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.

ECSN 2.120, Tuesdays/Thursdays 10 am – 11:15 am
Instructor: Dr. Justin Ruths
Office: ECSN 2.926
Email: juths@utdallas.edu
Office Hours: by appointment
Anonymous Feedback: http://justinruths.com/feedback

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)

Exams and Grading Policy
There will be regular lab assignments, three in-class quizzes (no programming), and a final project. Grades will be determined based on the following formula: Labs (30%), Quizzes (3x13%), Project (30%), Participation (1%).

Schedule: [class#; **BOOK**Sections], *partial, <u>lectured</u>
1. Network Analysis
    a. [1] <u>Introduction</u>, <u>visualization</u>, installations, [2] <u>programming fundamentals and Zen</u>
    b. Quantifying network properties
        i. Representations & basic definitions: [2; **N6.1-6.4**] graph types, adjacency matrix, <u>cocitation network</u>, [3; **N6.5-6.8**] bipartite graph, <u>trees</u>, [4] finish lab 1
        ii. Small scale structure: [5; **N6.9, N7.8-7.10**] degree, clustering, cliques, reciprocity
        iii. Connectivity: [5; **N6.10-6.11**] <u>paths</u>, components, [5; **N10.3-10.4**] <u>shortest path</u>, [6; **N6.12, N10.5**] cut set, max flow
        iv. Centrality: [7; **N7.1-7.7, K4.2.2**] degree, <u>eigenvector</u>, Katz, Page Rank, betweenness, closeness
        v. Large scale structure: [8; **N8.1-8.4.1**] degree distribution, power law
2. Dynamic Network Structure
    a. Generative Models
        i. Random graphs: [9; **N12-12.5**] **QUIZ 1**, <u>Erdos-Renyi</u>, giant component, [10; **N13.2-13.2.1,13.2.2-13.4**] <u>configuration model</u>, friendship paradox
        ii. <u>Models of network formation</u>: [11; **N14.2*,14.5*,15.1.0***] preferential attachment, vertex copying, small world network

      b.   Robustness: [12; **Albert2000**, N16.1-16.2.0,16.4-16.5] percolation, connectivity, cascading failures

3. Return to Network Analysis
      i.   Large scale structure: [13; **N7.13**] assortativity, modularity
      ii.   Coverage: [14] Eulerian, Hamiltonian, minimum spanning tree, matching, [15; **N11.2-11.11**] partitioning, community detection
      b.   Comparing networks: [16; **N7.12**] isomorphisms, permutation, similarity [17; **Milo2002**, **Przluj2006**] network alignment, motifs, graphlets
      c.   Data collection: [18; **K5.1-5.3**] biasing, star/snowball sampling, link tracing, [19] topology inference

4. Network State Dynamics
      a.   Diffusion: [20; **N6.13**] **QUIZ 2**, Laplacian, consensus
      b.   Epidemics: [21; **N17-17.4,17.6-17.8.0,17.9-17.10.0,17.11.0**] SIR models, influence models (independent cascade, linear threshold)
      c.   [22] Dynamical systems, [23] linear phase portraits, [24] nonlinear linearization, [25] basins of attraction, stability, bifurcations, [26] Lyapunov stability
      d.   Control: [27-28] influence maximization, classic control, structural control, pinning control

5. Presentations [29] [30] **QUIZ 3**

Labs	Classes
Lab 1	[1, 2, 3, 4]
Lab 2	[5, 6]
Lab 3	[7]
Lab 4	[8, 9, 10, 11]
Lab 5	[13, 15]
Lab 6	[20, 21]
Lab 7	[22, 23, 24, 25, 26]

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.

Technical Support

If you experience any problems with your UTD account you may send an email to: assist@utdallas.edu or call the UTD Computer Helpdesk at 972-883-2911.

Student Conduct & Discipline

The University of Texas System and The University of Texas at Dallas have rules and regulations for the orderly and efficient conduct of their business. It is the responsibility of each student and each student organization to be knowledgeable about the rules and regulations which govern student conduct and activities. General information on student conduct and discipline is contained in the UTD printed publication, A to Z Guide, which is provided to all registered students each academic year.

The University of Texas at Dallas administers student discipline within the procedures of recognized and established due process. Procedures are defined and described in the Rules and Regulations, Series 50000, Board of Regents, The University of Texas System, and in Title V, Rules on Student Services and Activities of the university's Handbook of Operating Procedures. Copies of these rules and regulations are available to students in the Office of the Dean of Students, where staff members are available to assist students in interpreting the rules and regulations (SU 1.602, 972/883-6391) and online at http://www.utdallas.edu/judicialaffairs/UTDJudicialAffairs-HOPV.html

A student at the university neither loses the rights nor escapes the responsibilities of citizenship. He or she is expected to obey federal, state, and local laws as well as the Regents' Rules, university regulations, and administrative rules. Students are subject to discipline for violating the standards of conduct whether such conduct takes place on or off campus, or whether civil or criminal penalties are also imposed for such conduct.

Academic Integrity

The faculty expects from its students a high level of responsibility and academic honesty. Because the value of an academic degree depends upon the absolute integrity of the work done by the student for that degree, it is imperative that a student demonstrate a high standard of individual honor in his or her scholastic work.

Scholastic Dishonesty, any student who commits an act of scholastic dishonesty is subject to discipline. Scholastic dishonesty includes but is not limited to cheating, plagiarism, collusion, the submission for credit of any work or materials that are attributable in whole or in part to another person, taking an examination for another person, any act designed to give unfair advantage to a student or the attempt to commit such acts.

Plagiarism, especially from the web, from portions of papers for other classes, and from any other source is unacceptable and will be dealt with under the university's policy on plagiarism (see general catalog for details). This course may use the resources of turnitin.com, which searches the web for possible plagiarism and is over 90% effective.

Copyright Notice

The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted materials, including music and software. Copying, displaying, reproducing, or distributing copyrighted works may infringe the copyright owner's rights and such infringement is subject to appropriate disciplinary action as well as criminal penalties provided by federal law. Usage of such material is only appropriate when that usage constitutes "fair use" under the Copyright Act. As a UT Dallas student, you are required to follow the institution's copyright policy (Policy Memorandum 84-I.3-46). For more information about the fair use exemption, see http://www.utsystem.edu/ogc/intellectualproperty/copypol2.htm

Email Use

The University of Texas at Dallas recognizes the value and efficiency of communication between faculty/staff and students through electronic mail. At the same time, email raises some issues concerning security and the identity of each individual in an email exchange. The university encourages all official student email correspondence be sent only to a student's U.T. Dallas email address and that faculty and staff consider email from students official only if it originates from a UTD student account. This allows the university to maintain a high degree of confidence in the identity of all individual corresponding and the security of the transmitted information. UTD furnishes each student with a free email account that is to be used in all communication with university personnel. The Department of Information Resources at U.T. Dallas provides a method for students to have their U.T. Dallas mail forwarded to other accounts.

Withdrawal from Class

The administration of this institution has set deadlines for withdrawal of any college-level courses. These dates and times are published in that semester's course catalog. Administration procedures must be followed. It is the student's responsibility to handle withdrawal requirements from any class. In other words, I cannot drop or withdraw any student. You must do the proper paperwork to ensure that you will not receive a final grade of "F" in a course if you choose not to attend the class once you are enrolled.

Student Grievance Procedures

Procedures for student grievances are found in Title V, Rules on Student Services and Activities, of the university's Handbook of Operating Procedures.

In attempting to resolve any student grievance regarding grades, evaluations, or other fulfillments of academic responsibility, it is the obligation of the student first to make a serious effort to resolve the matter with the instructor, supervisor, administrator, or committee with whom the grievance originates (hereafter called "the respondent"). Individual faculty members retain primary responsibility for assigning grades and evaluations. If the matter cannot be resolved at that level, the grievance must be submitted in writing to the respondent

with a copy of the respondent's School Dean. If the matter is not resolved by the written response provided by the respondent, the student may submit a written appeal to the School Dean. If the grievance is not resolved by the School Dean's decision, the student may make a written appeal to the Dean of Graduate or Undergraduate Education, and the deal will appoint and convene an Academic Appeals Panel. The decision of the Academic Appeals Panel is final. The results of the academic appeals process will be distributed to all involved parties.

Copies of these rules and regulations are available to students in the Office of the Dean of Students, where staff members are available to assist students in interpreting the rules and regulations.

Incomplete Grade Policy

As per university policy, incomplete grades will be granted only for work unavoidably missed at the semester's end and only if 70% of the course work has been completed. An incomplete grade must be resolved within eight (8) weeks from the first day of the subsequent long semester. If the required work to complete the course and to remove the incomplete grade is not submitted by the specified deadline, the incomplete grade is changed automatically to a grade of F.

Disability Services

The goal of Disability Services is to provide students with disabilities equal educational opportunities. Disability Services provides students with a documented letter to present to the faculty members to verify that the student has a disability and needs accommodations. This letter should be presented to the instructor in each course at the beginning of the semester and accommodations needed should be discussed at that time. It is the student's responsibility to notify his or her professors of the need for accommodation. If accommodations are granted for testing accommodations, the student should remind the instructor five days before the exam of any testing accommodations that will be needed. Disability Services is located in Room 1.610 in the Student Union. Office hours are Monday – Thursday, 8:30 a.m. to 6:30 p.m., and Friday 8:30 a.m. to 5:00 p.m. You may reach Disability Services at (972) 883-2098.

Guidelines for documentation are located at http://www.utdallas.edu/disability/documentation/index.html on the Disability Services website.

Religious Holy Days

The University of Texas at Dallas will excuse a student from class or other required activities for the travel to and observance of a religious holy day for a religion whose places of worship are exempt from property tax under Section 11.20, Tax Code, Texas Code Annotated.

The student is encouraged to notify the instructor or activity sponsor as soon as possible regarding the absence, preferably in advance of the assignment. The student, so excused, will be allowed to take the exam or complete the assignment within a reasonable time after the absence: a period equal to the length of the absence, up to a maximum of one week. A student who notifies the instructor and completes any missed exam or assignment may not be penalized for the absence. A student who fails to complete the exam or assignment within the prescribed period may receive a failing grade for that exam or assignment.

If a student or an instructor disagrees about the nature of the absence [i.e., for the purpose of observing a religious holy day] or if there is similar disagreement about whether the student has been given a reasonable time to complete any missed assignments or examinations, either the student or the instructor may request a ruling from the chief executive officer of the institution, or his or her designee. The chief executive officer or designee must take into account the legislative intent of TEC 51.911(b), and the student and instructor will abide by the decision of the chief executive officer or designee.

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