Complex Systems — Problems for lab

Fall 2024/2025

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5 Complex networks – till 09.01.2025

1. Visit the following sites and check what kind of data can you acquire and what kind of visualization can you make:

   - `http://networkrepository.com/`
   - `http://snap.stanford.edu`
   - `http://www-personal.umich.edu/~mejn/netdata/`

   Download a chosen data set and draw as a network.

2. Go to Stanford Large Network Dataset Collection by Jure Leskovec (`https://snap.stanford.edu/data/index.html`) and download data for the social circles from Facebook (ego-Facebook). Calculate for this network:

   (a) Degree distribution $P(k)$ and an average degree $< k >$.

   (b) Distribution of clustering coefficients and an average clustering coefficient.

   (c) Distribution of the shortest paths, the diameter and the average path length.

3. Create the following random graphs. Implement at least one by yourself, for the rest you can use some libraries (e.g. NetworkX). Check online `http://networksciencebook.com`:

   (a) **Erdös-Rényi model** $G(N, L)$, in which N vertices are connected with L randomly placed edges.

   (b) **Erdös-Rényi-Gilbert model** $G(N, p)$, in which each pair $(i, j), i, j = 1, ..., N$ of vertices is connected (there is an edges between them) with probability p.

   (c) **Watts and Strogatz model** $WS(N, k, \beta)$. Within this model we start from the regular graph of size N, usually a ring of nodes, i.e. one-dimensional lattice with periodic boundary conditions. Each node is initially linked to its k neighbors, i.e. for the ring and $k = 2$ only to the nearest neighbors (nn), for k to the nn and next nearest neighbors (nnn), and so on. The same can be done for any other regular graph like the square lattice, but here use the most typical structure, namely the ring with $k = 4$. With probability β each link is rewired to a randomly chosen node.

   Calculate and plot for these graphs the following properties and compare them between the models:

   (a) Degree distribution $P(k)$ and an average degree $< k >$.

   (b) Distribution of clustering coefficients and an average clustering coefficient.

   (c) Distribution of the shortest paths, the diameter and the average path length.

   For what values of parameters does it make sense to compare these models?

In the report: 1) Present network from point 1; 2) Show network from point 2, describe method used for calculations and show results from points 2 (a-c); 3) Implement ONE model of random network in Python and show results from points 3 (a-c). (Extra 1): Explain and implement algorithm for shortest path (e.g. Dijkstra algorithm) (Extra 2): Study all 3 types of random graphs from point 3.