Network Analysis in Healthcare Syllabus

Course: CS3891/5891/BMIF7391 Special Topics: Network Analysis in Healthcare
Instructor: You Chen, Ph.D. (you.chen@vanderbilt.edu)
Teaching Assistant: Xinmeng Zhang (Xinmeng.zhang@vanderbilt.edu)
Semester: Fall 2024
Time: Tuesday & Thursday, 8:00 – 9:15 am
Location: Featheringill Hall 132
Website: https://brightspace.vanderbilt.edu/CS 3891-05
Office Hours: Upon Appointment
Academic session: 8/21/24-12/5/24
No classes: Nov 12&14 (AMIA 2024), and Nov 26&28 (Thanksgiving)

DESCRIPTION

Network analysis has become a pivotal tool in healthcare, offering powerful methods to extract meaningful insights from vast and complex healthcare data. This course provides an overview of recent advancements in network analysis within the healthcare sector, emphasizing perspectives from data mining, machine learning, and statistical approaches. The course will cover the history of network analysis, key metrics, and their applications in learning healthcare systems. It consists of three main components:

- Instructor-led sessions introducing the foundational concepts of network analysis and its relevance to healthcare.
- Student-led presentations on published research in the field.
- Student projects applying network analysis to solve real-world healthcare problems.

OBJECTIVES

By the end of this course, students will be able to:

- Understand the history and foundational concepts of network analysis.
- Apply network analysis techniques to analyze and solve healthcare-related problems.
- Develop the skills necessary to design and execute a small-scale research project using network analysis.
- Integrate network analysis as an additional dimension in approaching and solving complex problems.
- Understand and work with various types of health and healthcare data within the context of network analysis.

PREREQUISITES

There is no official prerequisite for this course. However, Students are expected to

- have proficiency in designing and writing software programs (Python or any language of their preference) (CS 3270: Programming Languages)
- have basic knowledge of statistical analysis (MATH 2820/5820: Introduction to Probability and Mathematical Statistics).

GRADING

Criteria		Percentage of grade
Student-led presentations	Sep 17&19	15%
Project	Initial proposal and presentation, Due Sunday, Oct 6th	20%
	Status report and presentation, Due Sunday, Nov 3rd	20%
	Final report and presentation, Due Sunday, Dec 1	35%

Class participation		10%

Student-Led Presentations (15 minutes: 10 minutes for presentation, 5 minutes for Q&A)

Each student presentation should focus on a single article, which can be chosen from the provided list or selected independently. The presentation should cover the following key points:

- **Research Question:** What is the main question or problem addressed by the article?
- **Data Overview:** What type of data is used? How is the data generated, processed, and analyzed?
- **Network Composition:** What constitutes the network in the study? Specifically, what are the nodes, what are the edges, and how is the relationship between pairs of nodes measured?
- **Network Metrics:** Which network metrics are employed in the study? How are these metrics interpreted?
- **Application of Metrics:** How are the network metrics utilized? Are they applied in statistical models, visualizations, or machine learning models?
- **Findings:** What are the key findings of the study?
- **Interpretation of Findings:** What do the findings mean in the context of the research question and broader field?
- **Limitations and Reflection:** What are the limitations of the study? How do these insights influence your thoughts on the work, and will this study guide the design of your course project?

Reading List

1. Cott C. "We decide, you carry it out": a social network analysis of multidisciplinary long-term care teams. Soc Sci Med. 1997 Nov;45(9):1411-21. doi: 10.1016/s0277-9536(97)00066-x. PMID: 9351158.
2. Lorant V, Nazroo J, Nicaise P; Title107 Study Group. Optimal Network for Patients with Severe Mental Illness: A Social Network Analysis. Adm Policy Ment Health. 2017 Nov;44(6):877-887. doi: 10.1007/s10488-017-0800-7. PMID: 28341927; PMCID: PMC5640746.
3. Kalgotra P, Sharda R, Croff JM. Examining health disparities by gender: A multimorbidity network analysis of electronic medical record. Int J Med Inform. 2017 Dec;108:22-28. doi: 10.1016/j.ijmedinf.2017.09.014. Epub 2017 Sep 25. PMID: 29132627.
4. Yuan CT, Nembhard IM, Kane GC. The influence of peer beliefs on nurses' use of new health information technology: A social network analysis. Soc Sci Med. 2020 Jun;255:113002. doi: 10.1016/j.socscimed.2020.113002. Epub 2020 Apr 22. PMID: 32353652.
5. van der Schors W, Roos AF, Kemp R, Varkevisser M. Inter-organizational collaboration between healthcare providers. Health Serv Manage Res. 2021 Feb;34(1):36-46. doi: 10.1177/0951484820971456. Epub 2020 Dec 8. PMID: 33291978.
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11. Borsboom D, Deserno MK, Rhemtulla M, Epskamp S, Fried EI, McNally RJ, Robinaugh DJ, Perugini M, Dalege J, Costantini G, Isvoranu AM. Network analysis of multivariate data in psychological science. Nature Reviews Methods Primers. 2021 Aug 19;1(1):58.
12. Boyer L, Belzeaux R, Maurel O, Baumstarck-Barrau K, Samuelian JC. A social network analysis of healthcare professional relationships in a French hospital. Int J Health Care Qual Assur. 2010;23(5):460-9. doi: 10.1108/09526861011050501. PMID: 20845677.
13. Cheong LH, Armour CL, Bosnic-Anticevich SZ. Primary health care teams and the patient perspective: a social network analysis. Res Social Adm Pharm. 2013 Nov-Dec;9(6):741-57. doi: 10.1016/j.sapharm.2012.12.003. Epub 2013 Feb 8. PMID: 23395532.
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Project: In lieu of a final exam, students need to form groups (no more than 3 members per group) and must complete an independent project on the network analysis. Projects should investigate a topic of interest to the group and must demonstrate analysis and critical thinking in the 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 (Three classes – August 22 &27 & 29): Course Overview
In the first class, we'll go over ground rules for the course and review the syllabus. Next, we will introduce the history of network analysis and graph theory. Finally, we will review large scale networks, the history of social network analysis, and the topics covered in the course.

Part 2 (Four classes – September 3 & 5 & 10 &12): Network Analysis: Basic Metrics
We will use four classes to learn sociometric factors in the network analysis.

First, 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, core-ness, clustering, hierarchy, embeddedness, proximity, transitivity, clique, eigenvecor 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.

Second, 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.

Finally, 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.

Part 3 (Two classes - September 17&19): Student-Led Presentations

Part 4 (Four classes - September 24 & 26, and October 1 &3): Network Analysis to Explore Healthcare Systems
We will use four 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.

Initial proposal (Two classes – October 8 & 10)
The two classes will be dedicated to student projects. Students will write a short summary of their problem statement, and initial research design. The summary and slides should be submitted to the Brightspace. Each student/group will have 5 minutes to present their proposed projects in the class.

Part 5 Disease networks (Four classes – October 15, 17, 22 & 24)
In this section, we will learn the human-symptom disease network through comprehensive network analysis. After that, we will focus on two specific networks: oncology-cardiac patients' networks and rare disease networks. Finally, we will learn temporal phenotyping algorithms to infer disease progression pathways.

Part 6 (Two classes – October 29 & 31): Network Analysis in Machine Learning
We will use two 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. Finally, we will learn examples of applying network analysis in predicting patient morbidity and mortality.

Project Status Report Presentations (Two classes – Nov 5&7)
The two classes will be dedicated to student projects. Students will make a short presentation (8 minutes including 5 minutes presentation and 3 minutes question time) on the status of their projects for an in-class evaluation. Each group member needs to present their responsible part.

Part 7 (Two classes – Nov 19&21): Network Analysis in Biology
Students will learn network analysis in drug-drug interactions. Guest lectures provided by Eugene Jeong.

Student Final Presentations (Two classes, Dec 3 &5)
The final two lectures will be dedicated to students' presentations on their final project. 13 minutes presentation and 2 minutes for questions. Students will submit a summary of their project, including title, structured abstract (objective, materials and methods, results, conclusion), introduction, materials and

methods, results, and discussion and conclusion by Sunday, December 1. Requirements for the research summary are as follows:
Word count: up to 3000 words for projects.
Structured abstract: up to 250 words, including objective, materials and methods, results, and conclusion.
Tables: up to 4.
Figures: up to 6.
References: unlimited.