ECE 442 - Network Science Analytics

Syllabus - Spring 2025

Time: Mondays and Wednesdays, 3:25 pm - 4:40 pm.
Place: Computer Studies Building (CSB) 601.
Class website: http://www.hajim.rochester.edu/ece/sites/gmateos/ECE442.html
Make-up lectures: Few selected Fridays, 3:25 pm - 4:40 pm in CSB 601.

Instructor: Gonzalo Mateos (gmateosb@ece.rochester.edu).
Office hours: Tuesdays 10:30 am in CSB 726.
Teaching assistant: Hamed Ajorlou (hajorlou@ur.rochester.edu).
TA office hours: Fridays 11 am in CSB 701.

Bibliography:

- Eric D. Kolaczyk, *"Statistical Analysis of Network Data: Methods and Models,"* Springer.

Available online from the University of Rochester library.

Additional reading:

- M. E. J. Newman, *"Networks: An Introduction,"* Oxford University Press.
- D. Easley and J. Kleinberg, *"Networks, Crowds, and Markets: Reasoning About a Highly Connected World,"* Cambridge University Press.
- W. L. Hamilton, *"Graph Representation Learning,"* Morgan and Claypool.
- Research papers provided by the instructor.

The books will be on reserve for the class in Carlson Library.

Prerequisites: Useful to have good background in probability theory and linear algebra, as well as some exposure to graphs. For homework assignments we will use Python and possibly NetworkX as well as PyTorch Geometric.

Credit distribution: Homework laboratory assignments (4, 30%), and a research project in groups of two students involving three deliverables (proposal 10%, progress report 10%, final report and in-class presentation 50%). Detailed information on the project will be posted in the class website.

Academic dishonesty: Academic dishonesty will be dealt with according to the University of Rochester's Academic Honesty Policy.

Class description: Network Science Analytics (ECE 442) is a graduate class about networks. The science of networks is an emerging discipline of great importance that combines graph theory, probability and statistics, and facets of engineering and the social sciences. Topics in this course will help answer intriguing questions such as: Where does "six degrees of separation" come from? How can we make sense of large graphs, ranging from social networks to the smart power grid? What are the underpinnings of Google's search engine and webpage ranking? What are good models for predicting popularity in Twitter? How can we estimate the size of the Internet?

Class objectives: This course will provide students with the mathematical tools and computational training to understand large-scale networks in the current era of Big Data. It will introduce basic network models and structural descriptors, network dynamics and prediction of processes evolving on graphs, modern algorithms for topology inference, community and anomaly detection, as well as fundamentals of social network analysis. All concepts and theories will be illustrated with numerous applications and hands-on case studies from technological, social, biological, and information networks.

Topic outline: Topics covered in ECE 442 will tentatively include

1) Introduction and overview. Why study networks?
2) Preliminaries: background on graphs, statistical inference, and optimization.
3) Descriptive network analysis: degrees, centrality, cohesion, and communities.
4) Sampling and estimation in network graphs.
5) Network models: random, small-world, preferential attachment.
6) Network topology inference: link prediction, tomographic inference.
7) Modeling and prediction for processes (evolving) over network graphs.
8) Graph signal processing and learning with graph neural networks.

Additional topics that will be left as optional readings

1) Mapping networks, visualization of large graphs.
2) Analysis of network flow data.

Visit the class website http://www.hajim.rochester.edu/ece/sites/gmateos/ECE442.html for a description of the course contents including a lecture-by-lecture schedule.

Tentative class schedule - Spring 2025

Date	Description	HW/Project
Wed. 01/22	Introductions, class organization, networks, context, examples	
Fri. 01/24	Graphs, digraphs, degrees, movement, strong and weak connectivity	
Mon. 01/27	Families, algebraic graph theory, data structures and algorithms	
Wed. 01/29	Inference, models, point and set estimates, hypothesis testing	
Mon. 02/03	Tutorials on inference about a mean and linear regression	
Wed. 02/05	Graph visualization, stages of network mapping, mapping Science	
Fri. 02/07	Large graph visualization, k-core decomposition, Internet mapping	
Mon. 02/10	Degree distributions, Erdos-Renyi random graphs and power laws	HW1 due
Wed. 02/12	Visualizing and fitting power laws, preferential attachment	
Fri. 02/14	Closeness, betweeness and eigenvector centrality measures	
Mon. 02/17	Web search, hubs and authorities, Markov chains review	
Wed. 02/19	PageRank, fluid and graph random walk models, distributed algorithms	
Mon. 02/24	Cohesive subgroups, clustering, connectivity, assortativity mixing	
Wed. 02/26	Strength of weak ties, community structure in networks	
Mon. 03/03	Girvan-Newmann method, hierarchical clustering, modularity	
Wed. 03/05	Modularity optimization, graph cuts, spectral graph partitioning	Proposal
Mon. 03/10	Spring Break - No class	
Wed. 03/12	Spring Break - No class	
Mon. 03/17	Sampling, Horvitz-Thompson estimation, graph sampling designs	
Wed. 03/19	Network estimation of totals, groups size, degree distributions	
Fri. 03/21	Random graph models, model-based estimation, significance, motifs	
Mon. 03/24	Small-world, preferential attachment and copying models	HW2 due
Wed. 03/26	Latent network models, communities, random dot product graphs	Prog. Report
Mon. 03/31	Traveling to IISc - No class	
Wed. 04/02	Traveling to IISc - No class	
Mon. 04/07	Traveling to ICASSP'25 - No class	
Wed. 04/09	Traveling to ICASSP'25 - No class	
Mon. 04/14	Topology inference, link prediction, scoring and classification	HW3 due
Wed. 04/16	Inference of association networks, tomographic inference	
Fri. 04/18	Nearest-neighbor prediction of processes, Markov random fields	
Mon. 04/21	Graph kernel-regression, kernel design, protein function prediction	
Wed. 04/23	Diseases and the networks that transmit them, epidemic modeling	
Mon. 04/28	Machine learning on graphs, graph convolutional filters	HW4 due
Wed. 04/30	Graph neural networks, architectures, properties	
Fri. 05/02	In-class student project presentations	Presentation