Course Syllabus

Syllabus:

- Lesson One: What is Network Science?
  - What is (not) network science?
  - The main premise of network science
  - History and relation to graph theory, physics, sociology, and other disciplines
  - Examples of networks from different application domains

- Lesson Two: Relevant Concepts From Graph Theory
  - Undirected, directed, signed, weighted and spatial networks
  - Paths, connected components, random walks, etc
  - Directed Acyclic Graphs
  - Bipartite graphs
  - Max-flow/min-cut

- Lesson Three: Degree Distribution and ER Graphs
  - Degree distribution
  - Friendship paradox
  - ER graphs and their degree distribution
  - Giant component size in ER graphs
  - Assortative vs disassortative networks

- Lesson Four: Random vs. Real Graphs and "Scale Free" Networks
  - The degree distribution of real-world networks
  - Power-law degree distributions
  - Preferential attachment model
  - How to detect a power-law and estimate the exponent
  - Configuration model and degree-preserving randomization

- Lesson Five: Network Paths, Clustering and The “Small World” Property
  - Clustering and transitivity in networks
  - Diameter and characteristic path length
  - Small-world networks and the Watts-Strogatz model
  - Network motifs

- Lesson Six: Centrality and Netork-core Metrics and Algorithms
  - Link-based centrality metrics
  - Path-based centrality metrics
  - k-core decomposition
  - Core-periphery structure
  - Rich-club set of nodes

- Lesson Seven: Community Detection and Hierarchical Modularity
  - Hierarchical clustering in networks
  - Modularity metric
  - Algorithms for modularity maximization
  - Limitations of modularity
  - Hiearchical modularity

- Lesson Eight: Advanced Topics in Community Detection
  - Overlapping communities
  - Dynamic communities
  - Comparing community structures
  - The role of nodes within and between communities
  - Applications of community detection

- Lesson Nine: Network Contagion and Epidemics
  - Epidemics on networks
  - Epidemic modeling (SI, SIS, SIR, etc) under homogeneous mixing
  - Epidemic modeling under arbitrary degree distributions
  - Basic reproductive number and superspreaders

- Lesson Ten: Influence Phenomena On Networks
  - The linear threshold model and the Independent cascades model
  - Empirical studies in information and behavior spreading
  - Seeding strategies on how to maximize influence
  - Cascades and community structure

- Lesson Eleven: Other Dynamic Processes Of/On Networks
  - Percolation, random failures, and targeted attacks on networks
  - Search on networks
  - Synchronization on networks
  - Coevolutionary networks

- Lesson Twelve: Models of Static and Dynamic Networks
  - Stochastic network models that generate power-law degree distributions
  - Optimization-based network models
  - Stochastic block models
  - Hierarchical Random Graphs

- Lesson Thirteen: Statistical Analysis of Network Data
  - Network sampling methods
  - Estimation of network metrics
  - Association networks
  - Network tomography

- Lesson Fourteen: Machine Learning meets Network Science

- Node embeddings
- Graph neural networks
- Deep generative network models
- Limitations and applications of graph neural networks