NETS0000 Introduction to Network Science: Syllabus

Dates: January DD, 20YY– April DD, 20YY
Credit: 4 Credit Hours
Format: Hybrid

- asynchronously online on Canvas.
- in person in 177 Huntington Ave, Room 206 on Tuesdays, hh:mm – hh:mm pm.

Course Description

In this course, you will learn to use tools from network science to analyze and model complex systems encountered in the natural and social sciences. You will gain hands-on experience applying these tools in a small research project involving a network dataset of your choice. Throughout the course, you will experience the field's interdisciplinary nature through in-person and online discussions with your peers as well as course materials from different branches of network science.

Learning Outcomes

After successfully participating in this course, you should be able to:

1. Create network representations of complex systems from empirical data.
2. Analyze networks using different network measures.
3. Formulate hypotheses about a system's function based on its network representation.
4. Assess network-based, mathematical models of complex systems.

Instructor Information

Instructor
Name: Moritz Laber
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Office Hours: by appointment either in person 177 Huntington Ave., Room 1008 or via zoom.

Teaching Assistant
Name: Max Schweiger
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Office Hours: by appointment either in person 177 Huntington Ave., Room 1008 or via zoom.

How We Communicate

We, the instructor and TA, will use **Canvas Announcements** to send messages that concern all students. These are usually important and time-sensitive updates regarding the course. We encourage you to enable automatic email notifications about announcements in your Canvas notification settings. This guide can help you navigate Canvas' notification settings.

If you have questions about assignments or course content, please use the **General Q&A Discussion** on Canvas to post your questions. This allows your peers to benefit from the answers to your questions as well. We try to respond to a question within 24 hours. If you know the answer to one of your peer's questions, feel free to post it as a response to the original post.

For any questions you do not feel comfortable asking in the General Q&A Discussion or to schedule appointments, feel free to reach out via **email**. As we receive many emails and do not want to miss yours, we ask you to include *NETS5116* in the subject of your email and to use your Northeastern email address. You can expect a reply within 24 hours on weekdays and 48 hours on weekends. Please check your Northeastern email address daily on weekdays.

We are offering **Office Hours** by appointment in various formats. As students from different programs are enrolled in this course, finding a single time slot for office hours is challenging and we offer meetings by appointment instead. Feel free to reach out to either me or the TA, Max, to schedule an in-person or online meeting

Diversity Statement

We are committed to establishing a space that allows diverse learners to thrive. Diversity itself comes in many forms: People can differ in their identities as individuals or as members of larger groups. We believe that each of you brings a unique and valuable perspective to this course. We expect that you encounter these perspectives with openness and treat each other respectfully. You can expect the same from us.

I acknowledge that I am not free of biases. These biases influence the course design and the way I teach. I welcome your suggestions to make the course more inclusive and reflect diversity in the course activities, assignments, and readings.

How This Course Works

This course is offered in a hybrid format. This means that part of your learning experience will take place online on the Canvas site of the course, while another part will happen in weekly in-person meetings. The course is organized into weekly *Modules* that address different aspects of network science. Each week you will engage with the course content online, in the form of videos and readings. A weekly online quiz will allow you to test your understanding of the material before coming to the in-person sessions. The weekly in-person sessions will take place in Room 206 at 177 Huntington Ave. These sessions are not traditional lectures, but your opportunity to put to work the things you

read about. This means you will participate in active learning activities, including discussions and collaborative problem-solving with peers from various disciplines. Throughout the semester you will conduct a research project, analyzing a network from a domain you are interested in. The major assignments of the course will guide you through this process from the inception of the idea to the final paper. You will receive feedback from us on quizzes, assignments, and your in-class contributions. We also welcome your feedback and there will be a weekly opportunity to let us know what you like about the class and where you see room for improvement.

I acknowledge that the format of this course differs from many others you may have attended during your studies. I encourage you to be open to the approach that we are taking here and find out whether it works for you. If you want to learn more about the research behind it, these resources of the Center for Advancing Teaching and Learning Through Research (CATLR) are an excellent starting point. If you have any concerns about the course and how it is set up, please get in touch with me or the TA.

Prerequisites

As you will be writing code for assignments and your course project, you need to be able to **program in Python, R, or Julia**. You should be able to implement basic control statements (for-loops and if-statements), use different data structures (lists, arrays, dictionaries) as well as basic input/output operations (reading and writing files). You should also be familiar with the **fundamentals of linear algebra, calculus, and probability/statistics** as these give you the tools to construct different types of mathematical models and understand why we analyze data in certain ways. You should be able to explain terms like "vector", "matrix" and "eigenvalue", as well as "limit", "derivative", and "integration by parts" to another student. You will also deal with objects like "(conditional) probability distributions", "expectation values" and "moments". One thing that the course does explicitly *not* require is prior familiarity with graph theory. If you are unsure whether you have the necessary prerequisites or have other questions, please reach out to me via email including *NETS5116* in the subject.

Course Materials & Readings

As the online part of the course uses Canvas and some materials are provided in digital form, you will need a computer and laptop with internet access. You will also need internet access to work on the coding part of your assignments using Open OnDemand.

You are not required to purchase any books or lecture notes for this class. All required and supplementary readings and media will be made available via Canvas. You can find an overview in **Table 1** in the next section of this syllabus. To explore network science from various perspectives, we do not follow a single textbook. This does, however, not mean that there are no good textbooks on the subject. Both Mark Newman's *Networks – An Introduction* (2010) and *Network Science* (2015) by Láslzó Barabási are excellent books with a good balance between pedagogical exposition and mathematical rigor.

The course's Canvas page also contains an open discussion, called *Additional Materials*. It serves mainly two purposes:

- to ask me, the TA, or your peers for further resources on a particular topic.
- to share papers with your peers and me, that are not (yet) part of the reading list but that you think are particularly exciting.

There is **one rule** for suggesting a paper (either as an answer to a request or as a stand-alone post): You must have read the paper you are suggesting and explain in two (or more) sentences why you think it is relevant, exciting, or worth knowing about. This rule is in place as a guardrail against mindless or impulsive resharing of papers we encounter online or in newsletters. You should not let the rule discourage you from posting a resource about which you have doubts. The discussion is a good place to find out about its quality and usefulness.

Course Outline

Table 1 below gives you an overview of the entire course, including the materials, with which you should familiarize yourself before class, activities, that will take place during class, and due dates for assignments. The readings can undergo minor changes to accommodate your and your peers' interests and suggestions. Such changes will be discussed in class and announced in written form.

Date	Topic	Activities (in class)	Materials (before class)	Assignments
Week 01 Jan. 06 – Jan. 12	Describing Networks	• Introductions • Mini lecture: Welcome • Solving problems with basic definitions from graph theory.	Newman (2018) *Networks Ch. 6* Barabási (2016) *Network Science Ch. 2*	
Week 02 Jan. 13 – Jan. 19	Mathematical Modeling	• Identifying different types of mathematical models. • Assessing modeling assumptions.	Recorded mini-lecture: Mathematical Modeling (Harrison Hartle)	
Week 03 Jan. 20 – Jan. 26	Erdős-Rényi (ER) model as a model of sparse networks.	• Computing network density of real networks. • Implementing the ER model	Recorded mini-lecture: Null Models Newman (2018) *Networks Ch. 12* Dorogovtsev & Mendes (2022) *The Nature of Complex Networks* Ch. 3	**Project Proposal**

			Video: *giant component*	
Week 04 Jan. 27 – Fab. 02	Understanding heavy-tailed distributions	• Comparing exponentially bounded and heavy-tailed distributions. • Mini lecture: Types of Distributions • Log-binning of distributions and functions.	Hanel, Klimek, & Thurner (2018) *Introduction to the Theory of Complex Systems* Ch. 3.3 Barabási & Albert (1999) *Emergence of Scaling in Random Networks* Barabási (2016) *Networks Science Ch. 6* Video: *BA model*	
Week 05 Feb. 03 – Feb. 09	Network geometry as the origin of clustering	• Computing the clustering coefficient in real-world networks • Interpreting network geometry.	Recorded mini-lecture: Translating Between Disciplines Bogñá et al. (2021) *Network Geometry* Van der Hofstadt (2022) *Random Graphs and Complex Networks* Ch. 9.5	
Week 06 Feb. 10 – Feb. 16	The Small-World Phenomenon	• Mini lecture: Experiments & Networks • Comparing and assessing experiments in network science.	Recorded mini-lecture: From Observation to Theory and Back Watts & Strogatz (1998) *Collective Dynamics of Small-World Networks* Travers & Milgram (1969) *An Experimental Study of the Small-World Phenomenon* Dodds, Muhamad, & Watts (2003) *An Experimental Study of Search in Global Social Networks* Backstrom et al. (2012) *Four Degrees of Separation*	**Homework 1:** Basic Network Properties
Week 07 Feb. 17 –	Network Reconstruction	• Mini lecture: Reconstructing Networks • Reconstructing a network from survey data.	Peel, Peixoto, & DeDomenico (2022) *Statistical Inference Links Data and Theory in Network Science*	**Online Discussion 1:** Network Reconstruction

Feb. 23		• Finding suitable statistical models for network data. • Course Feedback.	Newman (2018) *Network Structure from Rich but Noisy Data*	
Week 08 Feb. 24 – Mar 02	Centrality Measures	• Computing centrality measures • Problem-solving with centrality measures.	Recorded mini-lecture: Centrality Measures in Current Research Newman (2018) *Networks* Ch. 7 Hanel, Klimek, Thurner (2018) *Introduction to the Theory of Complex Systems* Ch. 4.8	**Online Discussion 2:** Centrality Measures
Week 09 Mar 10 – Mar 16	Communities	• Mini lecture: Taxonomy of Community Detection Methods • Comparing and critiquing community detection methods.	Fortunato (2022) *20 Years of Network Community Detection* Peixoto (2023) *Descriptive vs. Inferential Community Detection in Networks*	
Week 10 Mar 17 – Mar 23	Assortativity & Homophily	• Comparing different homophily measures in simulations • Mini lecture: Homophily & Inequality • Discussion: Homophily and Inequality	Recorded mini-lecture: What is wrong with Pearson correlation for heavy-tailed distributions? Newman (2018) *Networks* Ch. 7.13 Barabási (2016) *Network Science Ch. 7* Karimi et al. (2018) *Homophily Influences Ranking of Minorities in Social Networks*	**Homework 2:** Advanced Network Properties
Week 11 Mar 24 – Mar 30	Robustness & Percolation	• Mini lecture: Cluster Size Distribution & PGFs • Using probability generating functions (PGFs) to solve problems in probability theory and network science	Newman (2018) *Networks* Ch. 16 Barabási (2016) *Network Science Ch. 8* Allard, Hérbert-Dufresne, & St-Onge (2022) *PGFunk*	
Week 12 Mar 31 –	Working on Projects		Harvard Catalyst *Posters* (video and articles)	**Poster & Poster Self-Assessment**

Apr. 06				
Week 13 Apr. 07 – Apr. 13	Poster Presentation	• Presenting a poster. • Giving and receiving feedback on posters.	Recorded mini-lecture: Poster Session Rules University of Waterloo: *Giving and Receiving Effective Feedback*	**Poster Presentation**
Week 14 Apr. 14 – Apr. 20	Network Science as a Discipline	• Mini lecture: Big Ideas in Network Science • Connecting different ideas in this course.	*NetSci Conference Satellites* *Women in Network Science* *Diversity NetSci*	**Project Report**

Table 1: Overview of course content and weekly readings.

Assignments and Grading

Weekly Assignments

Online Quizzes

There will be weekly online quizzes on Canvas. These quizzes are a way for you to check your understanding of each week's readings and make sure to get most of the activities in the in-person sessions. You will have as many attempts at these quizzes as you wish but need to complete them before each week's in-person session.

Major Assignments

A big part of this course is to conduct a research project in which you gain hands-on experience in using tools from network science on a dataset of your choice. Several major assignments, listed below, will guide you through this process. You can find detailed instructions for each assignment on Canvas.

Project Proposal

The project proposal consists of a 1-page description of the project you are planning to carry out and how it relates to your research interests. It should also include a brief qualitative description of the dataset you are planning to use.

Graded Online Discussions

There will be two graded online discussions: The first one focuses on *Network Reconstruction* and gives you a chance to investigate the origin of your dataset and the assumptions that were made during its creation. The second one gives you a chance to explore how *Centrality Measures* could be used to gain further insight into the system you are studying for your project. For each discussion,

you are required to write an initial post, at least 300 words in length, that addresses the discussion prompts, and to follow up on at least two of your peer's posts.

Homework Assignments

There will be two homework assignments as part of which you will write code to explore the dataset you are working on. For each assignment, you will be provided a template and will work on the Discovery cluster using Open OnDemand to ensure equitable access to computational resources. The first assignment focuses on the most basic network properties that form the foundation of analyzing any network. The second assignment deals with more advanced properties that may or may not be useful in a given context. It will require you to deliberate what properties to focus on and to justify your choice. For both assignments you will receive feedback on your initial submission and be able to resubmit a revised version to gain additional points.

Poster Presentation

An important part of any research project is being able to communicate one's findings to other scholars. In this assignment, you will create a research poster summarizing the findings of your course project and present it to your peers during a poster session. The assignment also requires you to submit a self-assessment of the poster that you created to draw your attention to common pitfalls in poster design.

Project Report

The project report is an 8-page document that synthesizes the insights you have gained while conducting your course project. Its structure mirrors the structure of a research paper that you would submit to a journal, including an introduction, brief literature review, methods section, presentation of results, and discussion.

Weighing

Your total grade will be calculated as the weighted average of your performance in each of the assignments with weights as detailed in **Table 2.**

Assignment	week	Percentage of Grade
Online Quizzes	weekly	20%
Course Project Proposal	3	5%
Homework Assignment 1	6	15%
Online Discussion 1	7	5%
Online Discussion 2	8	5%
Homework Assignment 2	10	15%

Poster Presentation	12/13	15%
Project Report	14	20%
Total		**100%**

Table 2: Weighing scheme that specifies the contribution of individual assignments to the final grade.

Late Submission & Attendance Policy

Active participation in the course and timely submission of assignments are important factors for achieving the learning outcomes of this course. I will not take attendance during in-person sessions. It is your responsibility to hold yourself accountable for coming to class to benefit from opportunities to practice and receive feedback.

As the online quizzes are meant to assess whether you familiarized yourself with the material to an extent that allows you to successfully participate in the in-person sessions, I will not give points for late submissions, i.e. submissions after the start of the in-person session. Similarly, as you will need a poster to participate in the poster session, no points will be given for late submissions to the poster session. For all other assignments, i.e. homework assignments, online discussions, the project proposal, and the project report, I will accept late submissions up to three days after the deadline but 10% of the maximum achievable points will be deducted per 24 hours.

If you know in advance that you cannot submit an assignment in time, please contact me. In case the schedule conflicts with secular or religious holidays or celebrations that are important to you, please reach out to me as well.

Academic Integrity Policy

Northeastern University is committed to the principles of intellectual honesty and integrity: the NU Academic Integrity Policy can be found on the website of the Office of Student Conduct and Conflict Resolution (OSCCR). Plagiarism is a form of cheating that involves presenting the words or work of others as if it were one's own, is a violation of the academic integrity policy. We will work together in this class to make sure the boundaries of shared and independent work are clear for every assignment. ***Deliberate instances of plagiarism will result in a grade of F for the class and will be reported to OSCCR***. Please always consult with me if you have any questions about how to include or reference materials from other sources in any assignment.

Resources

Technology Resources

This course will rely on Canvas. If you are not familiar with using Canvas you may want to read the Canvas Resources for Students or the Canvas Knowledge Base. You can learn more about the Discovery cluster at Northeastern University Research Computing Documentation. We especially recommend reading about Open OnDemand. For general IT questions and problems, you can reach out to Information Technology Services.

Title IX Protections and Resources

Title IX of the Education Amendments of 1972 protects individuals from sex or gender-based discrimination, including discrimination based on gender-identity, in educational programs and activities that receive federal funding. Any NU community member who has experienced such discrimination, sexual assault, relationship violence, stalking, coercion, and/or sexual harassment, is encouraged to seek help. Confidential support and guidance can be found through University Health and Counseling Services, the Northeastern Center for Spirituality, Dialogue, and Service, and the Office of Prevention and Education at Northeastern (OPEN). Note that faculty members are considered "responsible employees" at Northeastern University, meaning they are required to report all allegations of sex or gender-based discrimination to the Title IX Coordinator. For additional information and assistance please see the Office of Institutional Diversity and Inclusion webpage.

Disability Resource Center

The university's Disability Resource Center works with students and faculty to provide students, who qualify under the *Americans With Disabilities Act* with accommodations that allow them to participate fully in the activities at the university. Ordinarily, students receiving such accommodations will deliver teacher notification letters at the beginning of the semester. Students have the right to choose whether to disclose their specific disabilities to instructors but must provide a letter to receive accommodations.

WeCare

WeCare offers supports for students during times of difficulty or challenge. You can find WeCare at 226 Curry Student Center Monday - Friday from 8:30-5:00, call at 617-373-7591, or email wecare@northeastern.edu.

Mental Health Resources

In addition to mental health resources available through Northeastern University Health and Counseling Services Northeastern has added Find@Northeastern, which is a 24/7 mental health consulting line and can be reached at 1-877-223-9477.

Writing Center

The Northeastern University Writing Center offers free and friendly tutoring for any level of

writer, including help with conceptualizing writing projects, the writing process, and using sources effectively. Currently, the Writing Center has virtual appointments only. To make an appointment, or learn more about the Writing Center, visit https://www.northeastern.edu/writingcenter, or email WritingCenter@northeastern.edu. Advance and same-day appointments are available.

International Tutoring Center

The International Tutoring Center (ITC) provides current Northeastern University international students with free, comprehensive English language and academic support. The ITC includes English as a Second Language Tutoring (ESL), Language and Culture Workshops, and Reading Workshops. For more information on available workshops and tutoring opportunities please visit the ITC weblink above.

Snell Library

Snell Library offers a variety of resources for undergraduate research, including subject-specific Research Guides, help with citation and bibliography, and 24/7 chat support. The library also houses the Digital Media Commons, which offers a variety of resources for instructors and students for multimedia projects.

Disclaimer

This syllabus describes the route along which we will explore the subject of network science. However, sometimes unforeseen events may necessitate to deviate from this route. This means that **any announcements online, via email, or in class override the syllabus**. You can expect that any important changes will be communicated in written form.