C S 5483 – Network Science
Fall 2024

Instructor Dr. Sridhar Radhakrishnan (sridhar@ou.edu)

Office Location DEH 244
Office Hours 10:00 A.M to 11:30 A.M (Monday and Wednesday).

https://oklahoma.zoom.us/j/99724235448?pwd=mAtdxPBo3rngInDFee52l2A6G2w3xI.1

Course Timings Online; There will be announced Monday classes from 5:00 PM – 7:00 PM CST
This is for reviews, Project Proposal presentations, and other presentations.

https://oklahoma.zoom.us/j/97485606892?pwd=pQRzTbFVNze7LYaNA5I5j3pit3G9lj.1

Course Location On Canvas

Course Prerequisite CS/DSA 4413 or permission of the instructor

Course Objectives The topics covered will include fundamental algorithms for network analysis, exploring network properties, learning community detection techniques, understanding methods for network inference, and studying the dynamics of networks. We will also examine concepts such as percolation, resilience, spreading phenomena, social influence, and cascades. These concepts will be applied across various contexts, including physical, informational, biological, cognitive, and social systems.

Useful Course Material

1. *Networks:* Book by *Mark Newman*, 2nd Edition,
   Oxford University Press, 2021, ISBN-13: 978-0123850591,
   ISBN-10: 0123850592
2. *Social Media Mining*: *An Introduction*, Cambridge University Press New York, NY, USA ©2014
   ISBN:1107018854 9781107018853
3. Material that will be placed on the canvas.

Course Requirements: Students will be required to complete several quizzes throughout the course. In addition, there will be a series of homework assignments, some of which will include programming exercises using Python and the NetworkX library. Students will also be provided with a research paper, which they will read, prepare a presentation on, and submit a video recording of the presentation for evaluation. Additionally, each student will complete an individual final project, which will culminate in a presentation. Throughout the course, students will also be required to participate in peer reviews from time to time. Failure to complete the final project and its associated presentation will result in an automatic "F" as the overall course grade.

Course Grading: The course letter grade will be determined based on the overall percentage as follows: 90-100 (A), 80-89 (B), 70-79 (C), 60-69 (D), and below 60 (F). The breakdown of percentage allocations is provided below:

Grading Elements	Grade Distribution
Quizzes	15%
Python Programming Assignments	15%
Homework Assignments	12%
Peer Reviews	8%
Final Project • A proposal (5%) • Recording of the Demonstration of the project (9%) • Live Presentation (6%)	20%
Recording of the presentation of the research paper	10%
Each week's video lectures must be watched and listened to within 14 days of posting to be counted.	20%

Final Project and Milestones

There are several ways in which this course project can be completed:

(1) Development of software to perform network analysis or modeling on very large networks.
(2) Reproduce some results of a paper based on different data or different methods.

All projects must involve some visualization. Here are the due dates. The evaluation percentages are also provided below.

Grading Elements and Due Dates	
Prog. Assignment 1	September 6
Quiz 1	September 20
Homework 1	September 27
Prog. Assignment 2	October 4
Final Project Proposal	October 11
Quiz 2	October 18
Homework 2	October 25
Research Paper Selection	October 25
Prog. Assignment 3	November 1
Quiz 3	November 15
Recording of the presentation of the research paper	November 15
Homework 3	November 22
Recording of the Demonstration of the project	November 25
Live Presentation	December 6

Lecture Videos

Comprehensively watching all lectures is essential. Your engagement with the video lectures, which we will track through our media analytics where the videos are hosted, will account for 20% of your total grade in the class. Make sure to view them in their entirety. This participation will be documented in your Canvas GradeBook.

Tentative Lecture Schedule

Week of Date	Topics
8/19/24	Module 0: About this course and Introduction to Network Science Module 1: Network Definition, Types of Networks, Programming with Python and NetworkX
8/26/24	Module 2: Technological, Information, Social, and Biological Networks
9/2/24	Module 3: Fundamentals of Network Theory: Mathematics of Networks
9/9/24	Module 4: Fundamentals of Network Theory: Measures and Metrics
9/16/24	Module 5: Fundamentals of Network Theory: Graph Algorithms
9/23/24	Module 6: Fundamentals of Network Theory: Network Statistics and Measurement Error
9/30/24	Module 7: Fundamentals of Network Theory: The Structure of Real-World Networks
10/7/24	Module 8: Network Models: Random Graphs
10/14/24	Module 9: Network Models: The Configuration Model
10/21/24	Module 10: Network Models: Models of Network Formation
10/28/24	Module 11: Applications: Community Structure
11/4/24	Module 12: Graph Databases Module 13: Graph Neural Nets
11/11/24	Module 14: Applications: Percolation and Network Resilience
11/18/24	Module 15: Applications: Epidemics on Networks
11/25/24	**Thanksgiving Break**
12/2/24	Module 16: Advanced Topics
12/6/24	Final Project Presentations (Monday – 5:00 PM – 8:00 PM CST)

Module 0: About this course and Introduction to Network Science

0.1 Introducing your Professor
   a. Professor
   b. Contact Information
0.2 Course Contents
   a. About network science
   b. Textbooks used
   c. Topics to be covered
0.3 Course tools
   a. Python – GitHub, Jupyter, NetworkX, and visualization tools
0.4 Grading Policies
0.5 How to learn online

Module 1: Network Definition, Types of Networks, Programming with Python and NetworkX

1.1 Networks Definition and Examples
   d. What are networks? Nodes (vertices) and links (edges), directed, undirected
   e. Examples of various networks along with their sizes
1.2 Networks Classification and the Information it Conveys
   a. Classification of the types of networks: technology, information, social, and biological
   b. What can we learn from networks?
1.3 Properties of networks
   a. Degree, in-degree, out-degree, hubs, distance, radius, diameter, small-world effect (degrees of separation), clusters, communities
1.4 Python
   a. Python notebook, NetworkX, Simple visualization

Module 2: Technological, Information, Social, and Biological Networks

2.1 Technological Networks
   a. The Internet – How is it organized? How can we get its structure using TRACEROUTE? What are routing tables? How can be it used to understand the structure of the Internet?
   b. The Telephone Network: Circuit-Switched Network and Packet-Switched Networks
   c. Power Grids: How are they modeled? What are smart Grids?
   d. Transportation Networks: Modeling – Road network and train network
   e. Delivery and Distribution Networks
   f. Interdependent Networks
2.2 Information Networks
   a. The world wide web: A directed network
   b. Using a crawler to get WWW's structure: wget, Nutch, GRUB, and Sphinx
   c. Citation Networks, Peer-to-Peer Networks, Recommender Networks, and Keyword indexes
   d. Drug-drug interaction network
2.3 Social Networks
   c. Empirical study of social networks
   d. Constructing social networks: interviews and questionnaire, ego-centric networks, direct observation, archival data
   e. Affiliation networks
   f. Small-World Experiment
   g. Snowball sampling, contact tracing, and random walks
2.4 Biological Networks
   a. Metabolic networks, protein-protein interaction network, genetic regulatory networks

b. Networks in the Brain – Networks of neurons, networks of functional connectivity in the brain
c. Ecological networks: Food webs, Host-parasite networks, Mutualistic networks

2.5 Python
a. Downloading various types of networks and visualizing with python and graphViz

Module 3: Fundamentals of Network Theory: Mathematics of Networks

3.1 Networks and their representations:
a. Edge list, Adjacency Matrix, Adjacency List, Weighted Networks, Sparse vs Dense Graph

3.2 Varieties of graphs
a. Directed and Acyclic
b. Bipartite, Hypergraphs
c. Trees
d. Planar
e. Multilayer and Dynamic

3.3. Properties of Graphs: degree, density, sparsity, walks, paths, shortest paths, diameter
a. Degree, average degree, and moments
b. Density and Sparsity
c. Paths: walks, shortest paths, and diameter
d. Components: connected components, strongly connected components

3.3 Independent Paths, connectivity, cut sets, max flow, min cut
a. Vertex and edge disjoint paths
b. Connectivity: bi-connectivity and k-connectivity
c. Cut sets and relationship to connectivity, max flow and min cut on weighted networks

3.4 Graph Laplacian
a. Definition and properties
b. Graph Partitioning definition
c. Network Visualization
d. Random walks
e. Resistor networks

3.5 Python
a. Take a graph and show how the various properties, paths, cuts, connectivity, and graph Laplacian can be calculated

Module 4: Fundamentals of Network Theory: Measures and Metrics

4.1 Centrality
a. Degree Centrality
b. Eigenvector Centrality
c. Katz Centrality
d. Page Rank
e. Hubs and Authorities
f. Closeness Centrality
g. Betweenness Centrality

4.2 Groups of Nodes
a. Cliques
b. Components and K-Components

4.3 Transitivity
a. Clustering Coefficient
b. Reciprocity

4.4 Signed Edges and Structural Balance

4.5 Similarity
   a. Structural Equivalence
   b. Regular Equivalence
4.6 Homophily and Assortative Mixing
   a. Assortative Mixing by unordered characteristics
   b. Assortative Mixing by ordered characteristics
4.7 Python
   a. Take a graph's adjacency matrix and calculate various centrality measures
   b. Write a python code to determine a k-clique in a graph

Module 5: Fundamentals of Network Theory: Graph Algorithms

5.1 Running time and computational complexity
5.2 Representation of Networks: Edge List, Adjacency Matrix, Adjacency List
5.3 Depth First Search Algorithm: Finding Connected Components
5.4 Breadth First Search: Counting Triangles and Finding Diameter of a network
5.5 Single Source Shortest path algorithm – Dijkstra's
5.6 All-Pair Shortest path algorithm – Floyd's algorithm: Betweenness Centrality
5.7 Max-Flow and Min-Cut
5.8 K-disjoint paths algorithm
5.9 Finding maximal cliques in a graph
5.10 Python
   a. Using the NetworkX library and sample random graphs, determine compute the number of connected components in a graph.

Module 6: Fundamentals of Network Theory: Network Statistics and Measurement Error

6.1 Types and Sources of Errors
6.2 Estimating Errors: Statistical, Maximal Likelihood, Expectation Maximization Algorithm
6.3 Correcting Errors: Link Prediction, Node Disambiguation
6.4 Python
   a. Implement a link prediction algorithm using Phyton and NetworkX

Module 7: Fundamentals of Network Theory: The Structure of Real-World Networks

7.1 Real-World Networks and Features
7.2 Degree Distributions
7.3 Power laws and scale-free networks, Detecting and Visualizing power-laws
7.4 Distribution of Centrality measures
7.5 Clustering Coefficients
7.6 Assortative Mixing
7.7 Python
   a. Take a set of real-world graphs and show its degree distributions

Module 8: Network Models: Random Graphs

8.1 Random Graphs
8.2 Mean Number of Edges and Mean Degree
8.3 Degree Distribution
8.4 Clustering Coefficient
8.5 Giant Component
8.6 Small Components
8.7 Path Lengths
8.8 Issues with Random Graphs
8.9 Python
   a. Write a program to generate various type of random graphs

Module 9: Network Models: The Configuration Model

9.1 The configuration model: Edge probability and Expected degree
9.2 Excess Degree distribution
9.3 Clustering Coefficient
9.4 Tree-Like Networks
9.5 Number of second neighbors of a node
9.6 Giant, Small Components, and Diameter
9.7 Python
   a. Take a large graph, run connected components algorithm, show the giant component by removing edges at random.

Module 10: Network Models: Models of Network Formation

10.1 Preferential Attachment – Price Model
10.2 Barabasi and Albert Model
10.3 Node-copying Model
10.4 Python
   a. Implement the preferential attachment model.

Module 11: Applications: Community Structure

11.1 Dividing Networks into groups
11.2 Modularity Maximization: Louvain Algorithm
11.3 Kernighan-Lin Algorithm
11.4 Spectral Partitioning
11.5 Other Community Detection Algorithms: Betweeness, Hierarchical Clustering,
11.6 Measuring Performance of Community Detection Algorithms
11.7 Python
   a. Implement and execute the Louvain algorithm on a chosen network

Module 12: Graph Databases

12.1 Relational Database System
12.2 Introduction to Graph Database
12.3 Queries on Graph Databases
12.4 Introduction to Neo4j, Amazon Neptune and Graph Studio by Oracle
12.5 Real-world use cases

Module 13: Graph Neural Networks

13.1 Introduction to Neural Networks
13.2 Graph Convolution Network
13.3 Applications of GNNs
13.4 Introduction to PyTorch and PyGeometry

Module 14: Applications: Percolation and Network Resilience

14.1 Percolation
14.2 Uniform Removal of Nodes
14.3 Percolation in Real-World Networks
14.4 Algorithm for Percolation
14.5 Python
   a. Implement and execute the percolation algorithm discussed

Module 15: Applications: Epidemics on Networks

15.1 Models of Spread of Infection
15.2 SI Model
15.3 SIR Model
15.4 SIS Model
15.5 SIRS Model
15.6 Outbreak Sizes and Percolation
15.7 Python
    a. Implement and execute SI and SIR model on a random network

Module 16: Advanced Topics

16.1 Time-Evolving Network Structures and Algorithms
16.2 Interdependent Networks, Resilience, and Restoration
16.3 Dynamics of Brain Networks
16.4 Financial Markets Meets Network Science

University Policies

Persons with Disability or Special Accommodation or Accommodation for any reason

Please advise/inform your instructor of any of your special needs if you are an individual with disability. Also, please advise/inform your instructor of any special accommodation that you need, and all such matters will be addressed after conversations with relevant experts. It is important that you reach out to your instructor in a timely manner to address all matters relating to the need for accommodation. We will follow the makeup policies as provided in [See Faculty Handbook 4.7, 4.9, 4.10, and 4. 11]

Academic Integrity

Cheating is strictly prohibited at the University of Oklahoma, because it devalues the degree you are working hard to get. As a member of the OU community it is your responsibility to protect your educational investment by knowing and following the rules. For specific definitions on what constitutes cheating, review the Student's Guide to Academic Integrity at http://integrity.ou.edu/students_guide.html and https://www.ou.edu/integrity/students#OU-and-Integrity.

To be successful in this class, all work on exams and quizzes must be yours and yours alone. If you become aware of a fellow student engaging in suspicious behavior, I encourage you to report it to us or directly to the Office of Academic Integrity Programs. That student is devaluing not only their degree, but yours, too. Be aware that it is our professional obligation to report academic misconduct, which we will not hesitate to do. Sanctions for academic misconduct can include expulsion from the University and an F in this course, so don't cheat. It's simply not worth it.

Religious Observance

It is the policy of the University to excuse the absences of students that result from religious observances and to reschedule examinations and additional required classwork that may fall on religious holidays, without penalty.

Reasonable Accommodation Policy

The Accessibility and Disability Resource Center is committed to supporting students with disabilities to ensure that they are able to enjoy equal access to all components of their education. This includes your academics, housing, and community events. If you are experiencing a disability, a mental/medical health condition that has a significant impact on one or more life functions, you can receive accommodations to provide equal access. Possible disabilities include, but are not limited to, learning disabilities, AD(H)D, mental health, and chronic health. Additionally, we support students with temporary medical conditions (broken wrist, shoulder surgery, etc.) and pregnancy. To discuss potential accommodations, please contact the ADRC at 730 College Avenue, (ph.) 405.325.3852, or adrc@ou.edu.

Title IX Resources and Reporting Requirement

Anyone who has been impacted by gender-based violence, including dating violence, domestic violence, stalking, harassment, and sexual assault, deserves access to resources so that they are supported personally and academically. The University of Oklahoma is committed to offering resources to those impacted, including: speaking with someone confidentially about your options, medical attention, counseling, reporting, academic support, and safety plans. If you would like to speak with someone confidentially, please contact OU Advocates (available 24/7 at 405-615-0013) or another confidential resource (see "Can I make an anonymous report?"). You may also choose to report gender-based violence and discrimination through other means, including by contacting the Institutional Equity Office (ieo@ou.edu, 405-325-3546) or police (911). Because the University of Oklahoma is committed to the safety of you and other students, I, as well as other faculty, Graduate Assistants, and Teaching Assistants, are mandatory reporters. This means that we are obligated to report gender-based violence that has been disclosed to us to the Institutional Equity Office. This includes disclosures that occur in: class discussion, writing assignments, discussion boards, emails and during Student/Office Hours. For more information, please visit the Institutional Equity Office.

Adjustments for Pregnancy/Childbirth Related Issues

Should you need modifications or adjustments to your course requirements because of documented pregnancy-related or childbirth-related issues, please contact your professor or the Accessibility and Disability Resource Center at 405/325-3852 as soon as possible. Also, see the Institutional Equity Office FAQ on Pregnant and Parenting Students' Rights for answers to commonly asked questions.

Final Exam Preparation Period

Pre-finals week will be defined as the seven calendar days before the first day of finals. Faculty may cover new course

material throughout this week. For specific provisions of the policy please refer to OU's Final Exam Preparation Period policy.

Emergency Protocol

During an emergency, there are official university procedures that will maximize your safety.

Severe Weather: If you receive an OU Alert to seek refuge or hear a tornado siren that signals severe weather.

1. Look for severe weather refuge location maps located inside most OU buildings near the entrances
2. Seek refuge inside a building. Do not leave one building to seek shelter in another building that you deem safer. If outside, get into the nearest building.
3. Go to the building's severe weather refuge location. If you do not know where that is, go to the lowest level possible and seek refuge in an innermost room. Avoid outside doors and windows.
4. Get in, Get Down, Cover Up
5. Wait for official notice to resume normal activities.

Additional Weather Safety Information is available through the Department of Campus Safety.

Armed Subject/Campus Intruder:

If you receive an OU Alert to shelter-in-place due to an active shooter or armed intruder situation or you hear what you perceive to be gunshots:

1. *Avoid*: If you believe you can get out of the area WITHOUT encountering the armed individual, move quickly towards the nearest building exit, move away from the building, and call 911. 2. *Deny*: If you cannot flee, move to an area that can be locked or barricaded, turn off lights, silence devices, spread out, and formulate a plan of attack if the shooter enters the room. 3. *Defend*: As a last resort fight to defend yourself.

For more information, visit OU's Emergency Preparedness site.

Shots Fired on Campus Procedure – Video

Fire Alarm/General Emergency:

If you receive an OU Alert that there is danger inside or near the building, or the fire alarm inside the building activates: *1. LEAVE* the building. Do not use the elevators. *2. KNOW* at least two building exits *3. ASSIST* those that may need help *4. PROCEED* to the emergency assembly area *5 ONCE safely outside, NOTIFY first responders of anyone that may still be inside building due to mobility issues. 6. WAIT* for official notice before attempting to re-enter the building.

OU Fire Safety on Campus

Mental Health Support Services:

If you are experiencing any mental health issues that are impacting your academic performance, counseling is available at the University Counseling Center (UCC). The Center is located on the second floor of the Goddard Health Center, at 620 Elm Rm. 201, Norman, OK 73019. To schedule an appointment call (405) 325-2911. For more information, please visit University Counseling Center.

COVID - 19 policies

For information about the changes to the course from the University side, please keep yourself updated from OU's learn anywhere website - https://www.ou.edu/learnanywhere .

**Every part of this syllabus is subject to adjustment as the semester progresses. If you are dissatisfied with the course policies, grading, and assignments, please contact the instructor. Reasonable requests for modifications may be accommodated at the instructor's discretion.*