PHYS5116: Complex Networks and Applications
Fall 2019

Lead Instructors: Prof. Albert-László Barabási and Dr. Emma Towlson
Co-Instructors: Dr. Sebastian Ruf, Dr. Michael Danziger, and Dr. Louis Shekhtman
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Lecture hours: Mondays, Wednesdays and, occasionally, Fridays, 5:30 PM - 7:20PM
Classroom: CCNR. You will need a photo ID or your Husky Card to access the building.
Office hours: By appointment *only*. Please discuss with Dr. Towlson, Dr. Ruf, Dr. Danziger, or Dr. Shekhtman either via email or after class to schedule.

Textbook:
- *Network Science*, Albert-László Barabási (required)
- *Linked – The New Science of Networks*, Albert-László Barabási. Perseus Publ. (recommended)
- *Networks – an Introduction*, Mark Newman, Oxford University Press (recommended)

Other useful tools:
- Lecture slides will be uploaded to the class webpage: https://www.barabasilab.com/course
- Class communications will be done through a dedicated Google Group

Course description and objectives
The course is an interdisciplinary introduction to the emerging science of complex networks and their applications. Topics to be covered include the mathematics of networks (graph theory), data analysis, and applications to biology, sociology, technology, and other fields. Students will learn about the ongoing research in the field, and ultimately apply their knowledge to conduct their own analysis of a real network data set of their choosing as part of the final project.

Course organization
Lectures: Lectures will be given jointly by Prof. Barabási, by Drs. Towlson, Ruf, Danziger, and Shekhtman.

Homework: There will be three (3) homework assignments representing a mix of mathematical work and computational data analysis. Students are expected to turn in their source code for the computational exercises. Students

in the Network Science Ph.D. program will typically be asked to do at least one, more challenging, problem on top of each assignment.

Examinations: Final project presentation — complete analysis of a real network. In place of a midterm exam, there will be an intermediate presentation to check your progress and provide feedback.

Evaluation and grading

We will assign final grades based on four weighted components:
1) Homework: 45% (15% for each of 3)
2) Intermediate project progress presentation (on Mon. Nov. 4th. Guidelines for this evaluation will be given in lecture.): 10%
3) Final project presentation (tentatively, on Dec. 11th and Dec. 13th): 35%
4) Class attendance and participation: 10%

Class participation

We operate on the belief that true mastery of any subject occurs when one is able to explain it to others. Thus, we expect students to contribute to the lectures, answering questions posed during lectures and being engaged during hands-on computational exercises. Students are encouraged to read the appropriate textbook chapters/other assigned material *beforehand*, ready to participate. You should regard the in-class lectures as guided tours through the assigned texts, not as a substitute for them.

The co-instructors will determine a final class participation score based on each student's attendance record and overall engagement in class. Occasional absences are, of course, understandable. If you can't attend a class for any reason, please let either Dr. Towlson, Dr. Ruf, Dr. Danziger, or Dr. Shekhtman know in advance.

Final project

For the final project, students will collect data representing a real network of their choice and analyze it using the network measures and computational tools introduced in class. The goal is to craft a complete "story": what does network science tell us about the system's organization and function?

Datasets: We will provide some suggestions in class. If none of these interest you, you are free to seek out your own data within the guidelines that will be provided in lecture.

Groups: Graduate students in either Network Science or in Physics specialized in Networks will perform the project on their own. All other students are required to work in pairs, *with the two students coming from different programs/academic departments*.

Help: The final project is the largest single component of your grade, and in past years the primary determinant of a successful (vs. unsuccessful) project has been starting early and asking for help often. The project is intended to mirror a real network/data science research project. Real research occurs over the span of months or years, not days or hours, and things almost never work out the first time. There will inevitably be bugs in your code, flaws in your

analysis, and infelicities in your narrative and presentation. So don't wait until the last week to do your project—it will be obvious. Instead, be proactive and avail yourself of office hours in order to obtain feedback and fix problems early.

Computer programming and mathematics

Network science is a fundamentally computational science. Although helpful, strong programming ability is not a requirement to enroll in the course. Nonetheless, the homeworks and your final project will necessarily involve significant computational work. You will be expected to build the required skills as the course goes on through a series of hands-on lectures that will introduce some of the cutting edge software/libraries used for network and data science, supplemented by independent study. *Students are free to work in any computer language/network software they feel most comfortable*, but the hands-on lectures will be presented in Python using the NetworkX library (https://networkx.github.io/).

Likewise, mathematics is unavoidable in doing justice to network science. Some basic knowledge of probability (continuous and discrete), statistics, linear algebra, combinatorics, and calculus is certainly helpful. Yet in order to make this course open to an interdisciplinary audience of students these topics are *not* formal prerequisites to take the course. That said: if math is not your strongest suit, please know that by registering for PHYS5116 you are committing to going the extra mile to understand math-heavy concepts/derivations and complete the same homework assignments as peers who may have stronger math backgrounds. And remember, we are here to help.

Academic misconduct

Appropriate disciplinary action, up to and including failing the student, will be taken in the event of cheating, plagiarism, dishonesty, or other academic misconduct. The Northeastern University Policy on Academic Integrity can be found at http://www.northeastern.edu/osccr/academicintegrity/.

In this course we *encourage* students to work together (and indeed, this is *required* for the final project for non-Network Science PhD students). So what constitutes academic misconduct.

It is **not** considered academic misconduct if you:

- Work together on homework assignments, as long as you each work out and submit your own final answers. Here "final answers" includes such things as derivations, plots (where appropriate), written explanations, and source code (for computational exercises), etc.
- Get help from other professors, physics workshops, tutors, etc. on the homework assignments *provided* it is clear to us that you are the author of your own answers, and you understand what you've written down.

It **is** considered academic misconduct if you:

- Submit work substantially similar to that done by others as your own.
- Don't contribute equally to the final project (for those working in pairs)

The above lists are intended as examples and are not exhaustive. If in doubt, please ask.

Statement of non-discrimination

Northeastern University is committed to fair treatment of students. As the instructors of the course, we strive to maintain a positive learning environment based upon communication and mutual respect. Any suggestions about how to facilitate such a positive and open environment in this class will be appreciated and given serious consideration. Neither the University nor the instructors discriminate on the basis of race, sex, age, disability, religion, sexual orientation, color, or national origin. If you are a person with a disability and require any type of accommodation in order to participate in this class, please advise us and if necessary make arrangements with the Disability Resource Center (617) 373-2675.

Changes to syllabus and student responsibilities

The instructors reserve the right to modify this syllabus as deemed necessary any time during the semester. Emendations to the syllabus will be discussed with students during a class period. Students are responsible for information given in class; there may be also details about PHYS 5116 not covered in this syllabus. Do not assume something simply because it is not specified in the syllabus. If you are unsure about anything related to the rules guiding this course, consult with one of the instructors.