Contents

Syllabus

Network Science Module

Lecture 1: Introduction to the course

Overview of the course; introduction to networks

[**slides**]

reading material: Sec. 0.1-0.6 (Menczer, Fortunato, and Davis 2020) Sec. 1.1, 1.2 (Easley and Kleinberg 2010)

Lecture 2: Recap on graphs

Graph theory: basic definitions; density and sparsity; subnetworks; degree; directed networks; weighted networks; multilayer and temporal networks; network representations; drawing networks; paths and distances; connectedness and components; small world phenomena, clustering coefficient.

[**slides**]

reading material: Chapter 1-2 (Menczer, Fortunato, and Davis 2020) Sec. 2.1, 2.2, 2.3 (Easley and Kleinberg 2010)

Lecture 3: Strong and weak ties

Strong and weak ties; triadic closure; the strength of weak ties; tie strength and network structure in large-scale data; tie strength, social Media, and passive Engagement; closure, structural holes, and social capital.

[**slides**]

reading material: Sec. 3.1-3.5 (Easley and Kleinberg 2010)

Lecture 4: Homophily

Homophily; assortativity; mechanisms underlying homophily: selection and social influence; affiliation; tracking link formation in online data; a spatial model of segregation;

[**slides**]

reading material: Sec. 2.1 (Menczer, Fortunato, and Davis 2020) Sec. 4.1-4.5 (Easley and Kleinberg 2010)

Lecture 5: Complex Network Analysis Practice

Exercises; basics on network analysis with Python; introduction to NetworkX

[**slides**] [**slides on NetworkX**]

Lecture 6: Hubs and Centralities

Hubs; centralities; degree centrality; eigenvector centrality; closeness centrality; betweenness centrality; friendship paradox; robustness; core decomposition

[**slides**]

reading material: Chapter 3 (Menczer, Fortunato, and Davis 2020)

Lecture 7: Hubs and Centralities

More on centralities; exercises

[**slides**]

Lecture 8-9: Network Models

Network models; random network; small-world networks; the configuration model; preferential attachment

[**slides**]

reading material: Chapter 5 (Menczer, Fortunato, and Davis 2020)

Lecture 10: Power Laws and Rich-Get-Richer Phenomena

Popularity as a network phenomenon; power laws; rich-get-richer models; unpredictability of rich-get-richer effects; the long tail

[**slides**]

reading material: Chapter 18 (18.1 - 18.7) (Easley and Kleinberg 2010)

Lecture 11: Communities

Introduction to communities; community variables; community definitions; partitions; network partitioning algorithms; data clustering; dendrograms

[**slides**]

reading material: Chapter 6 (Menczer, Fortunato, and Davis 2020)

Lecture 12: Communities

Girvan-Newman; modularity; modularity optimization; Newman's greedy algorithm; Louvain's algorithm; modularity's limits; label propagation; stochastic block modeling

[**slides**]

reading material: Chapter 6 (Menczer, Fortunato, and Davis 2020)

Lecture 13: Communities

method evaluation; artificial benchmarks; real benchmarks; partition similarity; exercises

[**slides**]

reading material: Chapter 6 (Menczer, Fortunato, and Davis 2020)

Lecture 14-15: Games and Traffic networks

what is a game?; reasoning about behavior in a game; best responses and dominant strategies; Nash equilibrium; multiple equilibria: coordination games; multiple equilibria: the Hawk-Dove game; mixed strategies; mixed strategies: examples and empirical analysis; Pareto and social optimality; traffic at equilibrium; Braess's paradox; the social cost of traffic at equilibrium

[**slides**]

reading material: Chapter 6 (6.1-6.9) Games (Easley and Kleinberg 2010) Chapter 8 (8.1 - 8.3) Modeling Network Traffic using Game Theory (Easley and Kleinberg 2010)

Lecture 16: Cascading behaviors in networks

diffusion in networks; modeling diffusion through a network; cascades and clusters; diffusion, thresholds, and the role of weak ties; extensions of the basic cascade model

[**slides**]

reading material: Chapter 19 (19.1-19.5) Cascading behavior in Networks (Easley and Kleinberg 2010)

Lecture 17: Computational Epidemiology

epidemic processes; SIR model; homogeneous mixing; stochastic SIR model; SIS model; epidemic spreading on heterogeneous networks

[**slides**]

Lecture 18: Computational Epidemiology

high-resolution contact networks

[**slides-a**] [**slides-b**]

Lecture 19: Cascading behaviors in networks

diffusion in networks; modeling diffusion through a network; cascades and clusters; diffusion, thresholds, and the role of weak ties; extensions of the basic cascade model

[**slides**]

reading material: Chapter 19 (19.1-19.5) Cascading behavior in Networks (Easley and Kleinberg 2010)

Lecture 20: The Web, Link Analysis, and Web Search

the structure of the web; searching the Web; link analysis; HITS: Hubs and Authorities; PageRank; Random Walks and PageRank; practical implications; modern Web search; link analysis beyond the Web

[**slides**]

reading material: Chapter 13 The Structure of the Web (Easley and Kleinberg 2010) Chapter 14 (14.1-14.5) Link Analysis and Web SearchTheory (Easley and Kleinberg 2010) Chapter 4 Directions and Weights (Menczer, Fortunato, and Davis 2020)

Lecture 21: Human Mobility: data, theory and models

Mobility types; mobility data; first human mobility studies; overview of mobility models; applications: urban spaces; epidemics

[**slides**]

Lecture 22: Traditional Machine Learning on Graphs

classic graph machine learning tasks; traditional machine learning pipeline; node-level tasks; edge-level tasks; graph-level tasks; node level features: graphlets; edge-level features: distance-based, local neighborhood, global neighborhood; kernel methods; graphlet kernel; Weisfeiler-Lehman kernel

[**slides**]

Lecture 23: Representation Learning on Graphs

graph representation learning; node embeddings; shallow encodings; random-walk embeddings; DeepWalk; node2vec; embedding entire graphs

[**slides**]

References

Easley, D., and J. Kleinberg. 2010. *Networks, Crowds, and Markets: Reasoning about a Highly Connected World*. Cambridge University Press. https://books.google.it/books?id=atfCl2agdi8C.

Menczer, F., S. Fortunato, and C. A. Davis. 2020. *A First Course in Network Science*. Cambridge University Press. https://books.google.it/books?id=q1abxgEACAAJ.