SYSM 6302 Dynamics of Complex Networks and Systems

This course treats the dynamics of complex networks and systems, such as the Internet, Power Grid, Biological Networks, Communication Networks, Financial Networks, and others. Fundamentals of graph theory and network theory will be presented along with a basic treatment of dynamical systems, stability, and chaos.

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Course Pre-requisites, Co-requisites, and/or Other Restrictions

- Basic knowledge of linear algebra, differential equations, probability theory.
- The course uses scripting in Python as the major workhorse to understand and use the course material. No prior experience with Python is needed, but familiarity with programming concepts (e.g., logic, conditionals, loops) is essential.

Student Learning Objectives/Outcomes

Upon successful completion of this course, students will:

1. have a basic understanding of the role and importance of complex networks on modern engineered systems
2. have a working knowledge of the fundamentals of graph theory and network theory
3. understand basic dynamical systems and stability theory have a basic understanding of the complex behaviors that can arise from even simple nonlinear systems
4. be able to model and analyze basic networks and dynamical systems and predict their behavior

Textbooks and Materials

Required readings and class notes will be provided. This is a mostly-"flipped" class, so readings are essential! Readings will be taken from the following textbooks:

1. Mark Newman, *Networks: An Introduction* (**N**) – Available through the university library (EBSCO Books)
2. Eric Kolaczyk, *Statistical Analysis of Network Data* (**K**) – Available through the university library (Springer eBooks)

Grading Policy

There will be 7 lab assignments, 24 quiz questions (no programming), and a final project. Grades will be determined based on the following formula:

- Reading Checks (20%) – Non-timed, open-book questions to answer to ensure you are keeping up with the reading
- Oral Exams (20%) – Twice (weeks 8 & 12), we will have a one-on-one 10 min MS Teams call to discuss topics covered
- Labs (30%) – Python-driven labs provide hands-on experience with the topics covered
- Project (30%) – Done individually or in pairs, this is an open-ended network construction and analysis project

Labs	Lab 1	Lab 2	Lab 3	Lab 4	Lab 5	Lab 6	Lab 7
Classes Covered	[2, 3]	[5, 6]	[7]	[8, 9, 10, 11]	[13, 15]	[20, 21]	[24, 25]
Due (week)	3 (Wed)	4 (Fri)	5 (Fri)	6 (Fri)	9 (Fri)	12 (Fri)	14 (Fri)

Schedule [class#; **BOOK**Sections], *partial

1. Network Analysis
   a. [1] Introduction, visualization, installations, [2] programming fundamentals
   b. Quantifying network properties
      i. Representations & basic definitions: [2; **N**6.1-6.4] graph types, adjacency matrix, cocitation network, [3; **N**6.5-6.8] bipartite graph, trees, [4] finish lab 1
      ii. Small scale structure: [5; **N**6.9, **N**7.8-7.10] degree, clustering, cliques, reciprocity
      iii. Connectivity: [5; **N**6.10-6.11] paths, components, [5; **N**10.3-10.4] shortest path, [6; **N**6.12, **N**10.5] cut set, max flow
      iv. Centrality: [7; **N**7.1-7.7, **K**4.2.2] degree, eigenvector, Katz, Page Rank, betweenness, closeness
      v. Large scale structure: [8; **N**8.1-8.4.1] degree distribution, power law
2. Dynamic Network Structure
   a. Generative Models
      i. Random graphs: [9; **N**12-12.5], Erdos-Renyi, giant component, [10; **N**13.2-13.2.1,13.2.2-13.4] configuration model, friendship paradox
      ii. Models of network formation: [11; **N**14.2*,14.5*,15.1.0*] preferential attachment, vertex copying, small world network
   b. Robustness: [12; **Albert2000**, **N**16.1-16.2.0,16.4-16.5] percolation, connectivity, cascading failures
3. Return to Network Analysis
      i. Large scale structure: [13; **N**7.13] assortativity, modularity
      ii. Coverage: [14] Eulerian, Hamiltonian, minimum spanning tree, matching, [15; **N**11.2-11.11] partitioning, community detection, spectral modularity maximization
   b. Comparing networks: [16; **N**7.12] isomorphisms, permutation, similarity [17; **Milo2002**, **Przluj2006**] network alignment, motifs, graphlets
   c. Data collection: [18; **K**5.1-5.3] biasing, star/snowball sampling, link tracing, [19] topology inference
4. Network State Dynamics
   a. Diffusion: [20; **N**6.13], Laplacian, consensus
   b. Epidemics: [21; **N**17-17.4,17.6-17.8.0,17.9-17.10.0,17.11.0] SIR models, influence models (independent cascade, linear threshold)
   c. [24] Dynamical systems, linear phase portraits, [25] nonlinear linearization, basins of attraction, stability, bifurcations, [26] Lyapunov stability
   d. Control: [27-28] influence maximization, classic control, structural control, pinning control
5. Presentations [29] [30]

Course & Instructor Policies

No late homework or make-up exams will be accepted without prior written approval of the instructor. You must inform the instructor in advance if you will miss class for any reason.

Comet Creed

This creed was voted on by the UT Dallas student body in 2014. It is a standard that Comets choose to live by and encourage others to do the same: *"As a Comet, I pledge honesty, integrity, and service in all that I do."*

UT Dallas Syllabus Policies and Procedures

The information contained in the following link constitutes the University's policies and procedures segment of the course syllabus.

Please go to http://go.utdallas.edu/syllabus-policies for these policies.

These descriptions and timelines are subject to change at the discretion of the Professor.