Dynamical Processes on Complex Networks

Lecture 1:
• Introduction to Networks:
  o Applications, examples of dynamical processes on networks.
• Basic Concepts:
  o Representation of networks: matrices, lists, and sparse matrices.
  o Degree-related measures: degree, average nearest neighborhood degree, concentric degree.
  o Degree distribution, statistical moments of degree distribution.
  o Special cases: Power law distribution and Poisson distribution.

Lecture 2:
• Measure for network characterization
  o Distance: the Dijkstra algorithm
  o Clustering coefficient.
  o Hierarchical networks.
  o Shannon entropy of degree distribution, complexity measure.

Lecture 3:
• Network Centrality
  o Degree centrality, betweenness centrality, closeness centrality, k-core, random walk accessibility, PageRank, eigenvector centrality.
  o Localization: nonbacktracking matrix.
  o Applications.

Lecture 4:
• Correlation in networks
  o Assortative mixing.
  o Degree-degree correlation.
• Community detection
  o Modularity
  o Methods: Based on betweenness centrality, Walktrap, eigenvector of matrices, Fast greedy.

Lecture 5:
• Models of network formation I:
  o Random graphs
  o Small-world networks
  o Barabási-Albert model

Lecture 6:
• Models of network formation:
  o Nonlinear BA model
  o Spatial models
  o Other models
Lecture 7:
• Percolation and resilience on networks
  o Percolation.
  o Random failures and attacks.
  o Cascade failure.
  o Applications.

Lecture 8:
• Epidemic spreading on networks
  o SIR and SIS on homogeneous networks.
  o Epidemics on scale-free networks
  o Heterogeneous mean-field approximation.
  o Monte Carlo simulation.
  o Continuous time simulation.
  o Rumor spreading on networks.

Lecture 9:
• Synchronization of coupled oscillators.
  o Collective behavior and phase transition.
  o The Kuramoto model on homogeneous networks.
  o Mean-field approximation.
  o The Kuramoto model on complex networks.
  o Mathematical analysis and simulation.
  o Explosive synchronization.

Lecture 10:
• Additional topics:
  o Epidemic spreading with awareness.
  o Multilayer networks.
  o Temporal networks.