Practical session

Graph models

Fabien Tarissan

In the followingwe represent networks by graphs. We denote a graph $G = (V, E)$, where V is the set of vertices (also called nodes) of the graph and E is the set of links (also called edges).

1 Graph properties

Choose a network, described as a list of links. You can either :
- use the protein-protein interaction network of the drosophila :
  see `http://tarissan.complexnetworks.fr/iaml/drosophila_PPI.txt`
- choose one from a database :
  - `http://konect.cc/`
  - `http://snap.stanford.edu/data/`
  - `http://networkrepository.com/`
  - `https://github.com/awesomedata/awesome-public-datasets`
  - ...
- take one of your own

In the following, we will consider the protein-protein interaction network (referred to as PPI-DROSO from now on).

Exercise 1 — ***Getting started.*** Downlod the following files :
- `http://tarissan.complexnetworks.fr/iaml/sandbox.py`
- `http://tarissan.complexnetworks.fr/iaml/plotdist.py`

Use those files to :

1. Compute the basic statistics of your network : number of nodes and edges, density, average degree, highest degree, clustering coefficient, the degree distribution.
2. Display the degree distribution of the network

2 Erdös-Rényi random graphs

Exercise 2 — ***Generation.*** Create a program which, given two integers n and m generates an Erdös-Rényi random graph with n nodes and m edges and writes the list of edges in a file. Multiple edges are allowed, but not loops.

Exercise 3 — ***Characteristics.*** Using the previously defined programs,

1. Generate an Erdös-Rényi graph with the same size of your network (ie. $n = 7236$ nodes and $m = 22270$ edges for PPI-DROSO).
2. Compute the basic features of this graph
3. Display the degree distribution of this graph.
4. Comment these results.
5. Compare the measurements obtained on your network with those made on the Erdös-Rényi graph. Comment.

3 Random graphs with fixed degree distribution

Exercise 4 — *Generation using direct method* We first generate a random graphs with a fixed degree distribution using the direct method, that is the configuration model.

1. Create a program which, given a degree list, creates a random graph with a similar degree list using the configuration model seen during the course.
2. Extract the degree list of network to generate a random graph with a similar degree distribution.

Exercise 5 — *Generation using switching method* Now, we implement the switching method.

1. Create a program which, given a real graph, achieves S random switches of links ends. Take good care that switches do not create any loop or multiple edge.
2. Starting from your network, realize $S = 10^6$ permutations, and writes the result in a file the list of edges obtained.
3. Add to the code a way to measure the clustering of the graph every 10^4 switches, and to write in a file the value of the clustering throughout the process.
4. Plot the corresponding values obtained with your network and comment the results.

Exercise 6 — *Comparisons.* We now have two random graphs with the same degree distribution as your network.

1. Compare these two graphs using the important features previously cited : are they identical ? If not, what is different from one to the other ?
2. Compare the measurements obtained on your network with those made on the graph generated using the configuration model. Comment.

4 Barabási-Albert random graphs

Exercise 7 — *Barabási-Albert graph generation.* Create a program generating a graph according to Barabási-Albert method such that :

1. the graph is built by adding n nodes to the initial graph, the initial graph will be given as an input of the program,
2. any node is connected to m' nodes of the existing graph according to the preferential attachment rule, m' is an input parameter of the program too.

Exercise 8 — *Comparison to* ppi-droso *drosophila network.* Use the previous algorithm to generate a scale-free Barabási-Albert network with similar number of nodes than your network, according to the following indications :

1. use as an initial graph the 4 nodes graph containing the following edges :
   0 1
   1 2
   2 3
2. set the value of m in such a way that the density is of the same order as the density of your network.

Compare the structure of the graph obtained to the one of your network. Comment.

5 Watts-Strogatz random graphs

Exercise 9 — *Open question.* Suppose that you want to compare the structure of your network to a Watts-Strogatz network with comparable size and density.

1. Describe how you would proceed. (Meaning how would you choose the characteristics to generate the graph ?)
2. Implement the solution that you proposed and then discuss the results.