

Check list

- [] Microphone turned on
- [] Zoom room open
- [] MyBinder launched
- [] Sound Volume on

Advanced Topics in Network Science

Lecture 01: Introduction & Seven Bridges of Königsberg

Sadamori Kojaku



Binghamton University

EngiNet™

State University of New York



WARNING

All rights reserved. No part of the course materials used in the instruction of this course may be reproduced in any form or by any electronic or mechanical means, including the use of information storage and retrieval systems, without written approval from the copyright owner.

**©2024 Binghamton University
State University of New York**



Contact Information:

EngiNet Office Staff:

Janice Kinzer

Email: enginet@binghamton.edu

Phone: 1-800-478-0718 or 607-777-4965

Media Production Operator: Rafia Rahman

Instructor: Sadamori Kojaku

Email: skojaku@binghamton.edu

Phone: 607-777-5039



SSIE 641 –Advanced Topics in Network Science

Sadamori Kojaku

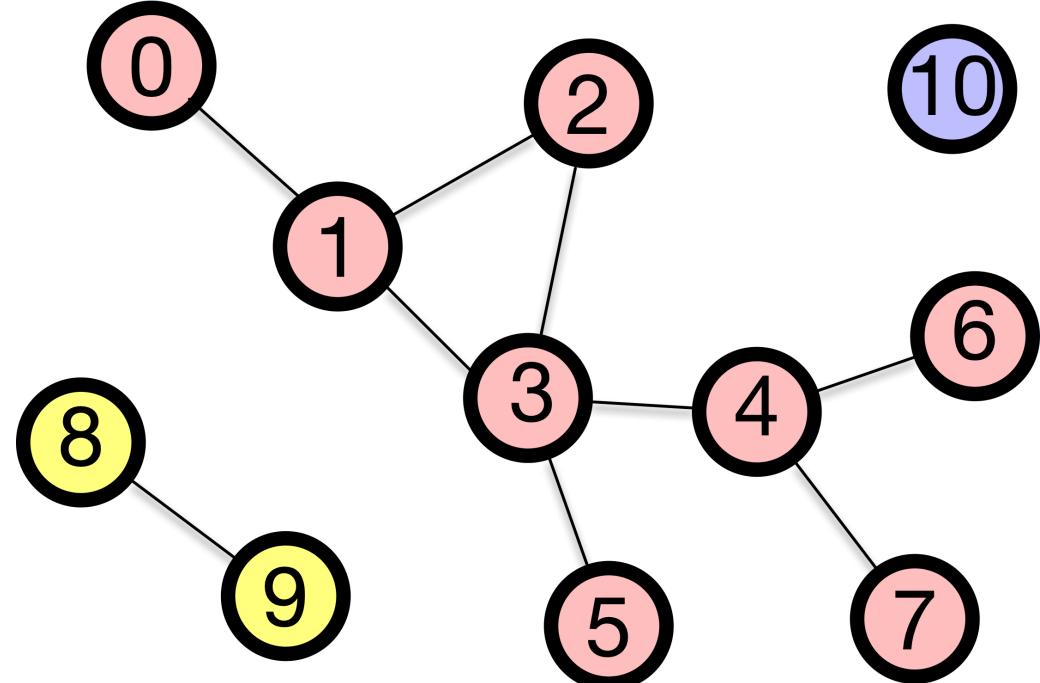
Lecture

Course Overview

- **Instructor:** Sadamori Kojaku (幸若完壯)
- **Email:** skojaku@binghamton.edu
- **Office Hours:** Tue & Thu 14:30-16:30
- **Course Website:** <https://skojaku.github.io/adv-net-sci>

What is Network Science?

- What is *Network*?
- Why do we care about *Network*?
- What is *Network Science*?



Find networks around you!

   My zoo of networks   

Is it just a branch of graph theory?

-  Graph Theory:
 - Focuses on structured graphs (trees, grids, regular graphs)
 - Emphasizes mathematical properties
-  Network Science:
 - Studies complex networks in real-world systems
 - "Complex" ≠ "Complicated"
 - Seeks simple laws to explain seemingly intricate structures

How is it different from data science?

-  **Data Science: $1 + 1 = 2$**
 - Often assumes independence between data points (i.i.d.)
 - Focuses on extracting insights from structured data
-  **Network Science: $1 + 1 > 2$**
 - Embraces dependencies between entities
 - Recognizes that real-world systems are often interconnected
 - Analyzes how these connections influence system behavior

Course Objectives

We will:

-  Analyze networks
-  Learn key concepts
-  Apply AI to networks

After this course, you'll be able to:

-  Understand network science papers
-  Do advanced network analysis
-  Design network research
-  Connect Systems Science and networks

Philosophy of Learning in this course

[https://www.youtube.com/watch?
v=RQaW2bFieo8](https://www.youtube.com/watch?v=RQaW2bFieo8)



WHAT DOESN'T KILL YOU



THE BEACH CHAIR BOOK

MAKES YOU STRONGER

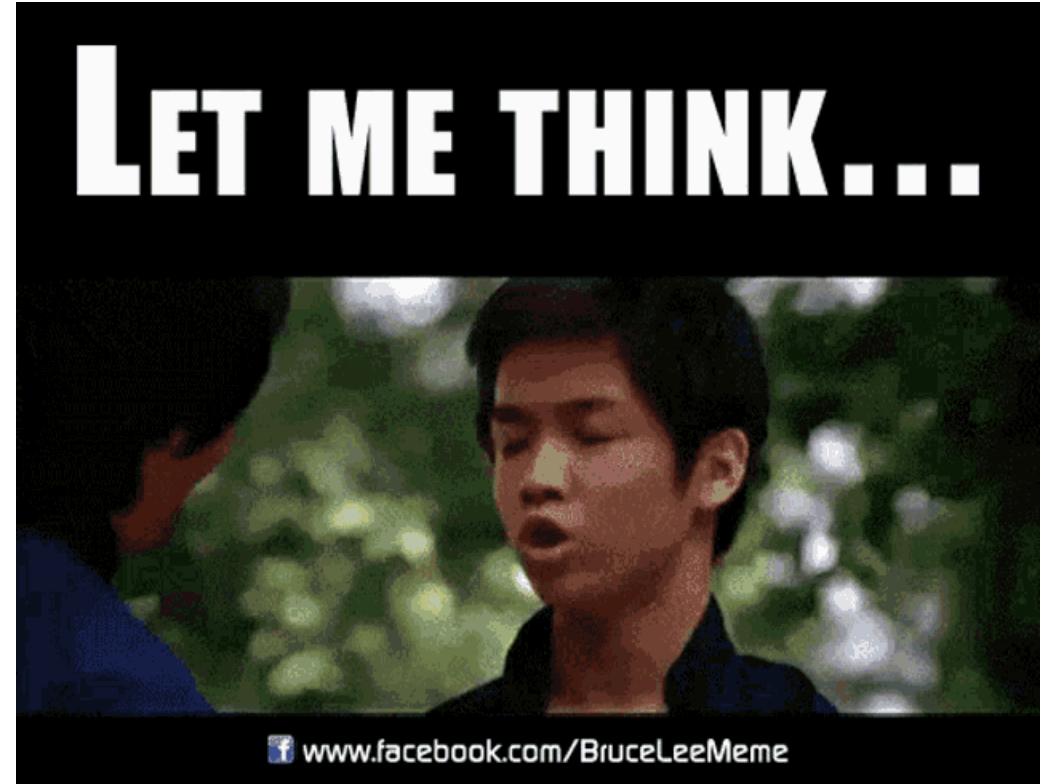
thebeachchairbook.com

www.wordsonimages.com

Course Structure

"Don't think! Feeeeeeel" - Bruce Lee

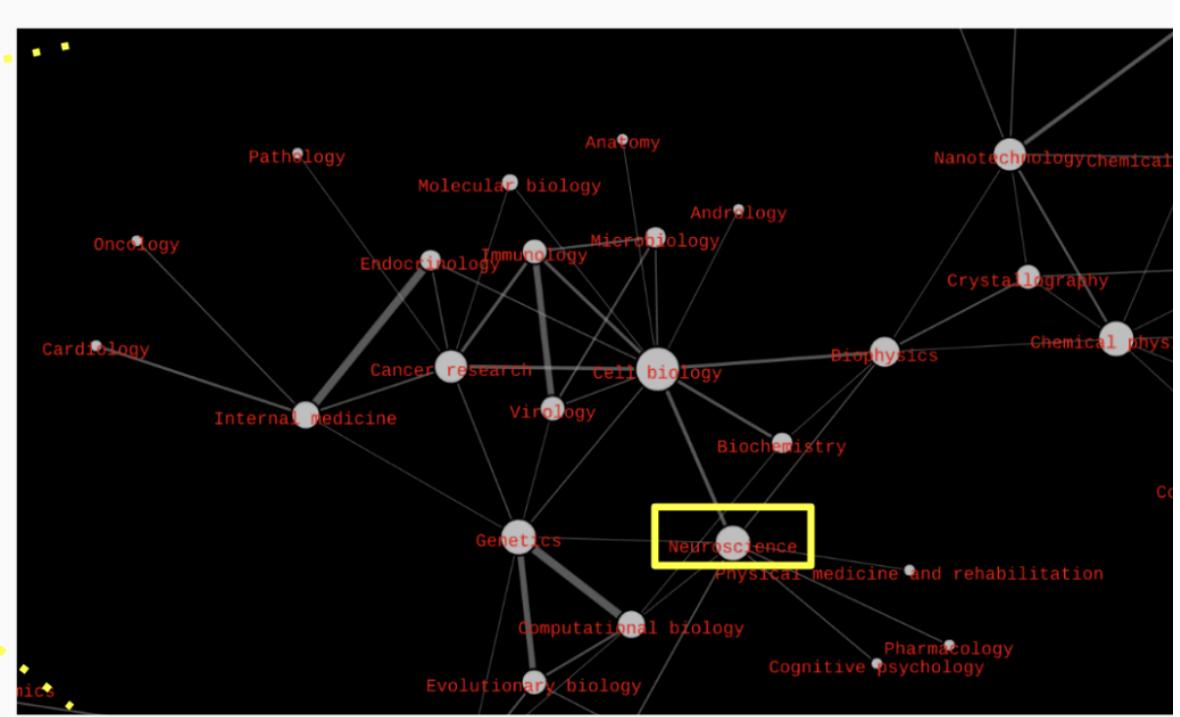
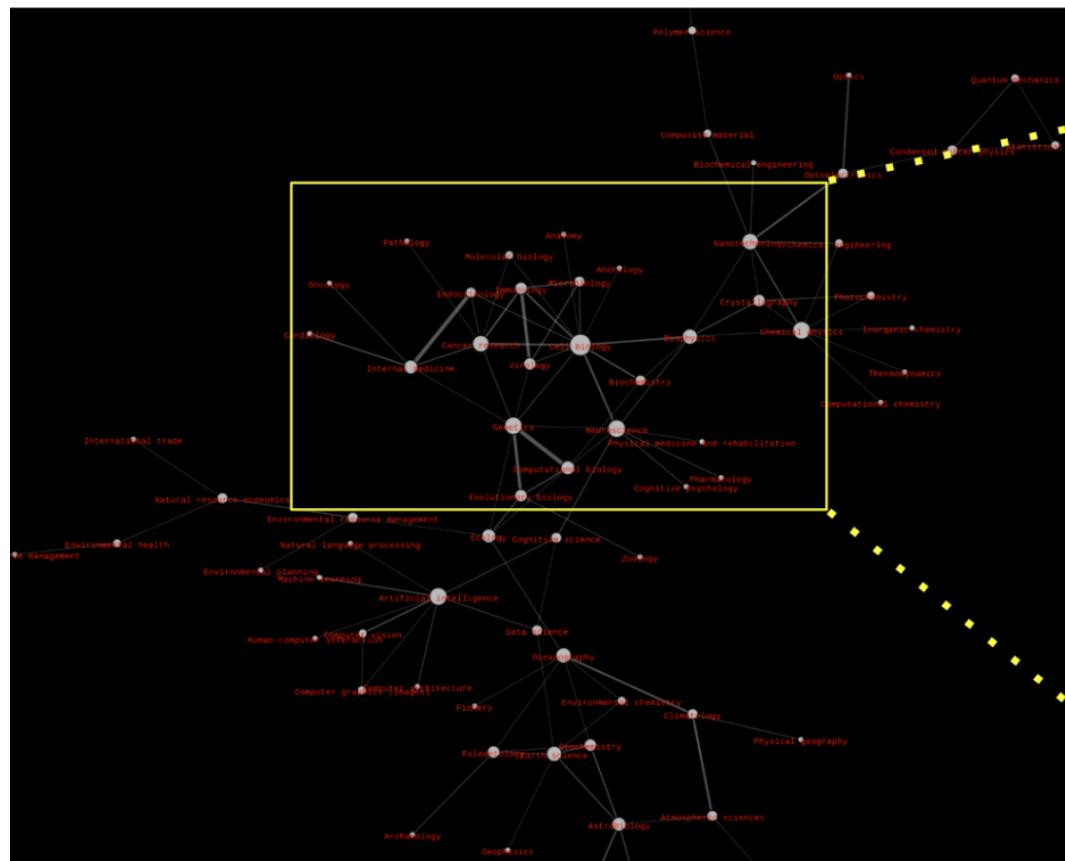
-  Lectures
-  Hands-on exercises
-  Weekly quizzes
-  Biweekly coding assignments
-  Final project
-  Exam

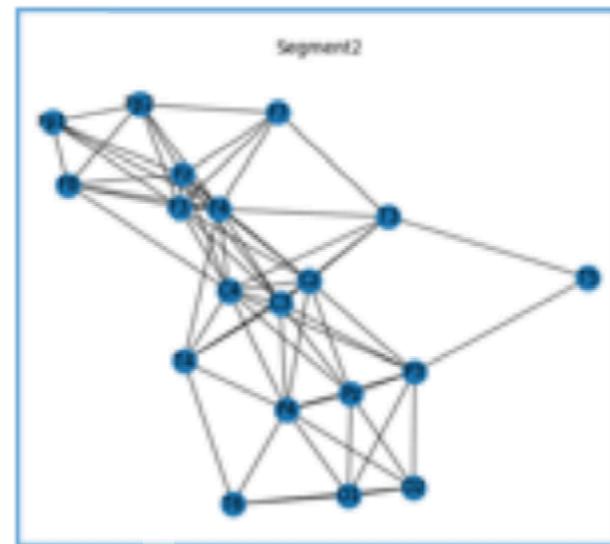
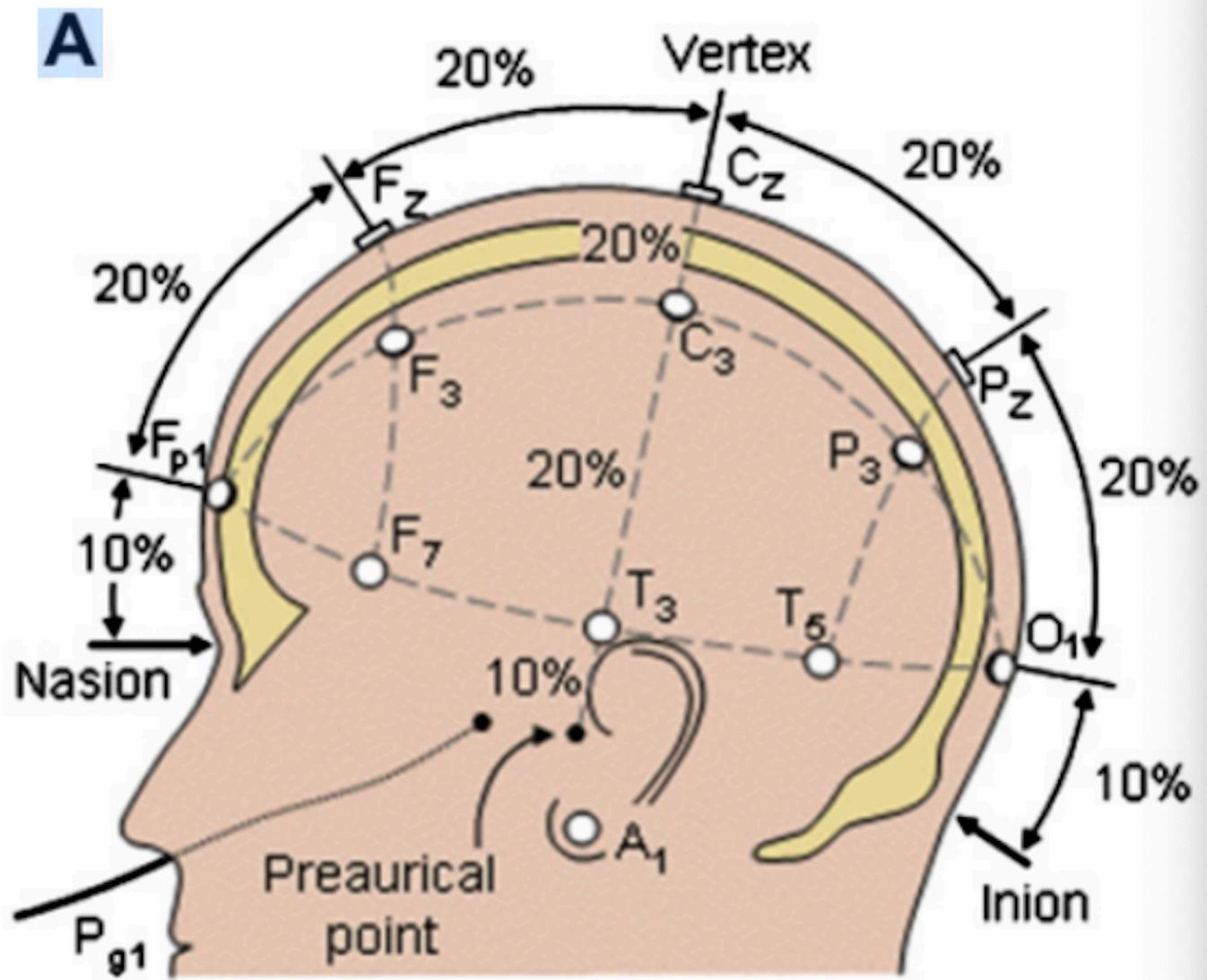


Final Project

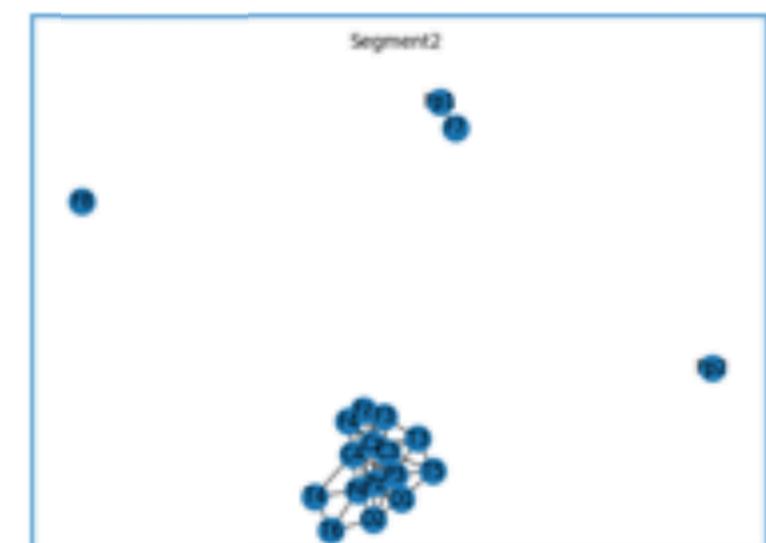
- Individual project (30% of grade) 
- Timeline 
 - Proposal: Sept 29; Paper: Dec 4; Presentations: Dec 8
- Requirements 
 - Apply concepts to real problem 
 - Analyze network dataset 
 - Show course integration 
 - Clear presentation 

Example Project 01





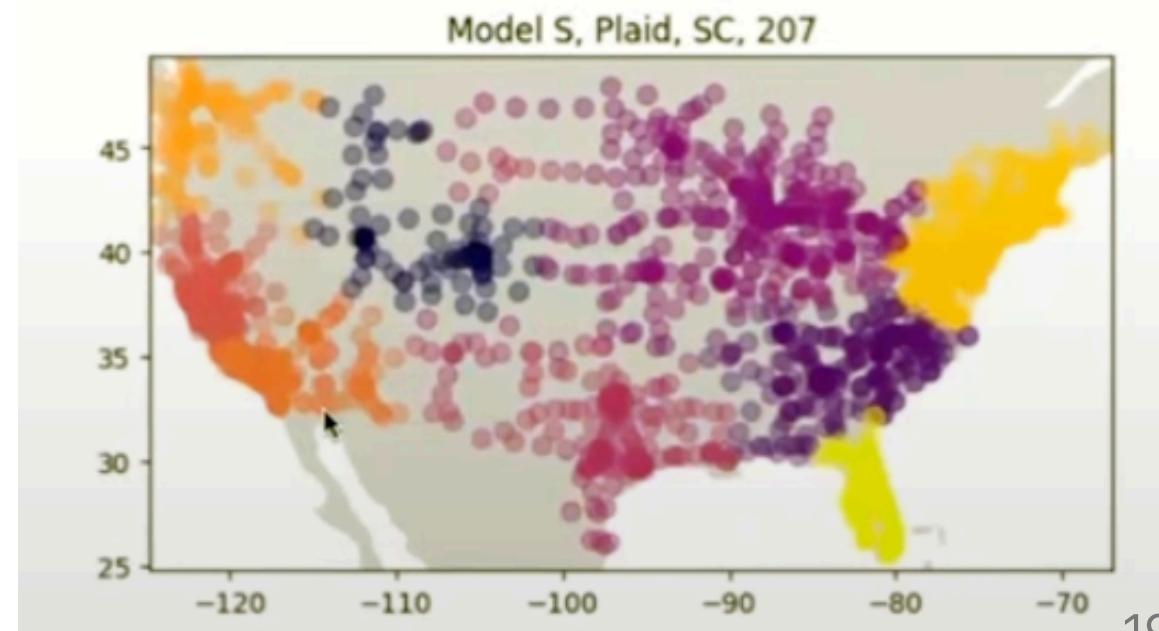
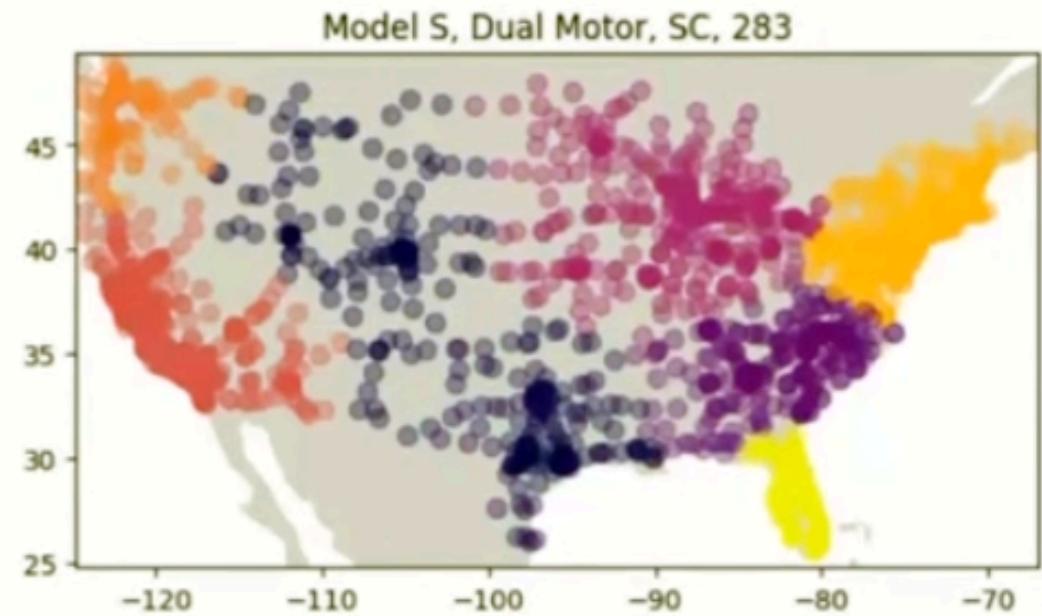
Before



During

Example Project 03

Tesla Supercharger Network



Exam

-  Final exam on all topics (weight: 30%)
-  During exam week (Dec 9-13)
-  Theory + practical problems
-  Apply concepts to real scenarios
-  Review sessions before exam

Weekly Quiz on Brightspace

-  Quizzes: A tool to identify misconceptions (weight: 20%)
-  Covers previous week's topics
-  Deadline: before final exam
-  Unlimited attempts until correct

Assignment

-  Roughly bi-weekly (weight: 20%)
-  Coding exercises
-  Autograded assignments
-  Deadline: before final exam
-  Unlimited attempts until correct

Lecture note

-  [Interactive Jupyter book](#)
-  Run code directly on the page
 -  First-time loading may take 2-3 mins
-  Or download as Jupyter notebook
 -  Use on cloud (Google Colab, Kaggle) or locally
 -  Install packages from `environment.yml` for local use
 - See [The course GitHub repo](#) for details

Policy

-  3-credit course: 6.5+ hours of work/week outside class
-  AI tools allowed for learning, but cite if used in assignments
-  Back up all data and code (loss not an excuse for late work)
-  Accommodations available for students with disabilities
-  Zero tolerance for academic dishonesty

Questions?

Before we start

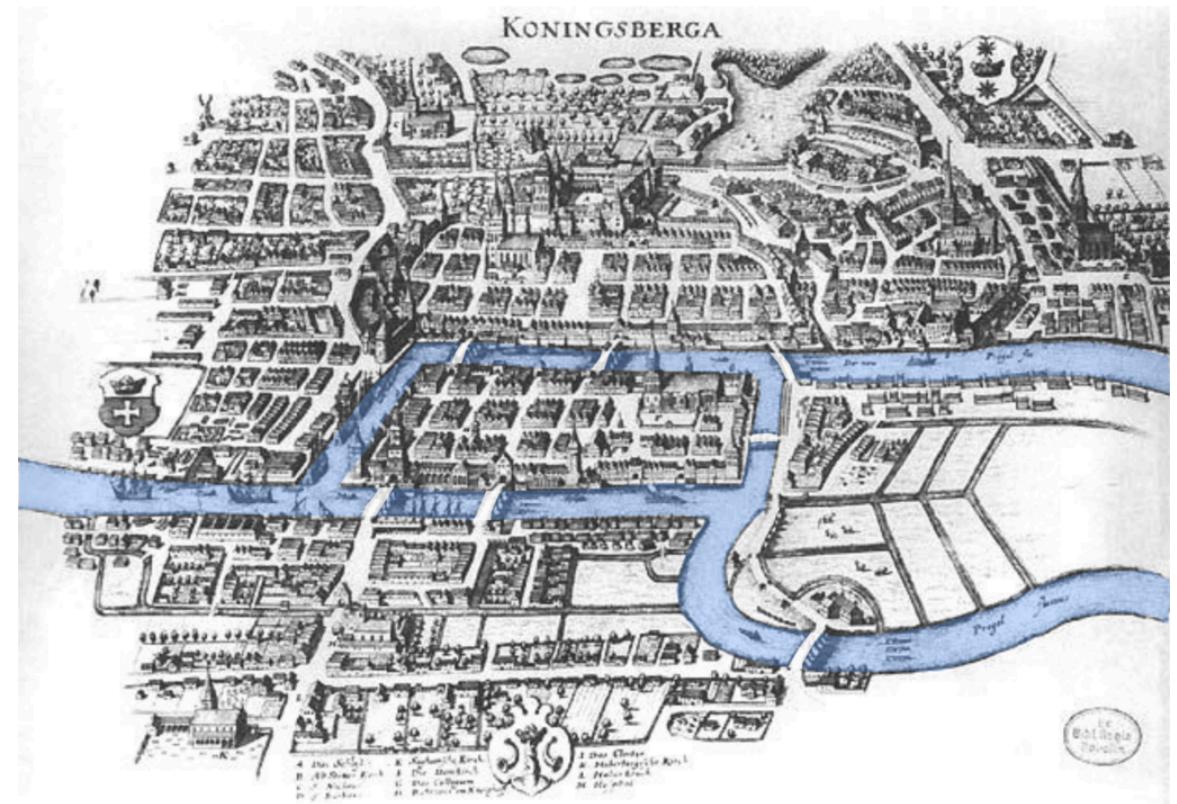
What motivates you to take this course (if you want to)?



<https://www.youtube.com/watch?v=u6XAPnuFjJc>

~8:23

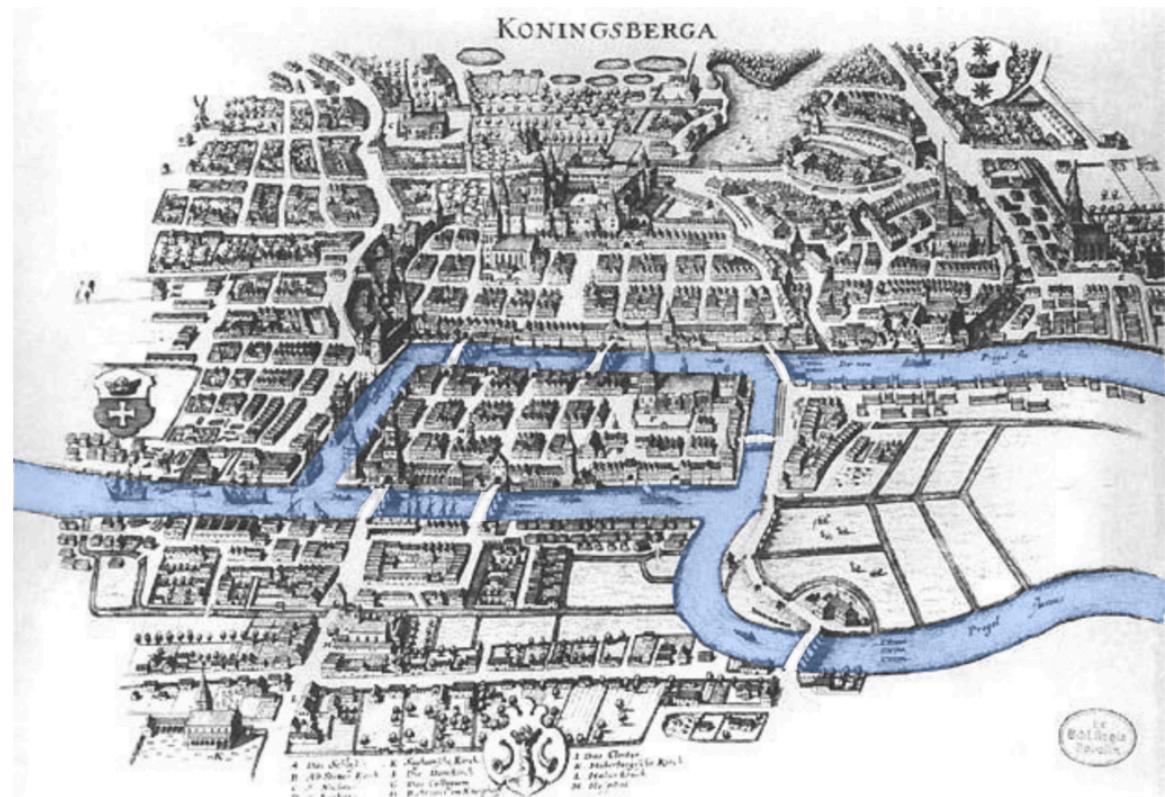
M01: Seven Bridges of Königsberg



The Königsberg Bridge Puzzle



- 18th century puzzle in Königsberg, Germany
- City had 7 bridges connecting 2 islands and mainland
- **Challenge:** Find a route that crosses each bridge exactly once



Find a route that crosses each bridge exactly once 🚶

How would you approach this problem?

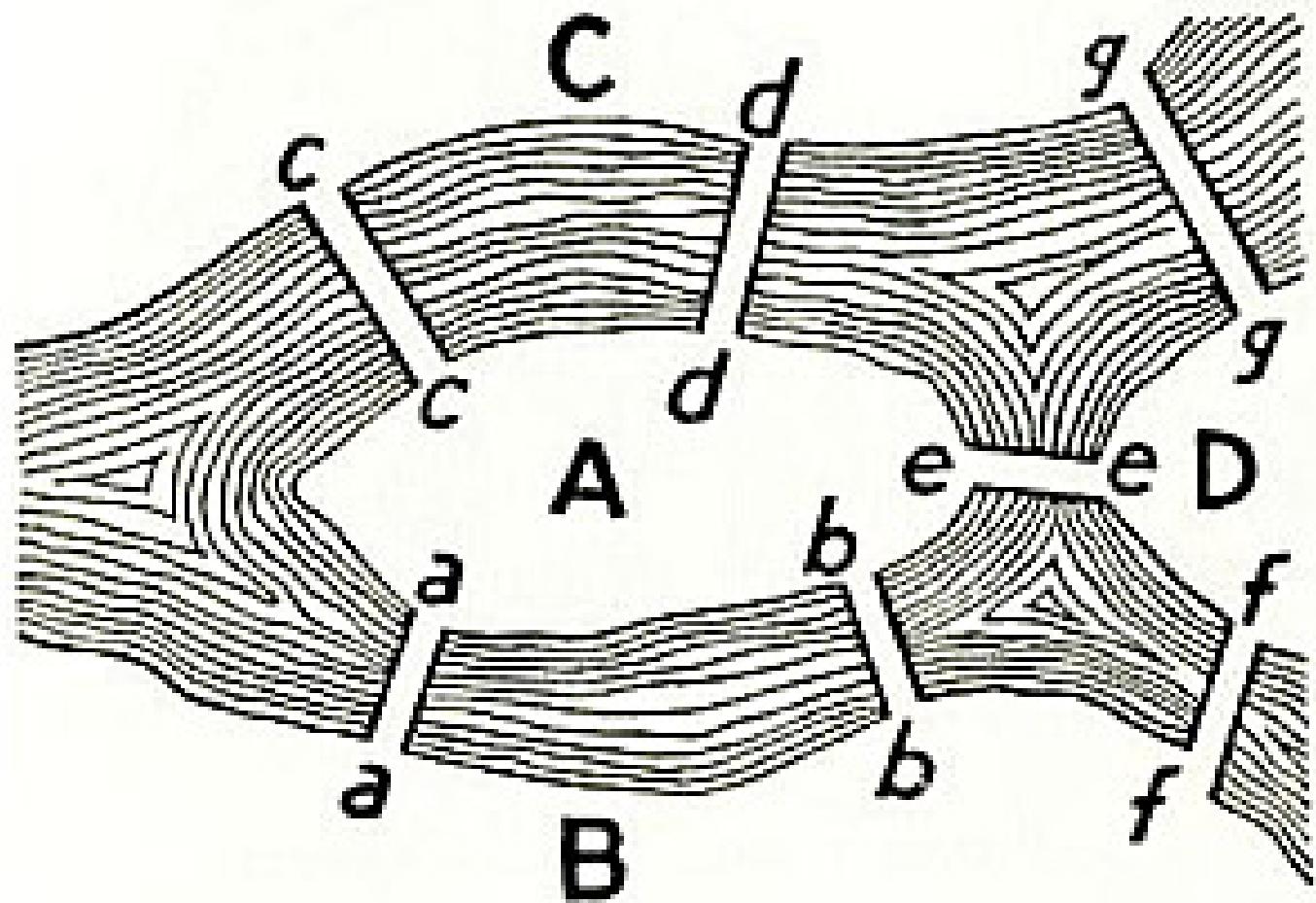
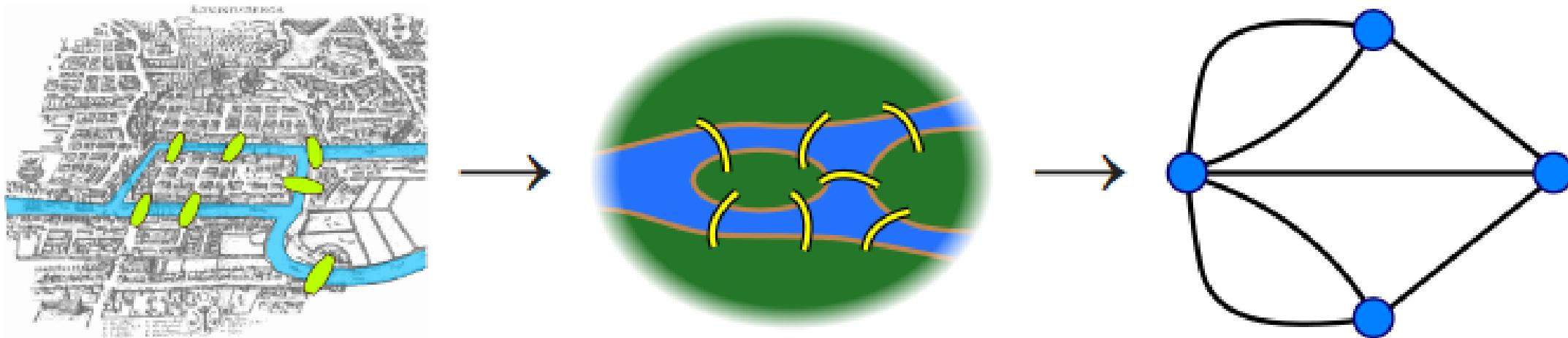


FIGURE 98. *Geographic Map: The Königsberg Bridges.*

Euler's Brilliant Solution



-  Simplified city to network of landmasses and bridges
-  Focused on connections, not layout

Pen and Paper Exercise

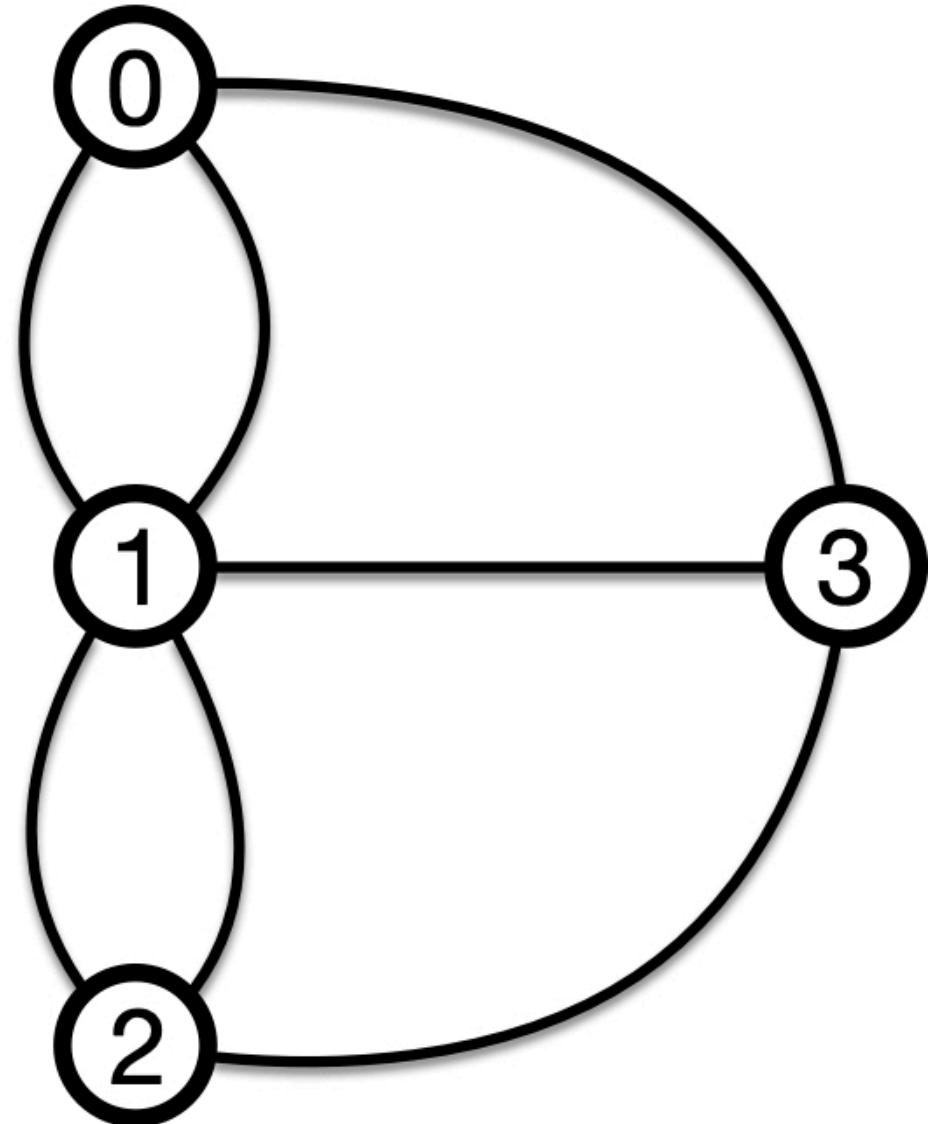


- Let's work on a pen-and-paper [exercise](#) 
- Let's form a group of 3-4 people and discuss the solution together.

Euler's Solution



-  Euler considered: even vs odd edge nodes
-  Key insights: Even - enter/leave k times, Odd - one edge left
-  **Euler's Theorem:** Path exists if all even degree or two odd degree
-  Königsberg: All odd degree, no Euler path



Aftermath: The Bridges' Fate



- 🇷🇺 During World War II, Soviet Union bombarded Königsberg
- 💣 Two of the seven bridges were destroyed
- ✅ Ironically, this destruction made an Euler path possible!

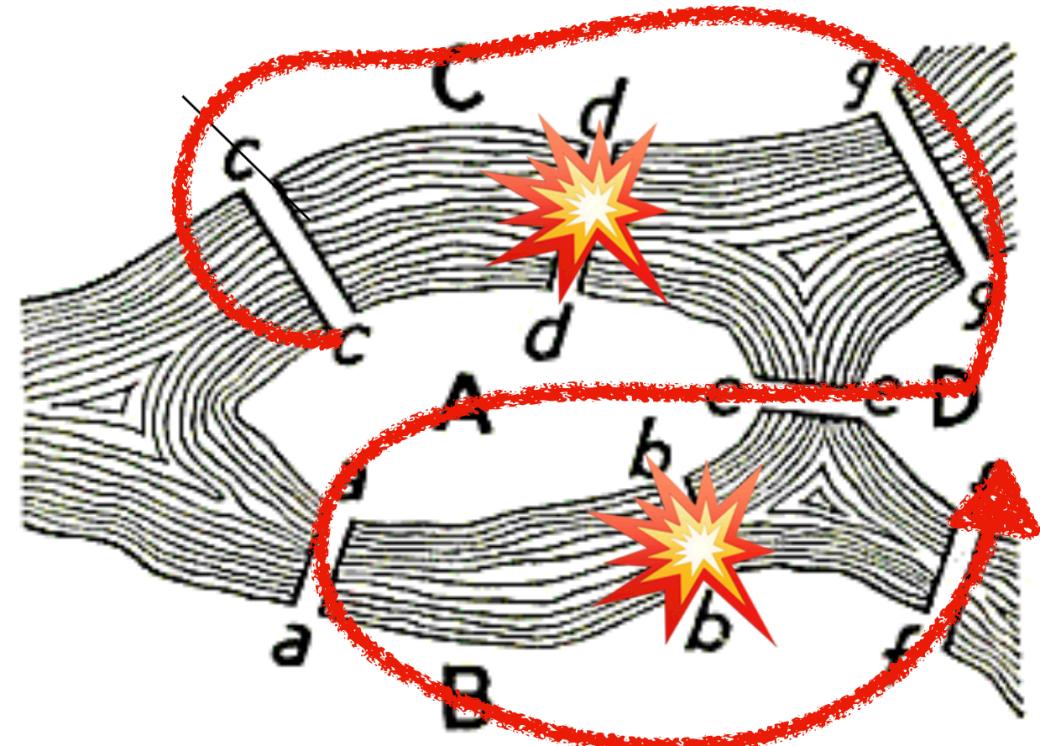


FIGURE 98. *Geographic Map: The Königsberg Bridges.*



Coding Time: Networks in Code!

Let's represent networks with Python!

Key Takeaways

- Networks are powerful tools for modeling complex systems
- Euler's path problem: a foundation of graph theory and network science
- Python for network analysis

Any questions?