Network Analysis in Healthcare

- **Course:** CS5891/CS3891
- **Instructor:** You Chen, Ph.D. (you.chen@vanderbilt.edu)
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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
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Course overview

• A new course - no textbook for the course
• Scientific paper–driven
• A tour of network analysis in health via various scientific studies
• Assignments – six reading summaries plus a network analysis project
• Goal – open a door for students entering network science and learn how to apply network analysis in health

• Syllabus
Topics covered

• Sociometric factors – basic network science
• Network analysis in learning health systems
• Network analysis in prediction
• Network analysis in drug repurposing and drug-drug interactions
Learning health system
**Patient referral paths**

Physician-patient encounter records

A: family practice  
B: internal medicine  
C: Cardiology  
D: Vascular surgery

β: B(2011-03-01)→C(2011-03-20)

**Net patient flow:**  
# of referrals in - # of referrals out

It encodes the flow of patients and information between physicians in a healthcare system or across healthcare systems.

It related to treatment outcomes and effectiveness of medical resources utilization.

A referral network with 30 physicians and 101 directed edges in a single hospital

Net patient flow: # of referrals in - # of referrals out

- positive
- zero
- negative

• Targets of referrals are marked with shadow on directed edges

U.S. patient referral network

Directed edges of each state’s top five out-of-state referrals

Intra-hospital collaboration - networks of departments at VUMC

Hierarchical structure

Changes in collaboration structures in the neonatal intensive unit

Mannering H, et.al. Assessing Neonatal Intensive Care Unit Structures and Outcomes Before and During the COVID-19 Pandemic. JMIR, 2021
Healthcare workers are much more highly densely connected (active in EHRs) in the COVID-19 network than in the Non-COVID-19 network.

Internal medicine physicians and nurse practitioners in the COVID-19 connect with each other; while those in the Non-COVID-19 are separated.
VUMC put full-time non-trainee healthcare workers in the management of critically ill COVID-19 patients, mirroring the national graduate medical education protections of residents placed at the outset of the COVID-19 pandemic.
Collaboration structures and clinical outcomes
Nursing handoff structures are associated with family satisfaction

Critical care nursing team structures are associated with mortality risk

Nodes with white color are nurses who had received and disseminated useful information from a wide range of sources to their colleagues

Relating network structure to length of stay

Higher out-degree group is associated with shorter length of stay

Cancer survivors whose providers have more patients in common tend to have higher quality and lower cost care.

Patients with high care density—indicating high levels of patient-sharing among their providers—had significantly lower rates of hospitalization and lower inpatient and outpatient costs.

Prediction
Symptoms

- Headaches (severe)
- Abdominal or chest pain
- Pallor
- Severe malignant hypertension
- Tremors
- New onset diabetes

- Anxiety, nervousness “Impending doom”
- Excess sweating
- Racing heart
- Nausea/vomiting
- Weight loss

- “Spells” may be spontaneous or precipitated by change in body position, anxiety, medications

Disease

PHEOCHROMOCYTOMA

Rare adrenal gland tumor

Cells darken
Given symptoms, can we predict/diagnose diseases?

Temporal disease trajectories

• The directed graph describes a normal progression from having hyperplasia of prostate diagnosed to having prostate cancer, cancer metastasis and anaemia.
Link prediction – medical referral systems

Which specialists are more likely to receive future referrals, and which specialists are more likely to lose their links with the general practitioners in the same network.

Link prediction – reconstructing protein-protein interaction networks

Drug repositioning and drug-drug interactions
Discovering novel drug-disease associations

Predicting drug-drug interactions – similarity score

Predicting drug-drug interactions via machine learning

A tour of 150 years of interconnected, interdisciplinary research, as represented by Nature's publication record.