國 立 成 功 大 學 模 組 化 課 程

開課學年度/學期：115 學年度第 1 學期　　領域：自然與工程科學

複雜系統中的網路結構、模型和特性
Network Structure, Modeling, and Properties for Complex Systems

授課教師	任職單位	畢業學校
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課程類別	學分數	選必修	開課人數	其他注意事項
Lecture + Recitation	**1.5**	**選修**	**20**	

先修課程或先備能力

無

課程難易度

□難 ■中偏難 □中偏易 □易

建議修課學生背景

理學院、工學院、生科院、電資學院、管理學院、醫學院、規劃設計學院、社科學院

教學方法

講授 70%，實作 23%，報告 7%

補充說明：

The daily schedule is split between theoretical lectures in the morning and hands-on laboratory sessions in the

afternoon. While prior experience with Python is not a prerequisite, a basic grasp of programming logic will be

beneficial.

The afternoon labs are structured into two distinct segments:

- **Guided Practice: We will walk through functional code examples and review Python-based homework assignments. All source code will be provided, allowing you to follow along in real-time and continue your practice independently after class.**
- **Interactive Workshop (TA Hour): The latter half of the session serves as a dedicated block for troubleshooting homework and developing your research projects. TAs will be available for one-on-one guidance, and students are encouraged to use this time for collaborative work.**

評量方式

問題考試 28 %：

四次隨堂測驗，第二天至第五天 9:00-9:30，範圍為前幾日所教的課程內容。

作業 40 %：

四次作業分別針對第一天至第四天課程內容，第二到第五天下課前上傳繳交至課程平台。

報告 32 %

Grading Policy & Assessment

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Your final grade is composed of three primary components designed to measure theoretical understanding, technical proficiency, and independent research capability.

1. Daily Quizzes (28%)

- **Schedule: Administered at the start of class (09:00–09:30) from Day 2 through Day 5.**
- **Content: Each quiz evaluates your comprehension of the material covered during the *previous* days' lecture.**

2. Homework Assignments (40%)

- **Format: Four assignments will be distributed (one for each of the first four lectures).**
- **Deadline: Completed work must be submitted by the end of the following day's lecture.**

3. Research Project (32%)

- **Collaboration: Students will work in groups of up to four to investigate a network problem, explore potential solutions, and share data/computational results.**
- **Individual Accountability: While data and code may be shared within the group, reports must be authored individually. To ensure academic integrity and unique insight, the following sections must be original work:**
  - **Problem Statement: Do not simply copy the instructor's description or hand out. Describe the problem through your own lens, incorporating multiple perspectives.**
  - **Analysis & Discussion: Use your unique combination of metrics and characteristics to provide original reasoning and interpretations.**
  - **Conclusion: Summarize your specific findings and focuses.**
- **Submission Details:**
  - **Deadline: Reports are due within 2 days of the course conclusion.**
  - **Language: Submissions are accepted in either English or Chinese.**
  - **Structure: Reports must include a Title, Author, Abstract, Introduction, Problem Statement, Methods, Results, Discussion, Conclusion, and References.**

學習規範

按時上課、按時交作業(報告)

課程概述

複雜系統不論其本質為何，皆可透過定義「點」（節點）與其間的「關係」（鏈結）建構為網路模型。

透過系統化地剖析網路的結構、動態行為與演化特性，我們能深入理解原系統的核心機制，例如：識別關鍵子系統、定位核心節點以及評估系統穩定性。

作為一門前沿的跨領域學科，「網路科學」已廣泛應用於各類自然與人造系統，涵蓋腦神經科學、

通訊網路、社群動力學、電力系統及蛋白質結構分析等領域。本課程將帶領學生掌握網路科學

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的
基礎概念，並透過實務案例探討網路模型與實體系統間的關聯，進而循序漸進地介紹網路型態、
量化指標與深層結構。

關鍵字：網路特性, 隨機網路, 無尺度網路, 小世界網路

課程概述(英文)

Whether they are biological or engineered, complex systems are frequently modeled as networks of interacting parts. Interestingly, these individual components are usually quite simple; the system's true complexity only "emerges" through their collective interactions.

Network science is a modern field dedicated to studying these structures—examining how they evolve, where they are vulnerable, and how their underlying patterns remain consistent across different scales. Because these networks are everywhere, the field's applications are vast, touching everything from the power grid and the internet to neuroscience and social dynamics.

In this course, we will explore the foundations of network literacy, providing you with the conceptual framework and technical tools needed to analyze and visualize these intricate systems.

Keywords : Network Characteristics, Random Network, Scale-Free Network, Small-World Network

課程進度

日期	時間	進度說明
6/29(一)	09:00 – 12:00 13:00 – 15:30	**Day 1: Foundations & Graph Theory** **Morning (09:00–12:00): Theory & Introduction** • **Course Launch: Overview of logistics, the interdisciplinary evolution of Network Science, and real-world motivational examples.** • **Graph Theory Essentials: Comprehensive review of directed/undirected graphs, connectivity (paths, cycles, DAGs), and flow problems (max-flow/min-cut).** • **Matrix Representations: Encoding networks via Adjacency, Incidence, and Laplacian matrices.** **Afternoon (13:00–15:30): Practical Lab** • **Environment Setup: Python installation and library configuration.**

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		• **Implementation: Transforming mathematical matrices into visual network structures using computational tools.**
6/30(二)	**09:00 – 12:00** **13:00 – 15:30**	**Day 2: Random & Real-World Network Topology** **Morning (09:00–12:00): Theory** • **Characterizing Networks: Defining key metrics including degree distribution, clustering coefficients, and diameter.** • **The Random Baseline: In-depth analysis of the Erdős-Rényi (ER) model and how it compares to observed "real-world" data.** **Afternoon (13:00–15:30): Practical Lab** • **Statistical Analysis: Scripting tools to calculate global properties of a dataset.** • **Simulation: Generating and visualizing ER random graphs to observe theoretical vs. actual connectivity.**
7/1(三)	**09:00 – 12:00** **13:00 – 15:30**	**Day 3: Advanced Network Models** **Morning (09:00–12:00): Theory** • **Small-Worlds & Kronecker: Exploring the Watts-Strogatz model and the recursive nature of Kronecker graphs.** • **The Scale-Free Paradigm: Studying power-law distributions and the Preferential Attachment mechanism.** • **Mixing Patterns: Distinguishing between assortative (like-connects-to-like) and disassortative structures.** **Afternoon (13:00–15:30): Practical Lab** • **Synthetic Modeling: Comparative visualization of small-world vs. scale-free networks.** • **Validation: Testing how different growth algorithms affect final network topology.**
7/2(四)	**09:00 – 12:00** **13:00 – 15:30**	**Day 4: Centrality & Core Structures** **Morning (09:00–12:00): Theory** • **Measuring Influence: Defining "importance" through Closeness, Betweenness, Eigenvector, and Katz centrality.** • **Structural Hierarchies: Exploring k-core decomposition, the Rich-club effect, and core-periphery architecture.** **Afternoon (13:00–15:30): Practical Lab** **Ranking Algorithms: Applying centrality measures to identify "super-spreaders" or critical bottlenecks in real-world network examples.**

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7/3(五)	**09:00 – 12:00** **13:00 – 15:30**	**Day 5: Local Motifs & Final Synthesis** **Morning (09:00–12:00): Theory** • **Micro-Structures: Analyzing subnetworks, recurring motifs, and graphlets.** • **The Small-World Phenomenon: A deep dive into the sociology and physics of the "Six Degrees" concept.** **Afternoon (13:00–15:30): Project Showcase** **Final Presentations: Students present their computer-aided research projects and network visualizations.**

課程學習目標

1. **Master the vocabulary** of network science by learning how to measure and characterize different systems.
2. **Gain hands-on experience** using specialized tools to visualize and interpret network data.
3. **Compare theoretical models** (like random graphs) against real-world observations to see where they succeed or fail.
4. **Solve complex problems** using algorithms that identify influential nodes and hidden community structures.
5. **Connect the dots** between biology, sociology, and technology to see how network principles apply across disciplines.

課程的重要性、跨域性與時代性

As a rapidly evolving field, network science provides the computational framework necessary to analyze the architecture, growth, and resilience of complex systems. Leveraging today's massive gains in computing power, researchers use these methods to decode the hidden patterns in the world around us—from biological pathways to global infrastructures. This interdisciplinary course—bridging mathematics, engineering, and computer science—offers a deep dive into network formations and their real-world applications. Through hands-on computational exercises and computer-aided research, students will move from theoretical understanding to practical mastery of complex system analysis.

其他備註

參考書目：

A. Barabasi, Network Science http://networksciencebook.com/

Other References:

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1. E.J. Newman, Networks: An Introduction, Oxford University Press, 2010. https://oxford.universitypressscholarship.com/view/10.1093/acprof:oso/9780199206650.001.0001/acprof-9780199206650

2. D. Easley and J. Kleinberg, Networks, Crowds and Markets, Cambridge Univ Press, 2010. https://www.cs.cornell.edu/home/kleinber/networks-book/

修課先備知識補充

Course Prerequisites

There are no formal requirements to enroll in this course. However, to get the most out of the lectures and labs, a foundational understanding of the following subjects will be highly advantageous:

- **Mathematics: Basic Graph Theory, Probability Theory, and Linear Algebra.**
- **Programming: Familiarity with Python syntax and logic.**

Software & Essential Tools

Following are powerful libraries may be used for network analysis and visualization.

1. **Core Environment**
   - **Python: The primary programming language for our computational tasks.**
2. **Network Analysis Libraries**
   - **NetworkX: The industry standard for studying complex networks and graph algorithms.**
   - **igraph: A high-performance library focused on efficiency and complex network research.**
   - **BCTPy: The Brain Connectivity Toolbox for Python, essential for biological network analysis.**
3. **Specialized Modeling & Visualization**
   - **RolX: A specialized tool for automated structural role extraction in networks.**
   - **Graphviz: An open-source graph visualization software for representing structural information as diagrams.**

本課程若因天災等不可抗力之因素或中央、地方政府公告停課，授課教師需依情況依建議補課方式調整課程進度與補課；若需使用假日、國定假日補課，則需與所有修課學生達成共識方能用例假日補課。

建議補課方式：

1. 線上授課方式補課；
2. 當預期可能會因天災(颱風、超大豪雨…等)宣佈停課時，建議老師先行調整加快課程進度或預先增加可能天氣預警之前幾次課程時數；
3. 停課後隔天起延後下課，補足停課延誤的進度；若停課超過 1 天，則在開始上課後延後下課補課，或當週星期六、日補課；

更改課程授課方式，例如：DEMO 改以考試、報告、作業取代。