Complex Networks: Structural Aspects and Algorithms

Theoretical Computer Science
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Contents

Administrivia

Administrivia

1. Block Seminar: seminar will be held on 4 days in the last two weeks of January.
2. Talks will be 30 mins in duration + 15 mins for questions: 45 mins in total.
3. You must hand in the seminar reports by December 19th. Please use the standard LaTeX file format from the seminar homepage.
4. Scoring: 50% Talk + 50% Report.

Introduction

Resources

General Books and Surveys

- Networks: An Introduction. M.E.J. Newman, Oxford University Press.
- The Structure and Function of Complex Networks. M.E.J. Newman, available online.

Papers

- The Small World Phenomenon. S. Milgram, available online.

Empirical Study of Networks

Types of networks

Topic 1 A survey of various types of networks and their properties:

1. Technological networks: The Internet, power grid, transportation networks.
2. Social networks: Facebook, twitter, LinkedIn.
3. Biological networks: Neural networks, ecological networks.

References

1. Networks: An Introduction. M.E.J. Newman. Oxford University Press.
2. The Structure and Function of Complex Networks. M.E.J. Newman. Available online.

Structural Properties of Complex Networks

Topic 2 A survey of the common structural properties displayed by complex networks.

1. The small-world effect.
2. Clustering.
3. Degree distribution of vertices.
4. Network resilience.
5. Community structure.
6. Network motifs.

References

1. Networks: An Introduction. M.E.J. Newman. Oxford University Press.
2. The Structure and Function of Complex Networks. M.E.J. Newman. Available online.

Network Theory Fundamentals

Measures and Metrics: Centrality Measures

Topic 3 A survey of measures that capture features of network topology.

1. Degree centrality.
2. Eigenvector centrality.
3. Katz centrality.
4. Closeness and Betweenness centrality.

References

1. Networks: An Introduction. M.E.J. Newman. Oxford University Press.
2. A Critical Review of Centrality Measures in Social Networks. Landherr, Friedl, Heidemann. Available online.
3. Axioms for Centrality. Boldi and Vigna. Available online.

Measures and Metrics: Centrality Measures

Topic 4 A study of the Page Rank centrality measure and its application in the Google search engine.

References

1. The Anatomy of a Large-Scale Hypertextual Web-Search Engine. Brin and Page. Available online.
2. Networks: An Introduction. M.E.J. Newman. Oxford University Press.
3. Axioms for Centrality. Boldi and Vigna. Available online.

Measures and Metrics: Similarity Measures

Topic 5 A study of the similarity measures in social network analysis.

References

1. Vertex Similarity in Networks. Leicht, Holme and Newman. Available online.
2. Networks: An Introduction. M.E.J. Newman. Oxford University Press.

Large-Scale Structure: The Small-World Phenomenon

Topic 6 A study of Milgram's classic work.

References

1. The Small World Problem. Milgram. Available online.

Large-Scale Structure: Degree Distribution and Scale-Free Networks

Topic 7 What does the degree distribution of a real-world network look like? This is typically a power-law distribution and is modeled usiang scale-free networks.

References

1. Networks: An Introduction. M.E.J. Newman. Oxford University Press.
2. Scale-Free Networks: A Decade and Beyond. Barabasi. Available online.

Large-Scale Structure: Degree Distribution and Scale-Free Networks

Topic 8 A survey on scale-free networks and their properties.

References

1. The Structural Properties of Scale-Free Networks. Cohen, Havlin, ben-Avraham. Available online.
2. Scale-Free Networks: A Decade and Beyond. Barabasi. Available online.
3. Scale-Free Networks. Barabasi and Bonabeau. Available online.

Network Algorithms

Fast Shortest Path Estimation in Large-Scale Networks

Topic 9 How do we quickly estimate the shortest path between two nodes of a network? Djikstra's algorithm solves this problem on weighted graphs in $O(n^2)$ time. This is still too slow for large-scale networks.

References

1. Fast Shortest Path Estimation in Large Networks. Potamias, Bonchi, Castillo, Gionis. Avialable online.

Graph Partitioning and Community Detection

How do we partition a network into clusters? The simplest partitioning problem is to divide the nodes of the network into two parts (of specified sizes) such that the number of edges crossing the two parts is minimized.

Topic 10 A study of the Kernighan-Lin partitioning heuristic.

References

1. Networks: An Introduction. M.E.J. Newman. Oxford University Press.
2. An Efficient Heuristic Procedure for Partitioning Graphs. Kernighan and Lin. Available online.

Graph Partitioning and Community Detection

Topic 11 A study of the Spectral Partitioning technique.

References

1. Networks: An Introduction. M.E.J. Newman. Oxford University Press.
2. Spectral Methods for Network Community Detection and Graph Partitioning. Newman. Available online.

Graph Partitioning and Community Detection

Topic 12 A study of the Spectral Modularity Maximization technique for community detection.

References

1. Networks: An Introduction. M.E.J. Newman. Oxford University Press.
2. Spectral Methods for Network Community Detection and Graph Partitioning. Newman. Available online.

Motif Finding

Topic 13 What are network motifs and how do we detect them efficiently?

References

1. Network Motifs: Simple Building Blocks of Complex Networks. Milo, Shen-Orr, Itzkovitz, Kashtan, Chklovskii and Alon. Available online.
2. Network Motif Discovery Using Subgraph Enumeration and Symmetry Breaking. Growchow and Kellis. Available online.

Network Models

Random Graph Models: The Erdós-Rényi Random Graph

How are networks modeled? Typically using random graph models.

Topic 14 A study of the Erdós-Rényi random graph model along with its salient properties.

References

1. Networks: An Introduction. M.E.J. Newman. Oxford University Press.
2. On Random Graphs I. Erdós and Rényi. Available online.

Random Graph Models: The Configuration Model

Topic 15 A study of the Configuration model along with its salient properties.

References

1. Networks: An Introduction. M.E.J. Newman. Oxford University Press.
2. The Configuration Model. Aaron Clauset. Lecture notes: Network Analysis and Modeling. Santa Fe Institute. Available online.

Random Graph Models: The Preferential Attachment Model

Topic 16 A study of the Preferential Attachment model along with its salient properties.

References

1. Networks: An Introduction. M.E.J. Newman. Oxford University Press.
2. The Emergence of Scaling in Random Networks. Barabási and Albert.