Dynamical Processes on Complex Networks

Lecture 1:

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

Lecture 2:

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

Lecture 3:

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

Lecture 4:

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

Lecture 5:

- Models of network formation I:
  - Random graphs
  - Small-world networks
  - Barabási-Albert model

Lecture 6:

- Models of network formation:
  - Nonlinear BA model
  - Spatial models
  - Other models

Lecture 7:

- Percolation and resilience on networks
  - Percolation.
  - Random failures and attacks.
  - Cascade failure.
  - Applications.

Lecture 8:

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

Lecture 9:

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

Lecture 10:

- Additional topics:
  - Epidemic spreading with awareness.
  - Multilayer networks.
  - Temporal networks.