National Cheng Kung University
Modular Course 2021 Summer Program

複雜系統中的網路科學
Network Science for Complex systems

Instructor	Affiliation	Graduation (Ph.d.)
朱書賢	**Intel Corporation, Hillsboro, OR**	**College of Science and Engineering, University of Minnesota-Twin Cities, Minneapolis, MN**

Course Type	Course Credit	Student Size (Maximum)	
Lecture + Recitation	**1.5**	**25**	**因 COVID-19 疫情嚴峻，本課程將延至 2022 暑假(111-1)。**

Student Background

College of Science、College of Engineering、College of Bioscience and Biotechnology、College of Electrical Engineering & Computer Science、College of Management、College of Medicine、College of Planning & Design、College of Social Science

Difficulty

☐ Challenging ■ Medium Well ☐Medium ☐ Entry Level (Basic)

Format of The Course

Lecture 70%，Practice 23%、Report7%

Note:

Lectures will be provided in the morning and lab sessions are in the afternoon. Knowledge of python is not required and understanding of basic programming logic will help. During the first part of lab sessions, we will go over examples and python homework questions. Source code will be provided so that students can follow the code in the class and practice after class. The second part of lab sessions are offered as TA hour for questions from homework and project. Students can work on them during this period of time as well.

Grading Policy

Quiz 28%、Homework 40%、Project 32%

Note:

- **Quiz 28%:**
  Quizzes will be given at the beginning (9:00-9:30) of lectures from day 2 to day 5. Quiz questions cover the previous lecture.
- **Homework 40%:**
  Homework will be hand out during the first four lectures and due by the end of the next lecture.
- **Project 32%:**
  Each group can have no more than four members who shall work on an assigned network problem, explore possible solutions, and share discussion and results. Reports are individual, especially for the following parts: problem description, analysis, discussion, and conclusion. Problems will be given from a single aspect, however, they usually can be better described from multiple perspectives. Therefore, the problem description should be composed based on all your understanding instead of just copying the problem statement from the instructor. Analysis,

discussion, and conclusion should be presented based on individual opinions and focuses due to the fact that combinations of metrics/properties/characteristics widely expand the variety of reasoning, explanation, and meaning. Group discussion may be taken as a reference to derive from, and group members are open to sharing data, solutions, code, and computational results. Everyone is expected to hand in a report in 2 days after the end of this course. The report should include title, author, abstract, introduction, problem statement, method, result, discussion, conclusion, and references. The report can be written in either English or Chinese.

Code of Conduct for The Course

按時上課、按時交作業(報告)

Course Description

It is often the case that complex systems, both living and man-made, can be represented as static or dynamic networks of many interacting components. These components are typically much simpler in terms of behavior or function than the overall system, implying that the additional complexity of the latter is an emergent network property. Network science is a relatively new discipline that investigates the topology, structural properties, evolution dynamics, and vulnerabilities of such complex networks, aiming to better understand the variant and invariant properties, such as patterns of connection, interaction, and relationships, of the underlying system. Applications of network science span a wide variety of areas that pervade our lives: internet, neuroscience, power grid, physical, biological, ecology, and social systems. This course will focus on essential concepts and core ideas of network literacy and introduce tools to analyze and visualize networks.

Timetable and Syllabus

Peroid	Timetable	Syllabus
	9:00-15:30	**9:00-12:00** (a) <u>Course Introduction</u> We first cover course specifics and logistics. We then introduce the notion of network and present a general notion of Network Science as a cross-disciplinary field. We will motivate this via several examples and highlight the associated challenges. (b) <u>Introduction to Graph Theory</u> We will cover basic notions and definitions related to undirected and directed graphs: vertices, edges, simple graphs, weighted graphs, neighborhoods, degree, path, cycle, connected components, random walks, directed acyclic graphs, bipartite graphs, max-flow/min-cut, etc. Also, we introduce matrix network representations, such as adjacency, incidence, and Laplacian matrices. **13:00-15:30** (c) <u>Lab</u>: Python introduction and installation; Network creation and visualization with adjacency, incidence, and Laplacian matrices.

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	9:00-15:30	9:00-12:00 (a) Random, Real, and Scale Free Networks • Network properties: degree distribution, clustering coefficients, path length, diameter, connectivity • Properties of real networks • Erdos-Renyi random graph model 13:00-15:30 (b) Lab: Compute network properties of a given network; Generate and visualize Erdos-Renyi random networks and review their properties
	9:00-15:30	9:00-12:00 (a) Random, Real, and Scale Free Networks • Watts-Strogatz (small-world) model • Kronecker graph model • Scale-free networks and preferential attachment algorithm • Assortative vs disassortative networks 13:00-15:30 (b) Lab: Generate and visualize small-world networks, Kronecker networks, and scale-free networks, and review their properties
	9:00-15:30	9:00-12:00 (a) Centrality and Network-core Metrics We introduce the notion of node centrality as a way to measure the importance of a node within the network. We compare classical measures such as degree, closeness, betweenness, eigenvector, and Katz centrality. We then continue with the following centrality metrics: • Link-based centrality metrics • Path-based centrality metrics • k-core decomposition • Core-periphery structure • Rich-club set of nodes 13:00-15:30 (b) Lab: Compute and compare centrality measures of previously generated networks and real network examples
	9:00-15:30	9:00-12:00 (a) Network Structures: Subnetwork, motifs, and graphlets (b) The Small-World Phenomenon 13:00-15:30 (c) Lab: Project presentation

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Goal of the Course

1. Understand the formation of digital images (Morphological, gray-scale, and color images)
2. Familiar with spatial domain image enhancement techniques
3. Capable of extracting information: component detection and segmentation
4. Develop insight in applying digital image processing tools to real-world problems

The Importance, Cross-Over Disciplinary and Contemporary of The Curriculum

The role of image processing has become critical with the advance in computing technology and machine learning development. Successful interdisciplinary applications can be found everywhere, such as medical imaging, machine/robot vision, pattern recognition (handwriting, traffic objects, computer-aided diagnosis), and cellphone cameras. After the class, students will be able to know how digital image processing is utilized. Furthermore, they will be able to apply digital image processing in their life, study, research, and work.

Remarks

References：

R.C. Gonzales and R.E Woods, Digital Image Processing 3rd or 4th ed.