Network Analysis in Healthcare Syllabus

Course: CS5891/CS3891 Special Topics: Network Analysis in Healthcare
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Semester: Fall 2021
Time: Monday & Wednesday, 3:30 – 5:00 pm
Location: Featheringill Hall, Room 211
Website: http://www.ohpenlab.org/courses/
Office Hours: Upon Appointment
Academic session: 08/25/2021 - 12/10/2021

DESCRIPTION
Network analysis has enjoyed extensive applications in healthcare. It has become a widely applied method to extract meaningful information from abundant healthcare data. This course will survey recent work in network analysis in healthcare, especially from a data mining, machine learning, and statistical perspective. This course aims to present network analysis methods for exploring and analyzing large-scale healthcare data and measuring associations between network metrics and clinical outcomes. The course will cover four research topics: 1) network analysis in learning healthcare systems; 2) network analysis to discover disease associations; 3) network analysis in prediction and machine learning; and 4) network analysis in drug repurposing and biology.

OBJECTIVES
After this course, students will be able to
i) love network analysis (I hope everyone will love network analysis)
ii) understand healthcare systems through network analysis
iii) identify interesting research questions which can be solved by network analysis

PREREQUISITES
There is no official prerequisite for this course. However, Students are expected to
i) have proficiency in designing and writing software programs (Python or any language of their preference) (CS 3270: Programming Languages); and
ii) have basic knowledge of statistical analysis (MATH 2820/5820: Introduction to Probability and Mathematical Statistics).
GRADING

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Percent of Grade</th>
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<tbody>
<tr>
<td>Project</td>
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<tr>
<td>Initial Proposal, Due in Week 4</td>
<td>10%</td>
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<tr>
<td>Status Report, Due Week 10</td>
<td>15%</td>
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<tr>
<td>Final Report &amp; Presentation, Due Week 15</td>
<td>45%</td>
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<tr>
<td>Reading Summaries</td>
<td>20%</td>
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<tr>
<td>Class Participation</td>
<td>10%</td>
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Required Reading Assignments: There is no primary textbook for this course. Reading assignments will be selected from various periodicals. Students will be required to read and submit brief summaries of assigned readings. Your summaries should be no longer than one page in length. Your summaries will be graded on a scale ranging from 1 point to 3 points.

- **1 point:** You skimmed the assigned reading and barely understood, or summarized, its meaning and implications.
- **2 points:** You demonstrated that you read the material by providing a reasonable account of its contents, its strengths, and its weaknesses.
- **3 points:** You provided a critical assessment of the reading and show insight regarding the reading’s topic.

These summaries constitute a total of 20% of your final grade. An average score of 2 points will provide the student with the full 20%. An average score greater than 2 points will entitle the student to “extra” credit, with a maximum of 5 additional percentage points on their final grade. You must email your summaries to you.chen@vanderbilt.edu before the due date.

Project: In lieu of a final exam, each student or a group (no more than 3 group members) must complete an independent project on network analysis. Projects should investigate a topic of interest to the student/group and must demonstrate analysis and critical thinking in network analysis. The project will require a significant commitment and contribute to a substantial part of the final grade. For the group project, each group member should have clear responsibilities and contributions to the project.
TOPIC AND SCHEDULE OVERVIEW *(Tentative and Subject to Change)*

Part 1 (One class – August 25): Course Overview
In the first class, we’ll go over ground rules for the course and review the syllabus. Next, we will review applications of network analysis in evaluating healthcare organization structures, measuring disease associations, and identifying new functions of existing drugs. At the end of the lecture, we will watch a network video, taking us on a tour of 150 years of interconnected, interdisciplinary research, as represented by Nature's publication record.

Part 2 (Three classes – August 30, September 1 & 8): Network Analysis: Basic Metrics
We will use three classes to learn basic sociometric factors in the network analysis.

In the first class, we will learn how to build undirected/directed networks from various data sources, and learn basic sociometric factors, such as degree, betweenness centrality, connectedness, isolates, coreness, clustering, hierarchy, embeddedness, proximity, transitivity, clique, eigenvector centrality, diameter, density, core–periphery structure, cluster coefficient, assortativity (homophily, two nodes of the same edge), gravity, reciprocity, cohesion (global cluster coefficient, shortest path, motifs (two node motifs, dyads; three mode motifs, triads), network density, structural holes/weak ties), random walks, small world (random networks), graphlets used in network analysis.

In the second class, We will investigate basic network structures such as random networks and scale-free networks (power-laws). We will also discuss the small word phenomenon (the alpha-model and the beta-model), random walks, weak ties' strength, and centrality balance and homophily. Finally, we will introduce models of information diffusion, spread, transmission, and contagion.

In the third class, we’ll focus on generative network models, including random graphs (The Erdos-Renyi random network, the configuration model – Bender and Canfield), small world network, core-periphery (core-periphery score, gini coefficients), preferential attachment models, Kronecker graphs, and stochastic blockmodels.

**Reading list: (select two papers) due Sep 8th.**


Part 3 (Six classes – September 13, 15, 20, 22, 27 & 29): Network Analysis to Explore Healthcare Systems
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We will use six classes to illustrate how network analysis is leveraged to measure healthcare organization structures, surgical team networks, patient referral networks, nursing team structures. In addition, we will introduce examples to illustrate the associations between network characteristics and clinical outcomes, such as length of hospital stay, mortality risk, job performance, and family satisfaction.

In the first class, we will introduce data collection and procedure (e.g., roster method, dual perspective method, care sites, EHR audit logs) to identify relationships between healthcare professionals in healthcare systems. In addition, we will learn network analysis software, Gephi, NetworkX, UCINET, Netdraw, Pajek, igraph, and Cytoscape.

In the second to four class, we will learn examples of using network analysis to identify healthcare organization structures.
- Identifying collaborative care teams through electronic medical record utilization patterns
- A case study exploring support among senior managers in a hospital network
- A network analysis using data from emergency surgical services
- Intra- and post-operative surgical team networks
- Patient referral networks
- Network analysis of patient flows
- Changes of neonatal intensive care unit care structures between pre- and intra-COVID-19
- Care structures of COVID-19 ICUs
- Medication advice-seeking interaction networks

In the fifth to sixth class, we will introduce the measurements of associations between network metrics and clinical outcomes.
- Healthcare worker networks in the neonatal intensive care unit associate with length of stay
- Network analysis of team structure in the neonatal intensive care unit (team structures and patient satisfaction)
- The importance of external contacts in job performance
- The structure of critical care nursing teams and patient outcomes: a network analysis
- Associations between networks and stress.
- Associations between networks and hospital costs.

Reading list 1: (select two papers) due Sep 15.
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Reading list 2: (select two papers) Due Sep 22.


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Initial proposal (One class – October 4)
This day will be dedicated to student projects. Students will write a short summary of their problem statement, initial research design. Each student/group will have 3 minutes to talk their proposed project.

Part 4 Disease networks (Two classes – October 6 & 11):

Reading list: (select two papers) Due October 6.
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Part 5 (Three classes – October 13, 18, &20): Network Analysis in Machine Learning

We will use seven classes to introduce the role of network analysis in machine learning. We will learn node embedding, and node and link prediction and classification. We will investigate approaches to extract network features (graphlet degree vector, graphlet correlation matrix) and feed them into traditional clustering and classification models. Next, we will learn graph neural networks, such as graph convolutional networks. In addition, we will learn how to model multi-scale data via a network of networks. Finally, we will learn examples of applying network analysis in predicting patient morbidity (weight loss, type 2 diabetes) and mortality.

Reading list: (select two papers) Due Oct 13.


Project Status Report Presentations (Two classes – Oct 25 & 27)

The two days will be dedicated to student projects. Students will make a short presentation (6 minutes including presentation and question time) on the status of their projects for an in-class evaluation. Each group member needs to present their responsible part.

Part 6 (Five classes – [Nov 1 & 3 - guest lectures], Nov 8, 10 & 15): Network Analysis in Biology

Classes on Nov 1 and 3 will be guest lectures – using network analysis to conduct drug repurposing. Students will learn how protein-protein interaction networks can be leveraged to discover new functions of existing used drugs.

The first class, and the classes from fourth to fifth classes, we will learn examples of network analysis in biology beyond drug repurposing. Such as measuring associations between sleep disorders and metabolic dysregulation.

Reading list: (select two papers) Due Nov 1.
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Student Final Presentations (Four classes, Nov 17, Nov 29, Dec 1 &6)
The final lecture will be dedicated to students’ presentations on their final project. 10 minutes presentation and 2 minutes for questions. Students will submit a summary of their project, including title, background, methods, results, and discussion and conclusion two weeks after the final presentations.