

## Large network structure and random graph models

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You are given a selection of **networks of different sizes and origins**.

- [Zachary's karate club network](#) (34 nodes)
- [Davis's southern women network](#) (32 nodes)
- [Lusseau's bottlenose dolphins network](#) (62 nodes)
- [Ingredients network by common compounds](#) (1,525 nodes)
- [Map of Darknet from Tor network](#) (7,178 nodes)
- [Human protein-protein interaction network](#) (19,634 nodes)
- [Internet map of autonomous systems](#) (75,885 nodes)
- [Amazon product copurchase network](#) (262,111 nodes)
- [Paper citation network of APS](#) (438,943 nodes)
- [Small part of Google web graph](#) (875,713 nodes)
- [Road/highway network of Texas](#) (1,379,917 nodes)

All networks are available in Pajek format.



### I. Toy network construction and Pajek format

1. Using your library, **construct small toy network** with a few nodes and edges. Print out its name, and the number of nodes and edges.
2. Using the methods provided by your library, **read in all networks** above and print out their size. What

is the size of the largest network you can read in say half a minute?

## II. Network statistics, connectivity, distances and clustering

1. Compute **basic statistics of networks** above. These are the number of nodes  $n$ , the number of isolated nodes  $n_0$ , the number of edges  $m$ , the number of self-edges or loops  $m_0$ , the average node degree  $\langle k \rangle = 2m/n$  and the undirected density  $\rho = \langle k \rangle / (n - 1)$ . Are the results expected?

*Computational complexity is  $\leq$  linear  $\mathcal{O}(m)$  and applicable to any network that fits in your memory.*

2. Using depth-first search methods provided by your library, compute **connected components of networks** above. Print out the fraction of nodes in the largest connected component  $S$  and the number of all connected components  $s$ . Are the results expected?

*Computational complexity is linear  $\mathcal{O}(m)$  and applicable to any network that fits in your memory.*

3. Using breadth-first search methods provided by your library, compute **distances between the nodes of networks** above. Print out the average distance between the nodes  $\langle d \rangle$  and the maximum distance or diameter  $d_{max}$ . Are the results expected?

*Computational complexity is quadratic  $\mathcal{O}(nm)$  and applicable only to medium sized networks.*

4. Using triad counting methods provided by your library, compute **clustering coefficient of networks** above. Print out the average clustering coefficient  $\langle C \rangle$ . Are the results expected?

*Computational complexity is superlinear  $\mathcal{O}(m\langle k \rangle)$  and applicable to all but the largest networks.*

5. (tentative) Using plotting functionality provided by your library, compute **degree distribution of networks** above. Plot degree distribution  $p_k$  on a doubly logarithmic plot. Are the results expected?

*Computational complexity is linear  $\mathcal{O}(n)$  and applicable to any network that fits in your memory.*

6. What is the **size of the largest network** you can analyze in say half a minute?

## III. Random graphs and standard network models

1. Using the methods provided by your library, construct **Erdős-Rényi random graphs**  $G(n, m)$  with the same number of nodes  $n$  and edges  $m$  as the networks above. Print out their basic statistics. Are the results expected?
2. (tentative) Using the methods provided by your library, construct **Barabási-Albert scale-free networks**  $G(n, \langle k \rangle/2)$  with the same number of nodes  $n$  and the average degree  $\langle k \rangle$  as the networks above. Print out their basic statistics. Are the results expected?