CptS 591: Elements of Network Science

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About me

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• Joined WSU: Fall 2014
• Research interests: data science, network science, high performance computing, bioinformatics, pervasive computing
• Lab: Scalable Algorithms for Data Science Laboratory ([https://scads.eecs.wsu.edu](https://scads.eecs.wsu.edu))
• NSF CAREER project: Fast and Scalable Combinatorial Algorithms for Data Analytics ([www.eecs.wsu.edu/~assefaw/fascada](http://www.eecs.wsu.edu/~assefaw/fascada))

Teaching at WSU:

- CptS 475/575: Data Science (Fall 2015, 2016, 2017, 2018)
- CptS/STAT 424: Data Analytics Capstone (Spring 2019)

CptS 591, Spring 2019

- Lectures: TuTh 12:00—13:15, Sloan 7
- Office Hours: Thursdays 3:00—4:30 pm
About Network Science Class of 2019
(What I know so far)

• Total enrolled: 34

• Breakdown
  • Computer Science: (23 MS, 7 PhD)
  • Sociology: (2 PhD)
  • Business Administration: (1 PhD)
  • Interdisciplinary: (1 PhD)
Big Picture
Who’s talking networks?
Complex *connectedness* is everywhere!

- The *social* interconnections we have
- The *information* we consume
- The *technological* systems we use
- The *economic* systems we live in
- The *political* systems we operate in
- The *organizations* we work at
- The *institutions* we belong to
- The *ecological* systems around us
- *Ourselves* (cell, brain)
- ...
Complex connectedness is everywhere (in pic)

(Pictures here and elsewhere, unless stated otherwise, are courtesy of Barabasi et al, Network Science Course, NEU, http://barabasilab.neu.edu/courses/phys5116/.)
An underlying feature:

Behind each such system there is an intricate wiring diagram, *network*, that encodes the interactions between the components.

And to understand the systems, we must understand the networks behind!
Networks: Social

The “Social Graph” behind Facebook
Networks: structure of an organization

www.orgnet.com

: departments
: consultants
: external experts
Networks: Brain

Human Brain has between 10-100 billion neurons.

http://barabasilab.neu.edu/courses/phys5116/
Networks: Financial

http://barabasilab.neu.edu/courses/phys5116/
Reasoning about networks

- Study aspects
  - Structure and Evolution
  - Behavior and Dynamics

- Full understanding requires synthesis of ideas from various disciplines, including
  - Computer science
  - Applied mathematics
  - Natural sciences
  - Statistics
  - Economics
  - Sociology
Networks, why now?

http://barabasilab.neu.edu/courses/phys5116/
Catalysts for emergence of network science

• Availability of network “maps”
  • The Internet, cheap digital storage, and computational technologies made it possible to collect, assemble, share, and analyze data pertaining to real networks

• Recurring similarity
  • Networks from science, nature, and technology are more similar than one would expect

• Confluence of ideas and tools
  • Newer ways of reasoning about interconnectedness are being born by integration of ideas and tools from various disciplines
Characteristics of Network Science

- **Interdisciplinary**
  - Common language for interaction
  - Cross-fertilization of ideas and tools

- **Empirical, data driven**
  - Focuses on data and utility

- **Quantitative and Mathematical**
  - Graph theory (to deal with graphs)
  - Statistical physics (to deal with randomness and universal organizing principles)
  - Engineering + control + information theory + statistics + data mining (to deal with extracting information from incomplete and noisy data)

- **Computational**
  - Size of networks and nature of data result in formidable computational challenges
  - Algorithms, database management, data mining
Impact of network science

- Economic
  - Web search
  - Social networking

- Health
  - Drug design
  - Metabolic engineering

- Security
  - Fighting terrorism (net-war)

- Epidemics
  - Epidemic prediction (biological, electronic viruses)
  - Halting spread

- Brain Science
  - In 2010 NIH initiated the Connectome project, aimed at developing a neuron-level map of mammalian brains

- Management
  - Uncovering the internal structure of an organization
Economic Impact

Google
Market Cap(2010 Jan 1):
$189 billion

Cisco Systems
Networking gear Market cap (Jan 1, 2919):
$112 billion

Facebook
Market cap:
$50 billion

www.bizjournals.com/austin/news/2010/11/15/facebooks... - Cached
Military impact

http://www.slate.com/id/2245232
EPIDEMIC FORECAST
Predicting the H1N1 pandemic

Real

Projected

http://barabasilab.neu.edu/courses/phys5116/
If you were to understand the spread of diseases, can you do it without networks?

If you were to understand the WWW structure, searchability, etc, hopeless without invoking the Web’s topology.

If you want to understand human diseases, it is hopeless without considering the wiring diagram of the cell.

http://barabasilab.neu.edu/courses/phys5116/
This course in focus
Goals

Students will be introduced to select

- mathematical and computational methods used to analyze networks
- models used to understand and predict behavior of networked systems
- theories used to reason about network dynamics

And students will apply what they learn by completing a semester project and three assignments
(Tentative) list of topics

- **Network structure, modeling and algorithms**
  - Graph theory refresher
  - Basic network properties
  - Random graphs
  - Spectral analysis
  - Centrality
  - PageRank, Hubs and Authorities
  - Graph similarity
  - Community detection
  - Signed networks
  - Graph embedding and representation learning

- **Network dynamics**
  - Cascading behaviors
  - Information diffusion
  - Epidemic models
  - Influence maximization
  - Small-world phenomenon

- **Temporal networks**
  - Models
  - Algorithms
  - Applications

List may be updated after consideration of survey response
Books

• Primary reference:
  • Easley and Kleinberg, Networks, Crowds and Markets, Cambridge Univ. Press, 2010

• Other/related references
  • M.E. J. Newman, Networks: An Introduction, Oxford University Press, 2010
  • U. Brandes and T. Erlebach (Eds.), Network Analysis: Methodological Foundations, Springer 2005
  • A. Barabasi, Network Science, e-book
Software

We will use igraph as the primary software tool for network analysis:

• *igraph*: [http://igraph.org](http://igraph.org)

Other related tools

• *networKit*: [https://networkit.iti.kit.edu/](https://networkit.iti.kit.edu/)
• *networkX*: [http://networkx.github.io](http://networkx.github.io)
• *gephi*: [https://gephi.org](https://gephi.org)
Expectation

Basic knowledge of:
• Algorithms
• (Graph theory)
• Linear algebra
• Probability and Statistics

Reasonable programming experience.
    Python, R, C/C++

Please fill and return the background survey.  
Your input will to a degree define the course!
Course work

• Three assignments (30%)
  • Individual

• One semester project (40%)
  • Collaborative (a team of two or three)

• In-class quizzes (10%)

• Mid-term exam (15%)

• Class participation (5%)
  • Discussions in class, occasional scribing

• Project breakdown: 40%
  • Reaction paper: 5%
  • Project proposal: 5%
  • Presentation: 5%
  • Final report: 25%
Project

• Could take one of several forms:
  • *Experimental analysis* of an interesting dataset using existing methods and software
  • *(Experimental) comparison* of existing methods and software tools in the context of a specific application
  • *Theoretical analysis* of a model/an algorithm in a specific application
  • *Implementation* of a new method
  • *In-depth survey* of a research topic
• Students required to work in teams of two or three
  (solo projects allowed if there are valid reasons)
Lecture material and resources

- Public course website:

- Slides, reading materials, announcements, and other resources will be posted via OSBLE and the course website

- OSBLE will be used to handle assignment and project submissions

- The Easley & Kleinberg reference book is available on-line

- Check the course website and your OSBLE account regularly for info and updates
Related courses elsewhere

• Cornell (Jon Kleinberg and Eva Tardos, Networks)
  • [https://courses.cit.cornell.edu/cs2850_2016fa/](https://courses.cit.cornell.edu/cs2850_2016fa/)

• Stanford (Jure Leskovek, Social and Information Network Analysis)
  • [http://web.stanford.edu/class/cs224w/](http://web.stanford.edu/class/cs224w/)

• Northeastern (Barabasi lab, Complex Networks, Fall 2018)
  • [https://www.barabasilab.com/course](https://www.barabasilab.com/course)

• Purdue (David Gleich, Network and Matrix Computations, Fall 2011)
  • [https://www.cs.purdue.edu/homes/dgleich/nmcomp/](https://www.cs.purdue.edu/homes/dgleich/nmcomp/)

• Yale (Dan Spielman, Spectral Graph Theory, Fall 2015)
A few words on policies

• Class room conduct
  • Silence personal electronics
  • Arrive on time and remain throughout the class

• Correspondence
  • All class related correspondence should be made via OSBLE

• Attendance
  • Class participation is encouraged and required (carries 5% weight towards final grade)

• Late work or missing work
  • OSBLE time stamps submissions
  • Submissions should happen by due dates and times
  • Late submissions up to 48 hours accepted with 10% grade penalty per 24 hours late
  • Missing work or work submitted more than 48 hours late will be counted as zero

• Academic Integrity
  • Strictly enforced

• Read syllabus for safety plans and other statements
Thanks!

- Welcome, once again
- It is going to be a fun semester
- Put your best effort
- You will be rewarded