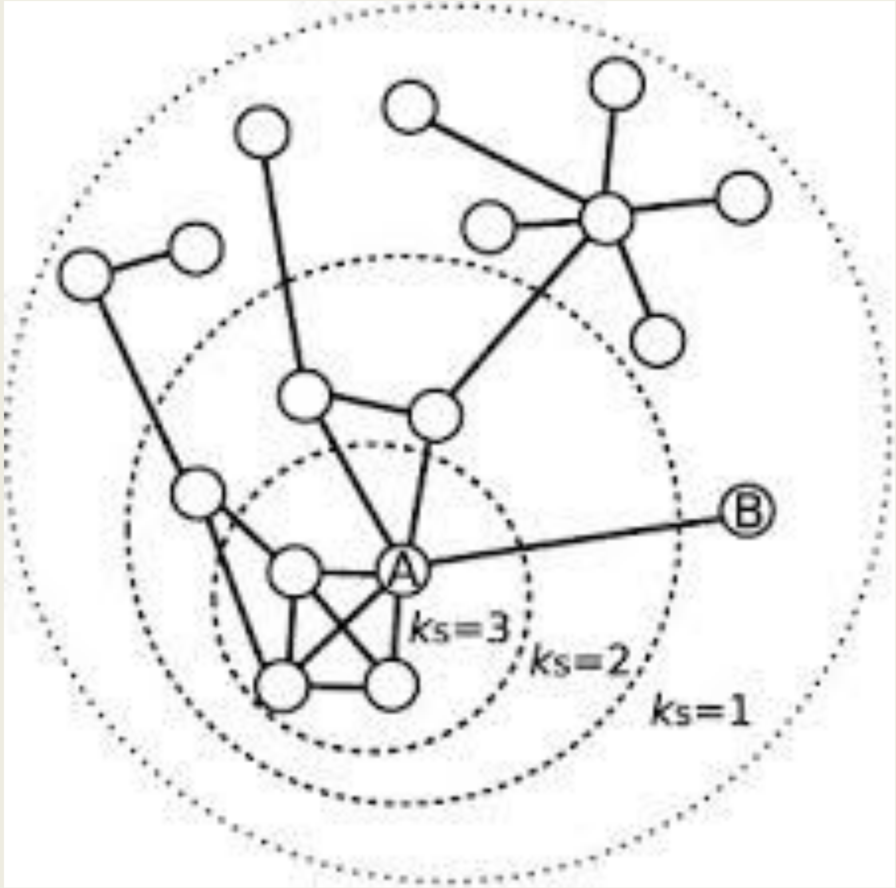




Albert, Réka, and Albert-László Barabási. "Statistical mechanics of complex networks." *Reviews of modern physics* 74. 1 (2002): 47.

Network Structure

- k-shell decomposition method (k-core)

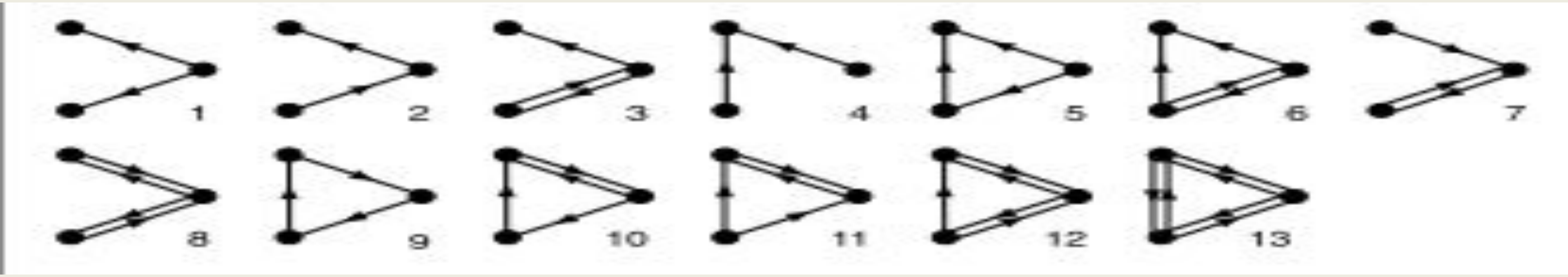


Kitsak Maksim, Gallos Lazaros K., Havlin Shlomo, Liljeros Fredrik, Muchnik Lev, Stanley H. Eugene , Makse Hernan A. “Identification of influential spreaders in complex networks”. Nat Phys. 2010,6(11)

Economic Network

- Z-score(network motif)

$$Z(G') = \frac{F_G(G') - \mu_R(G')}{\sigma_R(G')}$$



Milo, Ron, et al. "Network motifs: simple building blocks of complex networks.“ *Science* 298. 5594 (2002): 824-827.

Outline

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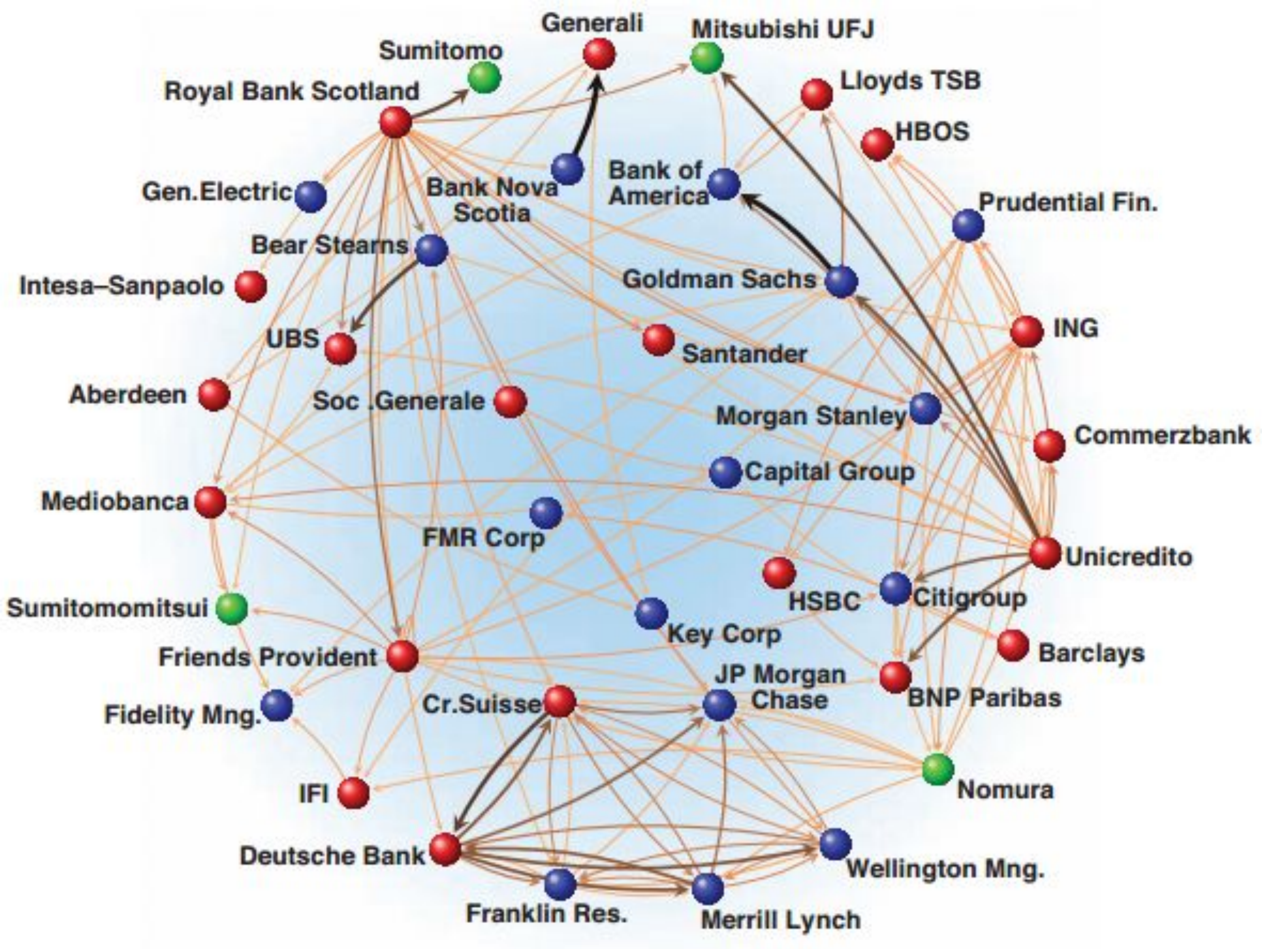
- Social Network
- Coupled Network

Economic Network

The economy, as any other complex system, reflects a dynamic interaction of a large number of different agents, not just a few key players.



F. Schweitzer, G. Fagiolo, D. Sornette, F. Vega-Redondo, A. Vespignani, and D. R. White, Science 325, 422 (2009).

Economic Network

Research examining economic networks has been studied from two perspectives :

((1))comes from economics and sociology
((2))originated in research on complex systems in physics and computer science

macro and micro?

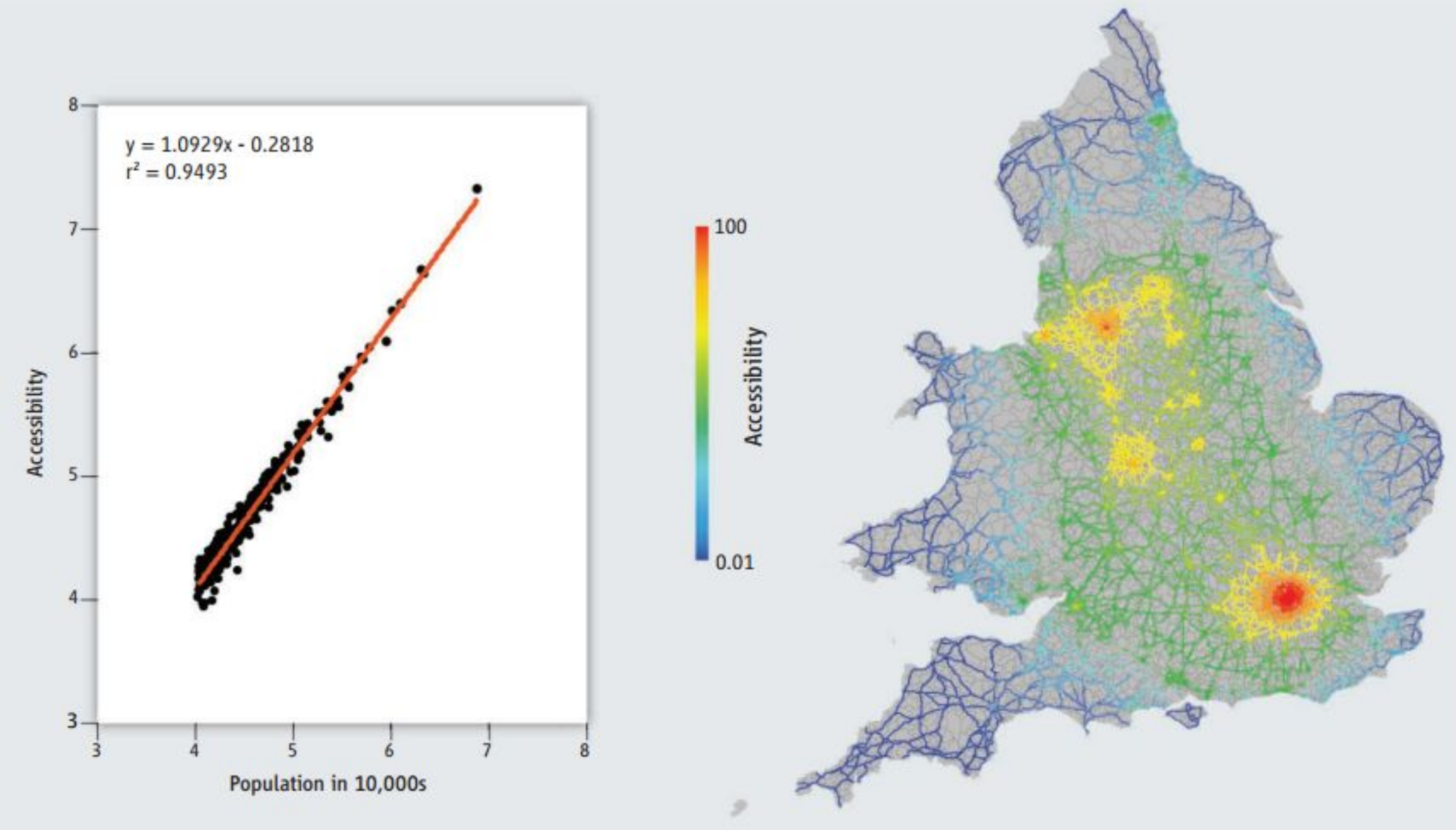
$$Y(t) = Y_0 N(t)^{\beta}.$$

Table 1. Scaling exponents for urban indicators vs. city size

Y	β	95% CI	Adj-R^2	Observations	Country–year
New patents	1.27	[1.25,1.29]	0.72	331	U.S. 2001
Inventors	1.25	[1.22,1.27]	0.76	331	U.S. 2001
Private R&D employment	1.34	[1.29,1.39]	0.92	266	U.S. 2002
"Supercreative" employment	1.15	[1.11,1.18]	0.89	287	U.S. 2003
R&D establishments	1.19	[1.14,1.22]	0.77	287	U.S. 1997
R&D employment	1.26	[1.18,1.43]	0.93	295	China 2002
Total wages	1.12	[1.09,1.13]	0.96	361	U.S. 2002
Total bank deposits	1.08	[1.03,1.11]	0.91	267	U.S. 1996
GDP	1.15	[1.06,1.23]	0.96	295	China 2002
GDP	1.26	[1.09,1.46]	0.64	196	EU 1999–2003
GDP	1.13	[1.03,1.23]	0.94	37	Germany 2003
Total electrical consumption	1.07	[1.03,1.11]	0.88	392	Germany 2002
New AIDS cases	1.23	[1.18,1.29]	0.76	93	U.S. 2002–2003
Serious crimes	1.16	[1.11, 1.18]	0.89	287	U.S. 2003
Total housing	1.00	[0.99,1.01]	0.99	316	U.S. 1990
Total employment	1.01	[0.99,1.02]	0.98	331	U.S. 2001
Household electrical consumption	1.00	[0.94,1.06]	0.88	377	Germany 2002
Household electrical consumption	1.05	[0.89,1.22]	0.91	295	China 2002
Household water consumption	1.01	[0.89,1.11]	0.96	295	China 2002
Gasoline stations	0.77	[0.74,0.81]	0.93	318	U.S. 2001
Gasoline sales	0.79	[0.73,0.80]	0.94	318	U.S. 2001
Length of electrical cables	0.87	[0.82,0.92]	0.75	380	Germany 2002
Road surface	0.83	[0.74,0.92]	0.87	29	Germany 2002

Data sources are shown in *SI Text*. CI, confidence interval; Adj-R^2, adjusted R^2; GDP, gross domestic product.

L. M. A. Bettencourt, J. Lobo, D. Helbing, C. Kühnert, G. B. West, Proc. Natl. Acad. Sci. U.S.A. 104, 7301 (2007).



We can represent this potential as $A_i = (N_i + \sum_{j \neq i} N_j \, d_{ij}^{-2})$, where N_i and N_j are the populations of cities i and j and d_{ij} is the distance between city i and city j.

M. Batty, Science, A theory of city size, 340, 1418 (2013).

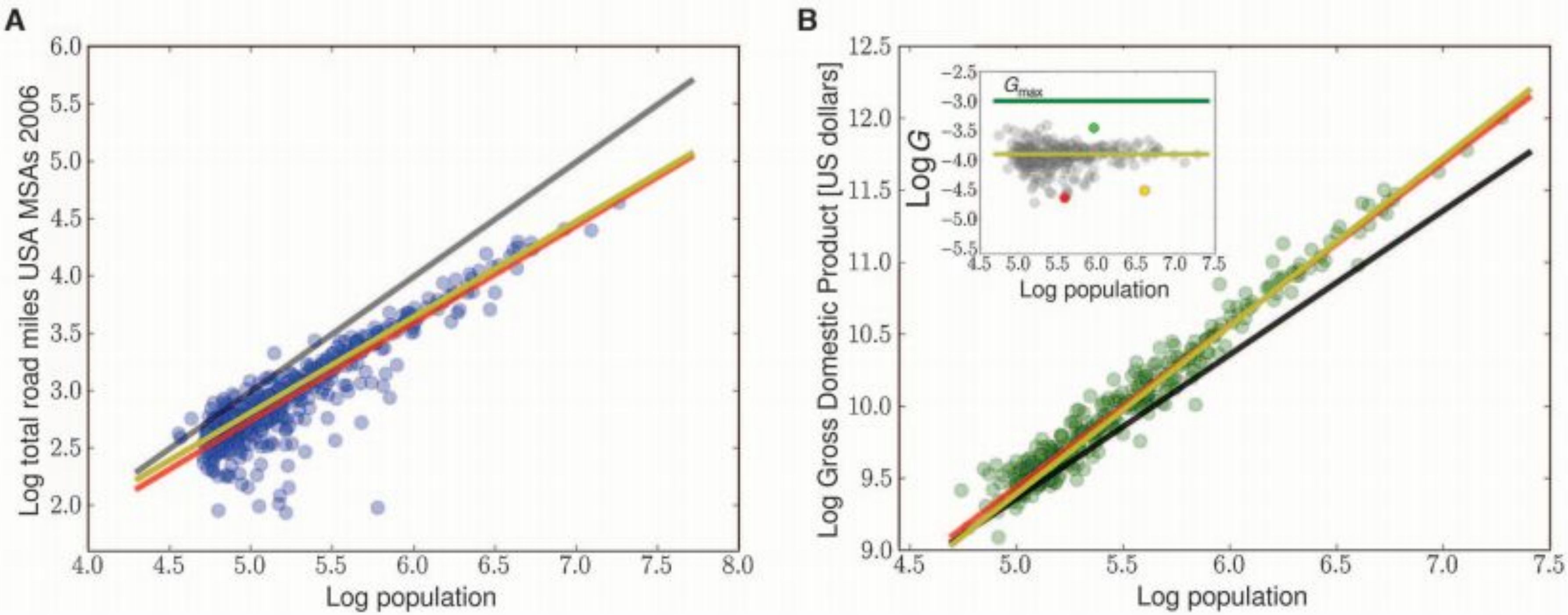
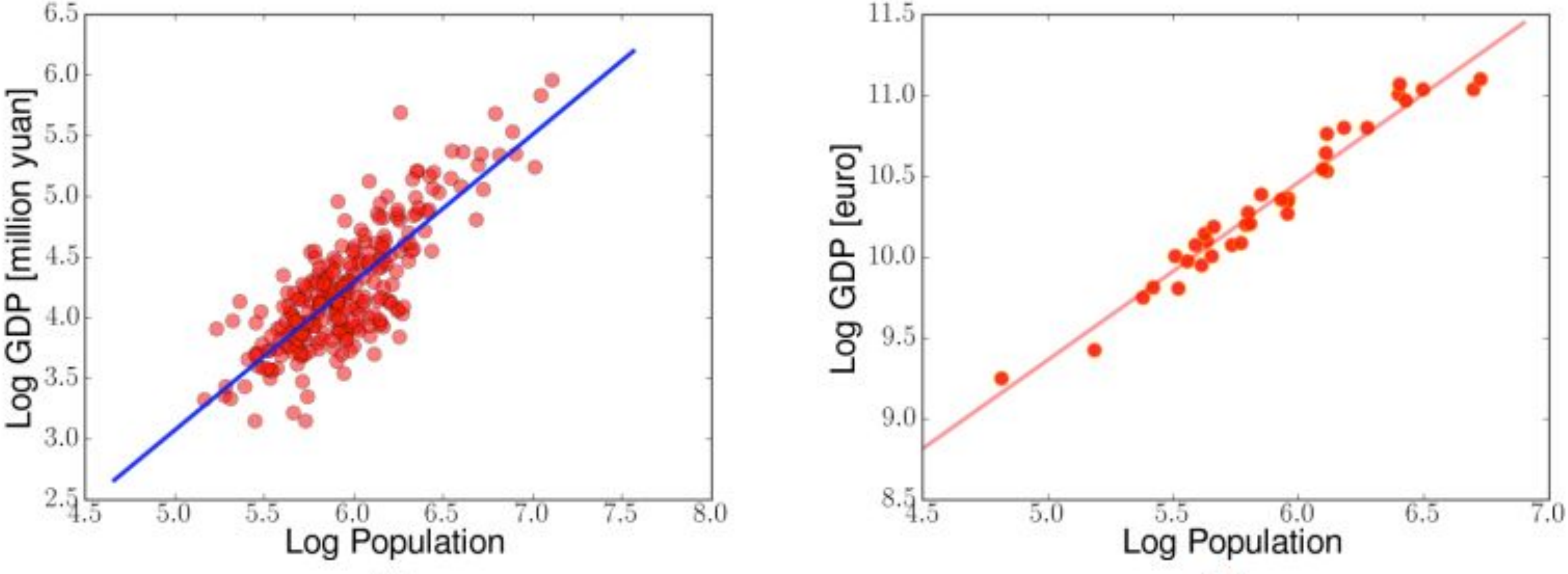


Fig. 1. Scaling of urban infrastructure and socioeconomic output. (**A**) Total lane miles (volume) of roads in U.S. metropolitan areas (MSAs) in 2006 (blue dots). Data for 415 urban areas were obtained from the Office of Highway Policy Information from the Federal Highway Administration (*14*). Lines show the best fit to a scaling relation $Y(N) = Y_0 N^{\beta}$(red), with $\beta = 0.849 \pm 0.038$ [95% confidence interval (CI), $R^2 = 0.65$]; the theoretical prediction, $\beta = 5/6$ (yellow); and linear scaling $\beta = 1$ (black). (**B**) Gross metropolitan product of MSAs in 2006 (green dots). Data obtained for 363 MSAs from U.S. Bureau of Economic Analysis (*14*). Lines describe best fit (red) to data, $\beta = 1.126 \pm 0.023$ (95% CI, $R^2 = 0.96$); the theoretical prediction, $\beta = 7/6$ (yellow); and proportional scaling, $\beta = 1$ (black). The two best-fit parameters in each scaling relation were estimated by means of ordinary least-squares minimization to the linear relation between logarithmically transformed variables (*14*). The inset shows the estimate of G for 313 U.S. MSAs and the conservation law $\frac{d \ln G}{d \ln N} = 0$ ($R^2 = 0.003$). G is measured as the product of gross domestic product and road volume, both per capita. As predicted by the theory, observed values of G for different cities cluster around its most likely value (mode, yellow line), which gives an estimate of the optimum G^*, and are bounded by the maximum $G_{max} \simeq 8G^*$(green line); see also Fig. 2B. Several metropolitan areas, such as Bridgeport, Connecticut (green circle); Riverside, California (yellow circle); or Brownsville, Texas (red circle), are outliers, suggesting that they are suboptimal in terms of their transportation efficiency or amount of social mixing.

L. M. A. Bettencourt, Science, The Origins of Scaling in Cities, 340, 1438 (2013).



(a) (b)

L. M. A. Bettencourt, Science, The Origins of Scaling in Cities (SI), 340, 1438 (2013).

Micro Economic Network

Previous work on the micro perspective was strongly rooted in oversimplifying assumptions on both the structure of the network and on agents' behaviors.

In recent micro approaches, economic networks were often viewed as the result of a network formation game among competing and cooperating agents.

As the number of nodes and possible links scales up, however, such problems become very difficult to solve, and classical approaches are unsatisfactory.

Economic Network

New Challenges

1. Massive data analysis
2. Time and space
3. Structure identification
4. Beyond simplicity
5. Systemic feedbacks

F. Schweitzer, G. Fagiolo, D. Sornette, F. Vega-Redondo, A. Vespignani, and D. R. White, Science 325, 422 (2009).

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Social Network

A **social network** is a social structure made up of a set of social actors (such as individuals or organizations) and a set of the dyadic ties between these actors. A social structure is determined by such interactions.

Social networks are self-organizing, emergent and complex.

Birds flocking, an example of self-organization in biology

A termite "cathedral" mound produced by a termite colony is a classic example of emergence in nature.

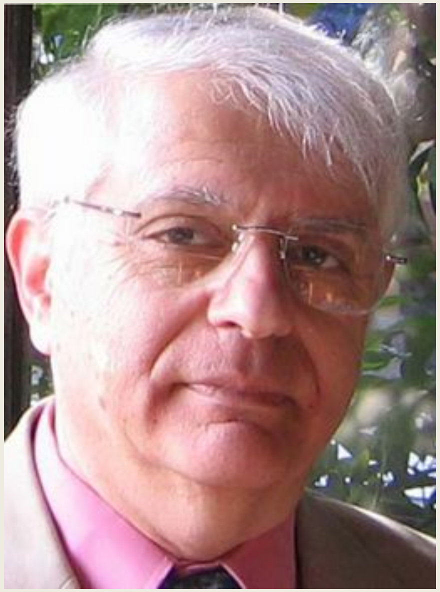
Social Network

- Milgram Experiment (about 6)
- Six Degrees of Kevin Bacon (2.94)
- Erdős number
- Small world experiment in Internet
  - Facebook (4.74)
  - QQ (3.8)

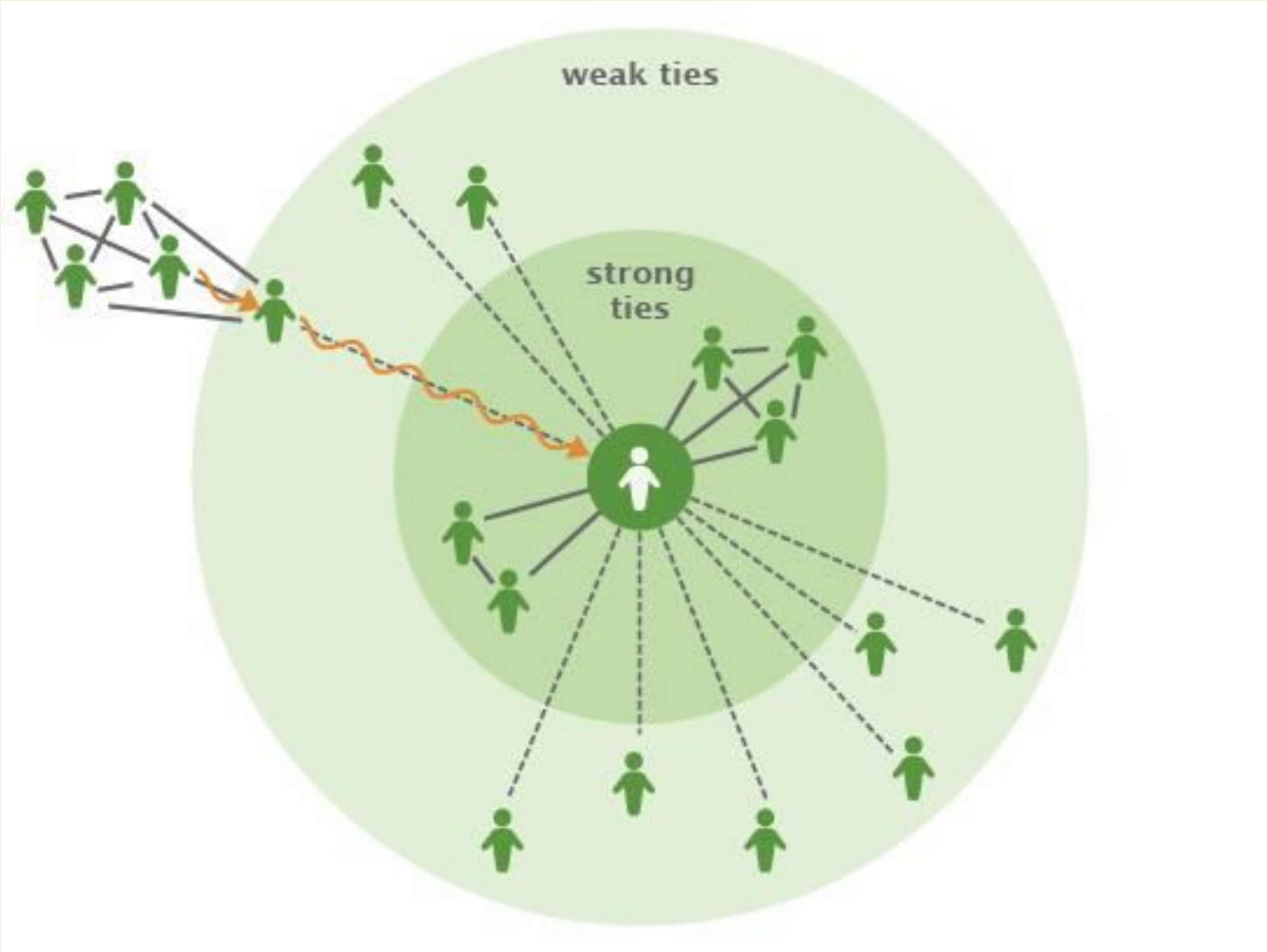
Social Network

The strength of weak ties

The major implication intended by this paper is that the personal experience of individuals is closely bound up with larger-scale aspects of social structure, well beyond the purview or control of particular individuals. Linkage of micro and macro levels is thus no luxury but of central importance to the development of sociological theory. Such linkage generates paradoxes: weak ties, often denounced as generative of alienation are here seen as indispensable to individuals' opportunities and to their integration into communities : strong ties, breeding local cohesion, lead to overall fragmentation.



Granovetter, M. S. (1973). "The Strength of Weak Ties". *The American Journal of Sociology* **78** (6): 1360–1380



Granovetter, M. S. (1973). "The Strength of Weak Ties". *The American Journal of Sociology* **78** (6): 1360–1380

Embeddedness

In the field of economic sociology, Granovetter has been a leader since the publication in 1985 of an article that launched "new economic sociology", "Economic Action and Social Structure: The Problem of Embeddedness". This article caused Granovetter to be identified with the concept of " Embeddedness", the idea that economic relations between individuals or firms are embedded in actual social networks and do not exist in an abstract idealized market.

Social Network

- Network Science
- Human Dynamics (barabasi)
- Recommendation
- Link Prediction

…

Outline

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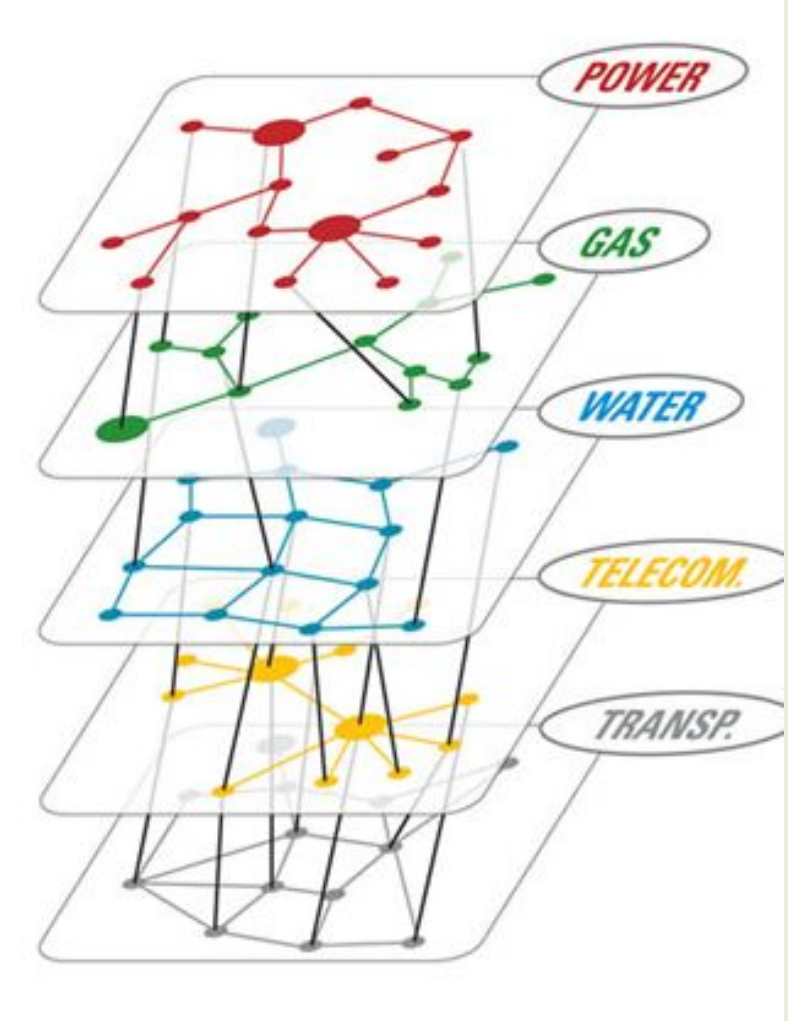
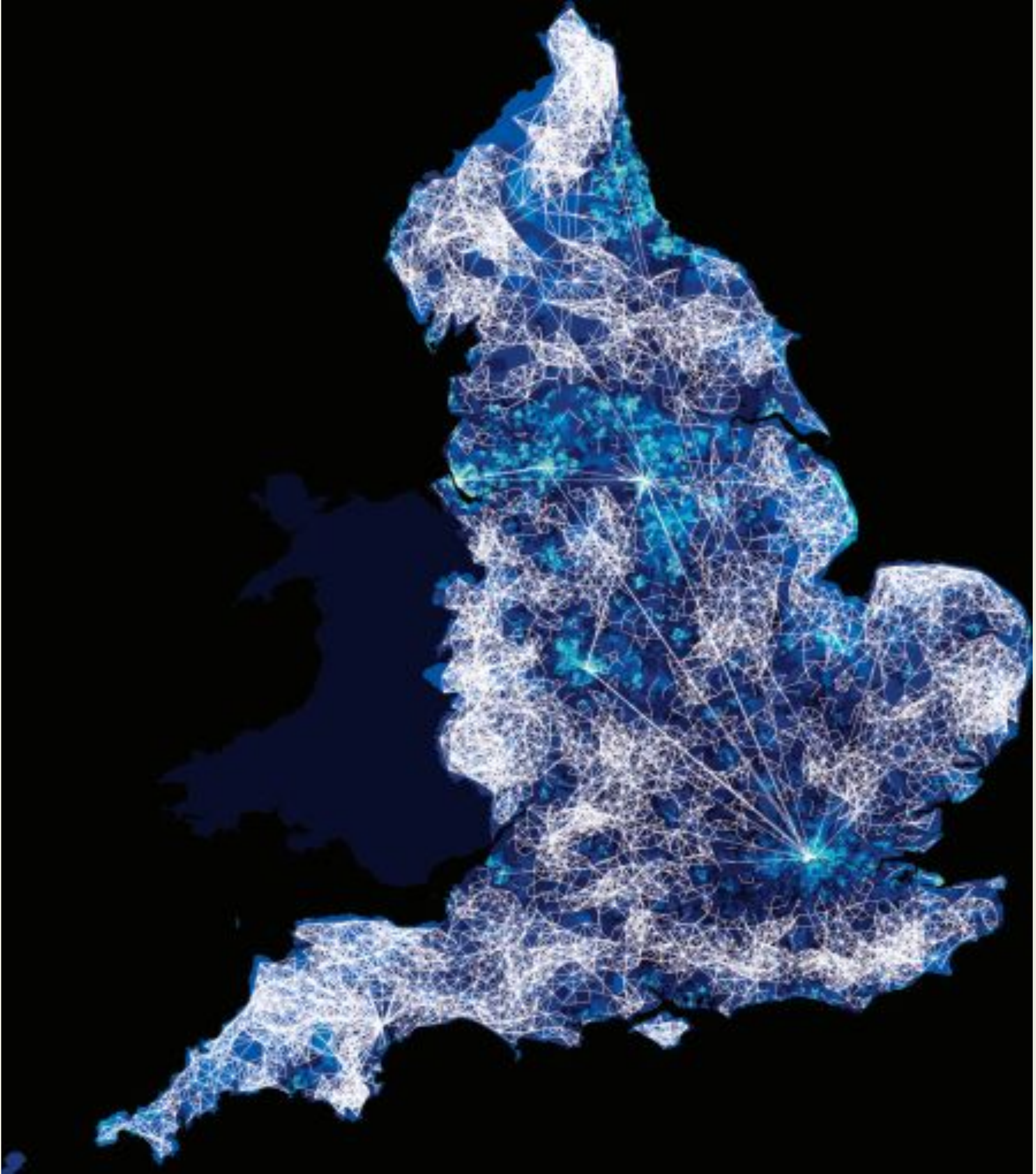
- **Coupled Network**

Coupled Network

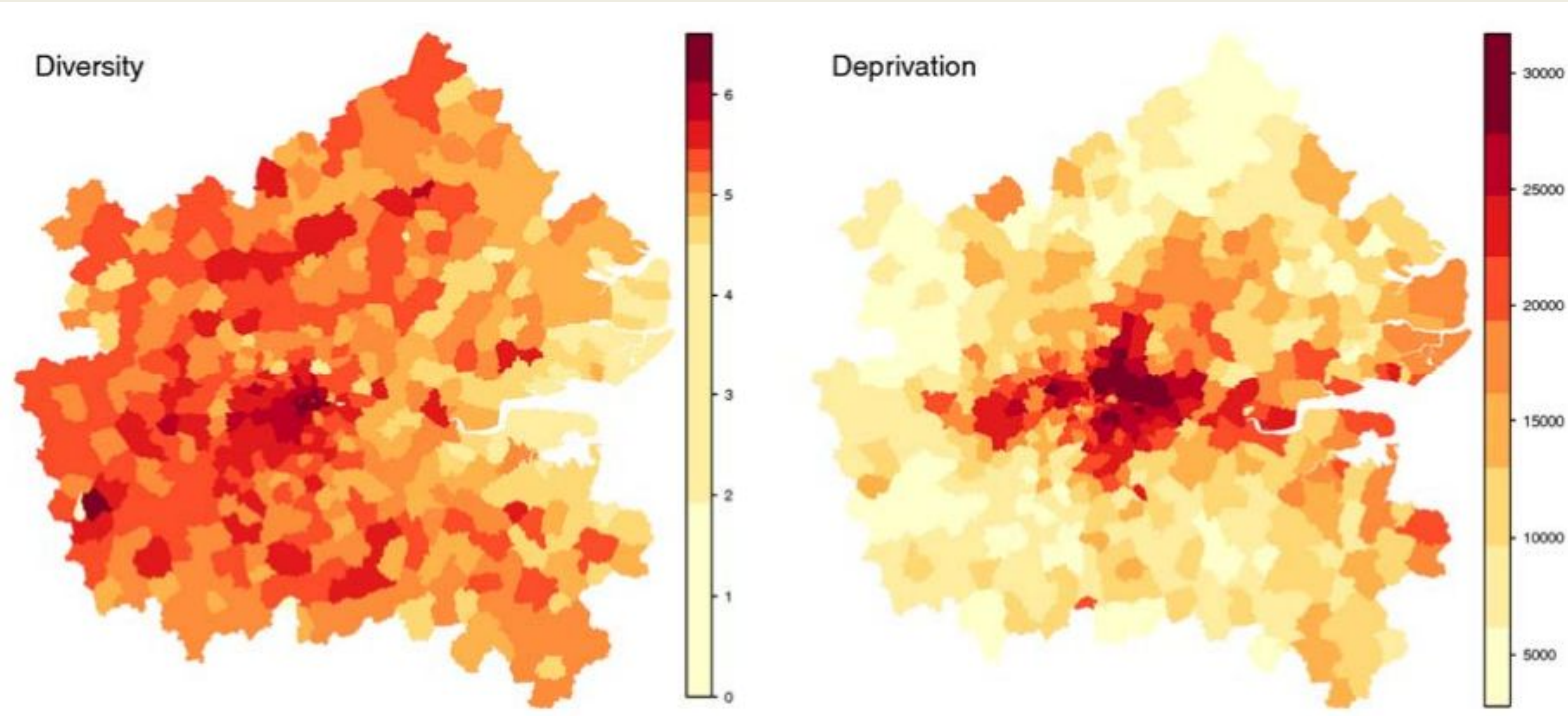
Two (or more than two) networks with the same nodes (just a part of nodes) are couple together.

Multi source data mining





An image of regional communication diversity and socioeconomic ranking for the UK. We find that communities with diverse communication patterns tend to rank higher (represented from light blue to dark blue) than the regions with more insular communication. This result implies that communication diversity is a key indicator of an economically healthy community.


Diversity
6
5
4
3
2
1
0
Deprivation
30000
25000
20000
15000
10000
5000

The real is the rational and the rational is the real!

Hegel

[Jure](#)

Jure Leskovec.

I am assistant professor of Computer Science at Stanford University. My research focuses on mining and modeling large social and information networks, their evolution, and diffusion of information and influence over them. Problems I investigate are motivated by large scale data, the Web and on-line media.

What's new

- Tutorial on Large Scale Network Analytics with SNAP at AAAI ICWSM conference.
- With Wei Wang we are serving as Program Chairs for **KDD 2014**. This year's theme is *using data mining for social good*. More details here.
- In Spring 2014 we are teaching CS341: Research Project in Mining Massive Data Sets.
- In Winter 2014 I taught CS246: Mining Massive Datasets, a graduate course on algorithms and techniques for processing, mining and learning with big dataset.
- In Winter 2014 I organized the Stanford Infoseminar.
- Submit to Frontiers of Network Analysis: Methods, Models, and Applications, a NIPS 2013 Workshop I am co-organizing.
- In Fall 2013 I taught CS224W: Social and Information Network Analysis, a graduate course on analysis, models and algorithms for large social and information networks.
- With Anand Rajaraman and Jeff Ullman we are working in a new edition of **Mining of Massive Datasets** book. PDFs are here!

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Network data
Network software
Teaching
Bio
Press
Contact

Talks

Jun 24,25
Complex Systems
Summer School, Santa

http://cs.stanford.edu/people/jure/pubs/

THANKS！


Q
&
A