Introduction to Network Science:
Graphs, Dynamics, and Randomized Algorithms

ECE 592 / CSC 591 - Section 069

Short Description

Many modern complex networks such as Internet of Things, Online Social Networks, large scale wireless ad-hoc networks, power-grid, biological networks, etc. can be represented as a (large) graph. This course will first provide an introduction to graph modeling, its characterization, metrics on graph, ranking, and how to describe popular dynamics on graphs, including random walk and epidemics. It also covers basics of graph sampling, property estimation, and randomized algorithms for computationally prohibitive (NP-hard) tasks such as clustering/partitioning. Applications include Google PageRank algorithm, graph sampling, property estimation, identifying/ranking nodes, security, with connections to various statistical methods in machine learning and big (graph) data.

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Prerequisites

Some background on linear algebra and basic probability will be helpful but not strictly required. Necessary background materials will be provided in class. Note: Most lectures will be based on lecture notes and some of the references below

References: (to be added more)

- **Network Science**, A. Barabashi, (http://barabasi.com/networksciencebook/)
- **Networks: An Introduction,** Mark Newman, Oxford University Press, 2010
- **Networks, Crowds, and Markets: Reasoning about a Highly Connected world**, by David Easley and Jon Kleinberg, Cambridge University Press 2010 (http://www.cs.cornell.edu/home/kleinber/networks-book/)
- **A First Course in Network Theory**, Ernesto Estrada and Philip A. Knight, Oxford University Press, 2015 (https://catalog.lib.ncsu.edu/catalog/NCSU4646489)
- **A First Course in Network Science**, Cambridge University Press, 2020 (GitHub page: https://cambridgeuniversitypress.github.io/FirstCourseNetworkScience/)

Tentative structure:

- ***Graphs for complex networks***
  1. Modeling, representation, classification, adjacency matrix, graph Laplacian
  2. Metrics on graph: degree, centrality, algebraic connectivity, etc.
  3. Random graph model, small-world graph, power-law, preferential attachment models
  4. Extension: multi-layer graphs, dynamic graphs

- ***Stochastic Graph Models***
  1. Erdős–Rényi random graph
  2. Power-law random graph: power-law distribution, preferential-attachment model (Barabashi-Albert)

- ***Dynamics on graphs***
  1. Reviews on Poisson process, Markov chains
  2. Random walk, Google PageRank walk
  3. Epidemics modeling (branching process, SIS, SIR, etc.)
  4. Epidemics on general graph for information/malware spreading

- ***Algorithms on graphs***
  1. Randomized algorithms with brief intro to MCMC (Markov chain Monte Carlo)
  2. Graph sampling, estimation
  3. MCMC approach to NP-hard optimization problem, Simulated Annealing
  4. Graph clustering/partitioning, community detection, node ranking, gossip algorithms, etc.

- ***Applications to various networks*** (e.g. WWW, online social networks, networked data structure)

Note:

- This is a special topic course, created in Fall 2017, revised in Fall 2018 and Fall 2020.
- Any necessary mathematical background will be given in class, almost from scratch.
- Basic knowledge on probability and linear algebra would be helpful but not strictly required.
- There will be some homework assignments.
- Exams will be either take-home or project-based.
- The course is more about learning the new techniques and concepts around network science and understanding their modern-days applications
- Your class attendance and participation are highly expected.