MATH 7.04 First-Year Seminar: *Analyzing Network Data*

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Office Hours: TBD, Kemeny 240

Overview: We live in a connected world, where the confluence of the different connections — social, political, financial, informational, technological, biological, behavioral, epidemiological — affects virtually every aspect of our lives. The mathematical study of networks provides a framework for describing these connections. Writing about the properties of networks leverages this framework to test ideas and increase understanding of the resulting impacts of a network on the system it interconnects, especially when describing the comparisons and contrasts between different types of networks. Most people are familiar with the concept of a network from hyperlinked web pages or online social networks. Online networks are of particular interest, but networks are also useful for representing and studying a wider variety of connected systems. With "nodes" representing actors of interest and "edges" connecting the nodes representing relationships, the concept of a network can be flexibly used across many applications. Students will analyze network data by developing three written documents — critical evaluation of a journal article, a computational notebook, and a journal-style project report — across multiple milestones through the term.

More Details About Writing Assignments: Through writing, the students will think through the properties and influences of networks. The course is organized around three different writing assignments that students develop and revise over the course:

1. a critical evaluation of a student-selected journal article written in a style similar to a *Nature* News & Views overview, analyzing the methods and conclusions described in the article;

2. a computational notebook combining detailed narrative description with short code blocks and results of hands-on network science computations on a student-selected real-world data set, detailing how the student explores and thinks through the many different available calculations to analyze and better understand the network; and

3. a journal-style project report wherein students critically evaluate the methods, describe the results, and explore the implications of a network analysis on a student-selected data set (which can be but need not be the same data set as in the second assignment).

Each of these three written products will be developed over multiple milestone assignments, including (a) preliminary and/or outlining documents, (b) a full submitted draft, and (c) a revised draft. All assignments will be graded for both narrative and scientific content, with feedback from the instructor and peers which students will be able to use to further refine their writing.

Learning Outcomes: Through these writing assignments, students will learn to critically evaluate scientific papers in the interdisciplinary space of network science; directly apply mathematical, statistical, and computational thinking and methods to perform and describe network data analyses; and develop their scientific ideas in multiple written formats for different audiences. Notably, the "news & views" summary should be written for a general scientifically-aware (but not expert) audience, whereas the computing notebook is aimed at readers who have developed some knowledge of network analysis (the instructor and peers in the class). Through the readings and the journal-style project report, students will become familiar with and write their own distinct elements typical of a scientific paper such as an Abstract, Introduction, Methods, Results, and Discussion. Students should also refer to the learning outcomes expected in all First Year Seminars.

Computation: One of the three documents written by students in this course will develop exploratory calculations and results in the form of a narratively heavy literate programming computational notebook, produced using Quarto inside R Studio, combining extensive descriptive text with embedded code and output (figures and tables). This document will promote, capture, and describe the critical thinking processes involved in performing network analysis computations to better understand the data set at hand. In particular, this notebook provides an opportunity to write about your thinking as you iteratively ask questions, test theories, obtain results, and explain the possible meanings of those results.

No prior mathematical or computing knowledge will be required or assumed. The course will provide a self-contained exposure to a spectrum of broadly accessible methods for analyzing network data. Students will be expected to develop and describe quantitative calculations in their critical thinking about these networks in their written assignments.

Students will be required to investigate, refine, and communicate network analyses of real-world data for both their written computational notebook and their written project report, which together comprise a majority of the course grade. Each student will identify a specific network data set, carry out and write about the different calculations we learn in the course as used in their exploring and analyzing that data set, and write up their results in the form of a journal-style report. Students will additionally search for relevant past research in scholarly journals, databases, and other online resources. Students will be responsible for a number of milestones on each written document.

Expectations for Class Meetings: The approach of this class will require you to take an active part in example computations and in class discussions. To do this effectively, you should review the required readings and follow references as appropriate prior to every class meeting. Documents due for each milestone assignment must be submitted electronically by upload to Canvas prior to the associated course meeting, so that selected students can present short walkthroughs of their writings and results to the class and/or in small groups. Class meetings will include discussion of assigned readings, discussions with peers, and example networks calculations performed individually and in small groups. As such, please plan to regularly bring your laptop computer to class. Class attendance is essentially critical to success in this class. Full attendance is expected; missing class except for approved absences will negatively impact a student's class participation grade. Please notify me as soon as possible about any classes you will miss.

Required Readings: To develop our thinking about network science that will inform your computational analyses and writing, we will read selected chapters of the following books.

- *Connected: The Surprising Power of Our Social Networks and How They Shape Our Lives* by Nicholas Christakis and James Fowler, 2009
- *Statistical Analysis of Network Data with R* by Eric Kolaczyk and Gabor Csárdi, 2nd ed., 2020 (full text available for up to 3 simultaneous users from https://search.library.dartmouth.edu/permalink/01DCL_INST/16rgcn8/alma991033590872505706)
- *Connecting in College: How Friendship Networks Matter for Academic and Social Success* by Janice McCabe, 2016 (full text available from https://search.library.dartmouth.edu/permalink/01DCL_INST/16rgcn8/alma991033652413605706)

All three texts are available at the Baker-Berry Library Course Reserve.

Course Communication: All registered students will be invited to the Slack team set up specifically for this course through Canvas, as the go-to primary point of electronic communication with the instructor, allowing for group discussions and for private direct messages.

Course Grades will include class participation (25%), including discussions about readings, participating in group feedback, Slack discussion threads, and other similar class items. Numerical scores will be assigned to every milestone of each of the three written products (each document product = 25%; each milestone within a given product will be weighted equally). Final course grades will be assigned by the following ranges of final averages:
A $\in [93, 100]$, A- $\in [90, 93)$, B+ $\in [87, 90)$, B $\in [83, 87)$, B- $\in [80, 83)$, C+ $\in [77, 80)$, C $\in [73, 77)$, C- $\in [70, 73)$, D $\in [60, 70)$, E < 60.

Assignments not submitted in the proper manner will not be accepted. Late assignments will not be accepted except where previously approved. All requests for extensions must be applied for in writing, in a timely manner, clearly stating the reasons for the request (e.g., an excused absence or a medical or other emergency) and proposing a new deadline. A zero score will be assigned for assignments not completed on time. Because class participation is part of the course grade, it is important to document excused absences in a timely manner. In short, be responsible.

Academic Honor Principle: The faculty, administration, and students of Dartmouth College acknowledge the responsibility to maintain and perpetuate the principle of academic honor, and recognize that any instance of academic dishonesty is considered a violation of the Academic Honor Principle. All academic work should be done with the highest level of honesty and integrity. You are encouraged to discuss course material with your peers, including the content of the readings and learning best practices from your peers how to do the calculations in the written assignments; but you must be clear to give credit to your peers as appropriate, just as you are expected to cite any ideas or information obtained from other sources. All submitted assignments and presentations must clearly represent your own work, with appropriate citations to others' contributions. Please be sure to always fairly and completely cite your sources.

Use of Generative Artificial Intelligence: As machine learning continues to advance, large language models (LLMs), such as ChatGPT, and other Generative Artificial Intelligence (GAI) technologies are becoming more widespread. These models can at times be useful tools to accelerate productivity and understanding. The use of such technologies is permitted for the assignments in our course, so long as the following guidelines are adhered to:

1. When using an LLM or other GAI to aid in completion of an assignment, all prompts and output should be saved and submitted as part of the assignment. This may be in the form of a screenshot, copy and paste, pdf, etc.

2. The work that you submit should reflect your own understanding of the assignment.

3. Copying the output from an LLM or other GAI and handing it in as your own work is not permitted, similarly to how copying a peer's work and submitting it as your own is not allowed.

Examples of situations where you might find it useful to use GAI in your work include when you know what kind of calculation you want to do but you don't know all of the details or syntax for how to code it, or you forgot an idea or concept from a previous class that is needed for the current item you are working on. Many other reasonable examples are surely possible; you are strongly encouraged to share your experiences using such tools. Please be aware that in many cases these technologies can give answers to a prompt that are completely incorrect (and sometimes wildly so). As such, you should always be skeptical of any GAI output you see and verify the veracity of the information contained within. If you have any questions about the use of GAI in the class, please reach out to the instructor.

Religious Observances: Dartmouth has a deep commitment to support students' religious observances and diverse faith practices. Some students may wish to take part in religious observances that occur during this academic term. If you have a religious observance that conflicts with your participation in the course, please meet with me as soon as possible — before the end of the second week of the term at the latest — to discuss appropriate course adjustments.

Student Accessibility and Accommodations: Students requesting disability-related accommodations and services for this course are required to register with Student Accessibility Services (SAS; Apply for Services webpage; student.accessibility.services@dartmouth.edu; 1-603-646-9900) and to request that an accommodation email be sent to me in advance of the need for an accommodation. Then, students should schedule a follow-up meeting with me to determine relevant details such as what role SAS or its Testing Center may play in accommodation implementation. This process works best for everyone when completed as early in the quarter as possible. If students have questions about whether they are eligible for accommodations or have concerns about the implementation of their accommodations, they should contact the SAS office. All inquiries and discussions will remain confidential.

Mental Health and Wellness: The academic environment is challenging, our terms are intensive, and classes are not the only demanding part of your life. There are a number of resources available to you on campus to support your wellness, including: the Counseling Center which allows you to book triage appointments online, the Student Wellness Center which offers wellness check-ins, and your undergraduate dean. The student-led Dartmouth Student Mental Health Union and their peer support program may be helpful if you would like to speak to a trained fellow student support listener. If you need immediate assistance, please contact the counselor on-call at (603) 646-9442 at any time. Please make me aware of anything that will hinder your success in this course.

Title IX: At Dartmouth, we value integrity, responsibility, and respect for the rights and interests of others, all central to our Principles of Community. We are dedicated to establishing and maintaining a safe and inclusive campus where all have equal access to the educational and employment opportunities Dartmouth offers. We strive to promote an environment of sexual respect, safety, and well-being. In its policies and standards, Dartmouth demonstrates unequivocally that sexual assault, gender-based harassment, domestic violence, dating violence, and stalking are not tolerated in our community.

The Sexual Respect Website (sexual-respect.dartmouth.edu) provides a wealth of information on your rights and obligations with regard to sexual respect and resources that are available to all in our community. As a faculty member, I am obligated to share disclosures regarding conduct under Title IX with Dartmouth's Title IX Coordinator.

Should you have any questions, please feel free to contact Dartmouth's Title IX Coordinator Kristi.Clemens@Dartmouth.edu and deputies if appropriate.

Socioeconomic Differences and Financial Difficulty: The materials for this course have been deliberately chosen to be reasonably priced, with two of the three texts available electronically free of charge and all three texts available through Baker-Berry Library Course Reserves. If you encounter financial challenges related to this class, please let me know.

Disclaimer: The instructor reserves the right to make changes to the syllabus, including the calendar of activities and due dates. Changes will be announced as early as possible. The latest syllabus and calendar will be maintained on Canvas.

Tentative Schedule: The schedule below represents an ambitious big-picture course framework. Details and emphasis will undoubtedly evolve as we move through the course, and there will also be possible changes to dates of class meetings. **The Canvas course site will be used to keep an updated calendar of reading, compuational, and written assignments as the course progresses.** We will use our X-hours periods as needed to make up lost class time (for which attendance will be expected and clearly communicated ahead of time by inclusion in the schedule, such as the instances indicated below).

This schedule of activities is provided as a guide to our course goals, including discussions about writing, computation, and readings from Christakis & Fowler (CF), Kolaczyk & Csárdi (KC), and McCabe. Each **"(r)"** *reading assignment* and **"(w)"** *writing milestone* indicated in the schedule below **must be completed before our class meeting that day**, because it will be central to the discussion and/or in-class peer feedback exercise that day (except when each final product is due). The **"(c)"** *computational topics* will be presented through literate programming computational notebooks in class.

- **Week 1:** Introduction to Network Analysis and Social Networks
  March 31: (c) R Studio, Quarto and igraph, with selected items from KC chapters 1–3.
  April 2: Class discussion about (r) CF chapters 1–2.
  April 4: Start R-igraph examples from KC chapter 4 and (w) first short summary about a journal article referenced in the CF reading.

- **Week 2:** Network Properties and Influence, Critically Evaluating a Journal Article
  April 7: (c) R-igraph examples from KC chapter 4.
  April 9: Class discussion about (r) CF chapters 3–4.
  April 11: Peer feedback about (w) second short summary about a journal article referenced in the CF reading.

- **Week 3:** Economic and Political Networks, Your Ego Network, Constructive Feedback
  April 14: Class discussion about (r) CF chapters 5–6.
  April 16: Class discussion about (r) McCabe chapters 1–2.
  April 18: Peer feedback about (w) "news & views" style summary.

- **Week 4:** Models of Networks
  April 21: (c) Start KC chapter 5.
  April 23: (c) Continue KC chapter 5.
  April 25: (c) KC chapter 6 and ego networks. (w) "News & views" revision due.

- **Week 5:** Writing as Thinking about Network Calculations in a Computational Notebook
  April 28: (c) Community detection and other ego network calculations. (r) "Ten simple rules for writing and sharing computational analyses..."
  April 30: Class discussion about (r) McCabe chapters 3–5 (each student picks 1).
  May 2: Peer feedback about (cw) first milestone checkpoint on computational notebook, including both own personal ego network and one publicly-available data set.

- **Week 6:** Network Calculations (cont'd), Constructive Feedback
  May 5: (c) Highlights of submitted computational notebooks.
  May 7: (c) Troubleshooting computational notebooks.
  May 8 (X-hour): TBD
  May 9: Peer feedback about (cw) computational notebook.

- **Week 7:** Reading to Improve Our Writing, Writing Like a Mathematical Scientist
  May 12: (c) Centralities, PageRank and SpringRank.

May 14: (c) Community Detection.
May 15 (X-hour): (c) Introduction to Overleaf and LaTeX.
May 16: (cw) Computational notebook revisions due.

- **Week 8:** More Applications of Networks, Constructive Feedback
  May 19: *No class meeting*
  May 21: (c) Highlights about data used in submitted notebooks.
  May 22 (X-hour): (c) More highlights about data used in notebooks.
  May 23: Peer feedback about (w) project report outline and preliminary content.

- **Week 9:** *No class meetings*

- **Week 10:** Final Project Reports, Constructive Feedback
  June 2: (c) Review what we've learned this term. (w) Project report due.
  June 4: Peer feedback on (w) project reports. (Last day of class.)
  (w) Revised project report due **June 11** (in lieu of a final exam; no class meeting).