A04: Communities and Random Networks

Network Science '21: Assignment 4

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Objectives

1. Explore the community structure of real networks
2. Explore the emergence of giant components in random networks
3. Gain intuition on the small world property of real networks

A04.1 Community detection

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Task: *For the given networks find the communities using (a) the greedy modularity maximization by Clauset Newman and Moore and (b) the label propagation algorithm. Assign to each community a color and draw the resulting graph.*

Task: *Randomise each network and compare the number of communities obtained before and after randomisation.*

A04.1 Hints

- Clauset et al. algorithm is available as `nx.greedy_modularity_communities()`
- Label propagation algorithm is available as `nx.label_propagation_communities()`

A04.1 Datasets provided

Datasets provided:

- Zachary Karate Club: Nodes represent members of the club and Edges represent a tie between two members **[1]**
- Dolphin social network: Nodes represent dolphins and Edges represent frequent associations observed among a group of 62 individuals **[2]**
- Facebook friendships: Nodes represent Facebook users and Edges represent their friendship relations collected from survey participants **[3]**

A04.1 Datasets provided

[1] W. W. Zachary, An information flow model for conflict and fission in small groups, Journal of Anthropological Research, 33 (1977), pp. 452–473
[2] D. Lusseau et al., ”The bottlenose dolphin community of Doubtful Sound features a large proportion of long-lasting associations.” Behavioral Ecology and Sociobiology 54(4), 396-405 (2003)
[3] J. Leskovec and J. J. Mcauley, Learning to discover social circles in ego networks, in Advances in Neural Information Processing Systems, 2012, pp. 539– 547.

A04.2 Random Graphs

A04.2 Erdos-Renyi random networks

Task: *Generate three Erdos-Renyi networks with* $N = 500$ *nodes and average degree (a)* $\langle k \rangle = 0.2$*, (b)* $\langle k \rangle = 1$ *and (c)* $\langle k \rangle = 2$. *Visualize these networks.*

Task: *Generate ER graphs with* $N = 100$ *nodes for different edge creation probabilities* $p \in [0, 1]$ *and:*

1. Plot the probability that a node belongs to the largest connected component N_G/N as a function of p and mark with a vertical line the critical probability $p_c = 1/N$
2. Plot the average clustering $\langle C \rangle$ as a function of p and give an interpretation of the result

A04.2 Hints

- Use the `nx.spring_layout()` for better visualization of the networks
- To plot the probability N_G/N you need to average your results by generating many (~ 100) graphs for each value of p
- Use logarithmic spacing for the values of p
- In ER graphs for each node the probability that two of its neighbors are connected is the same probability that any other two nodes will be connected and it is equal to p

A04.3 Small-world with high clustering

Task: *Generate many WS small-world networks with* $N = 100$ *nodes and fixed number of neighbors for each node* $2\kappa = 10$*. As a function of the rewiring probability* p*, using a logarithmic scale for the* p*-axis:*

1. Plot the average clustering $\langle C(p) \rangle / \langle C(0) \rangle$ and check if it correctly reproduces the analytical result

$$\langle C(p) \rangle \approx \frac{3}{2} \frac{(\kappa - 1)}{2\kappa - 1} (1 - p)^3 \tag{1}$$

2. Plot the average shortest-path length $D(p)/D(0)$

A04.3 Hints

- `nx.watts_strogatz_graph` generates a WS network
- `nx.average_shortest_path_length(g)` computes $D(p)$

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