network *sampling*

introduction to *network analysis* (*ina*)

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sampling *overview*

— *snowball sampling* and *contact tracing* in *sociology*

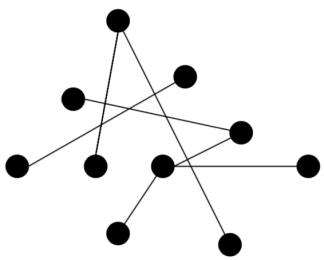
network-based methods for sampling hidden populations

— *fractality* and *self-similarity* of *real networks* [SHM05]

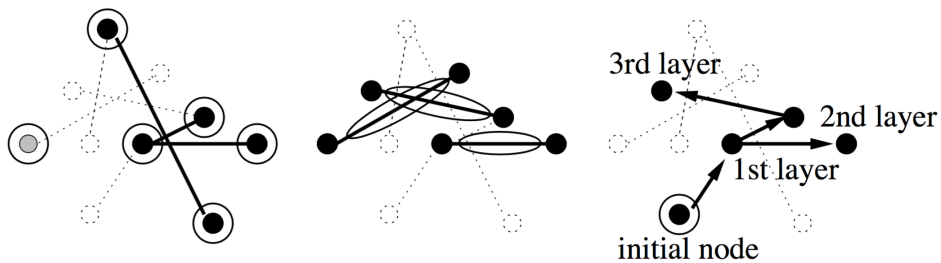
fractality is property of object that it is similar to part of itself

self-similarity demands power-law size scaling under renormalization

— any *real network* is just *sample* of *true network* [BŠWB15]



original network



node/link selection and snowball sampling

sampling *populations*

— *snowball sampling* similar to *breadth-first search*

nodes sampled proportional to their eigenvector centrality

— *contact tracing* similar to biased *best-first search*

nodes sampled according to some hidden variable

— *respondent-driven sampling* similar to *random walk*

nodes sampled proportional to their degree

$$\text{estimate } \langle x \rangle = \frac{\sum_i x_i}{\sum_i 1} \qquad \text{corrected } \langle x \rangle = \frac{\sum_i x_i / k_i}{\sum_i 1 / k_i}$$

sampling *methods*

— *random selection methods* for *global network sparsification*

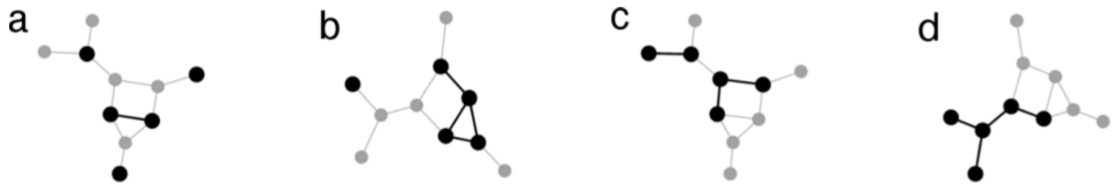
random node/link selection w/ or w/o induction etc.

— *network exploration methods* for *local network sampling*

random walks, snowball and expansion sampling etc.

— *merging/aggregation methods* for *network simplification*

box covering, cluster growing, community aggregation etc.



(a) node selection (b) by degree (c) link selection and (d) snowball sampling

(a) community aggregation and (b) cluster growing

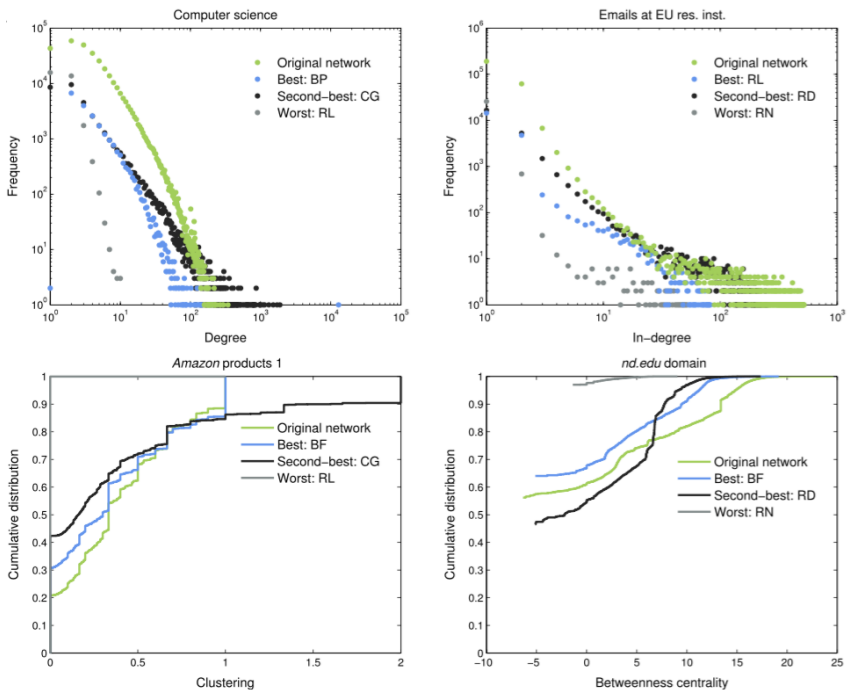
sampling *networks*

— *similar sampled networks* for $\gtrsim 15\%$ *network* [LF06]

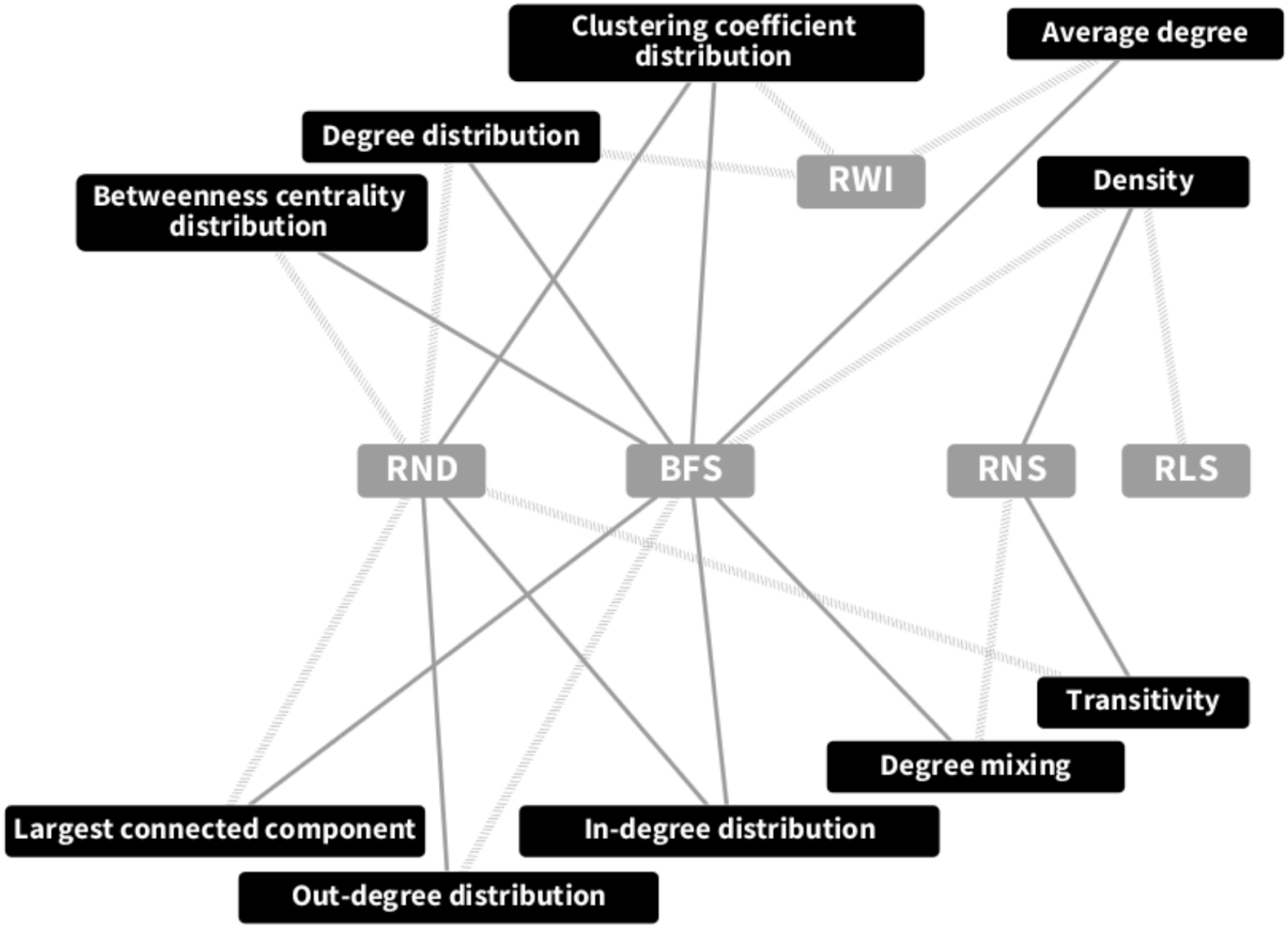
— *methods indistinguishable* for $\ll 1\%$ *network* [BŠB17]

— *selection/exploration* $\ggg$ *aggregation methods* [BŠB14]

independent of network type or size but not sample size



sampling *scheme*



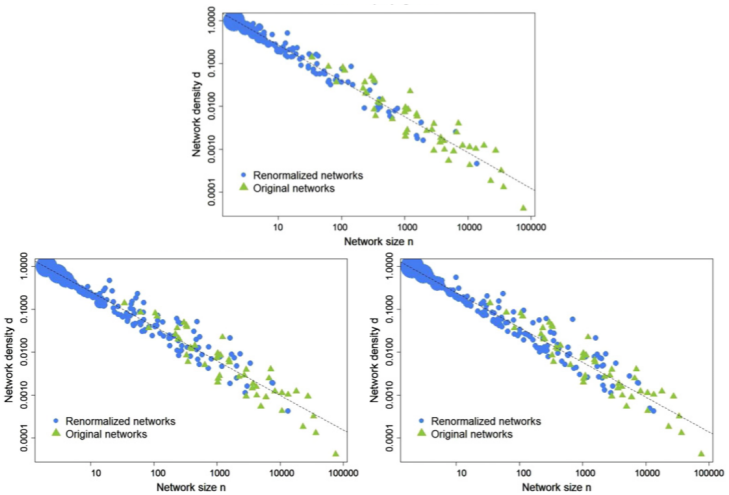
sampling *density*

— *self-similar network density* of *real networks* [LJT+11]

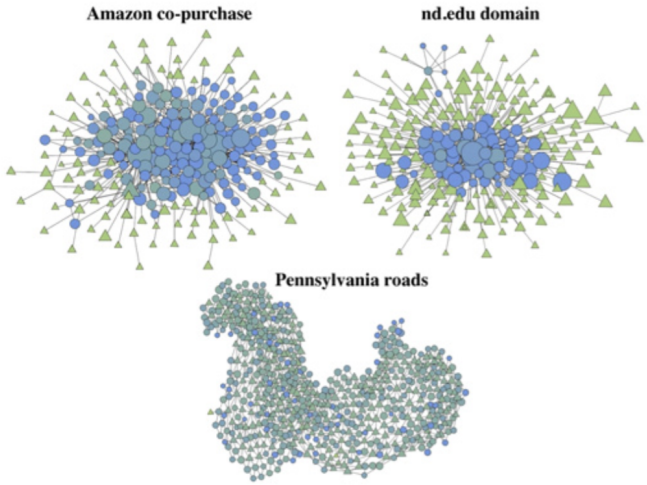
most real networks are sparse with $\rho \approx 7.89 n^{-0.99}$

— *network density invariant* under *any renormalization* [BŠB12]

box covering, cluster growing, community aggregation etc.



density invariance under renormalization



renormalized networks

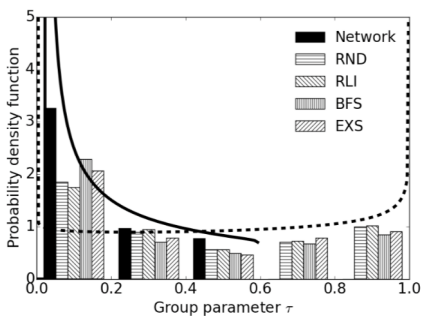
sampling *communities*

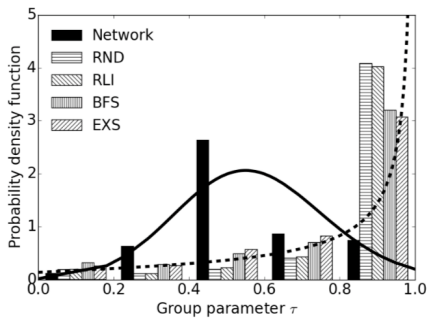
— *pronounced community structure* in *real networks* [GN02]

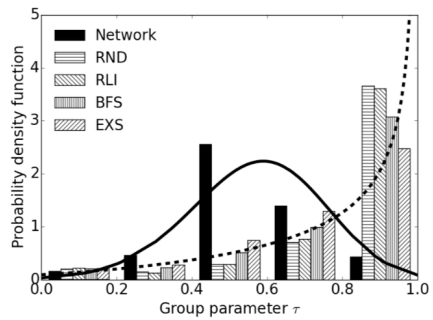
many real networks contain communities with $\tau \gg 0$

— *community structure enhanced* under *any sampling* [BŠWB15]

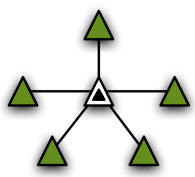
random selection, snowball and expansion sampling etc.

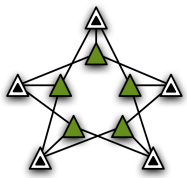




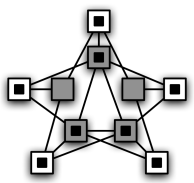


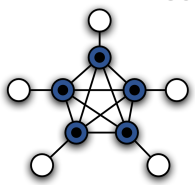
citation network



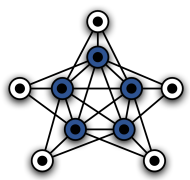


social network





collaboration network



sampling *references*

A.-L. Barabási.

Network Science.
Cambridge University Press, Cambridge, 2016.

Neli Blagus, Lovro Šubelj, and Marko Bajec.

Self-similar scaling of density in complex real-world networks.
Physica A, 391(8):2794–2802, 2012.

Neli Blagus, Lovro Šubelj, and Marko Bajec.

Assessing the effectiveness of real-world network simplification.
Physica A, 413:134–146, 2014.

Neli Blagus, Lovro Šubelj, and Marko Bajec.

Empirical comparison of network sampling: How to choose the most appropriate method?
Physica A, 477:136–148, 2017.

Neli Blagus, Lovro Šubelj, Gregor Weiss, and Marko Bajec.

Sampling promotes community structure in social and information networks.
Physica A, 432:206–215, 2015.

Wouter de Nooy, Andrej Mrvar, and Vladimir Batagelj.

Exploratory Social Network Analysis with Pajek: Expanded and Revised Second Edition.
Cambridge University Press, Cambridge, 2011.

David Easley and Jon Kleinberg.

Networks, Crowds, and Markets: Reasoning About a Highly Connected World.
Cambridge University Press, Cambridge, 2010.

Ernesto Estrada and Philip A. Knight.

A First Course in Network Theory.
Oxford University Press, 2015.

sampling *references*

M. Girvan and M. E. J Newman.
Community structure in social and biological networks.
P. Natl. Acad. Sci. USA, 99(12):7821–7826, 2002.

Jure Leskovec and Christos Faloutsos.
Sampling from large graphs.
In *Proceedings of the ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, pages 631–636, Philadelphia, PA, USA, 2006.

Paul J. Laurienti, Karen E. Joyce, Qawi K. Telesford, Jonathan H. Burdette, and Satoru Hayasaka.
Universal fractal scaling of self-organized networks.
Physica A, 390(20):3608–3613, 2011.

Mark E. J. Newman.
Networks.
Oxford University Press, Oxford, 2nd edition, 2018.

Chaoming Song, Shlomo Havlin, and Hernan A. Makse.
Self-similarity of complex networks.
Nature, 433(7024):392–395, 2005.