CptS 591: Elements of Network Science
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About me

• Name: Assefaw Gebremedhin
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• Webpage: www.eecs.wsu.edu/~assefaw
• Research interests: data science & AI, network science, high performance computing, and applications in bioinformatics, energy systems, and cybersecurity
• Lab: Scalable Algorithms for Data Science Laboratory (https://scads.eecs.wsu.edu)
• NSF CAREER project: Fast and Scalable Combinatorial Algorithms for Data Analytics www.eecs.wsu.edu/~assefaw/fascada
• Teaching at WSU:
  • CptS 475/575: Data Science (Fall 2015--2020)
  • CptS 591: Elements of Network Science (Spring 2015--2020)
  • CptS 317: Automata and Formal Languages (Spring 2020, Spring 2021)
  • CptS/STAT 424: Data Analytics Capstone (Spring 2019)

• CptS 591, Spring 2021
  • Lectures: TuTh 9:10—10:25am (via Zoom)
  • Office Hour: Tuesdays 12:00--1pm (via Zoom)
What I know about the class so far

- 29 enrolled (23 MS students, 6 PhD students)
- Disciplines:
  - Computer Science (22)
  - Electrical Engineering (3)
  - Anthropology (1)
  - Economics (2)
  - Veterinary Science (1)
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

- Red: departments
- Blue: consultants
- Green: external experts
Human Brain has between 10-100 billion neurons.
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 vs. Projected

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 a set of 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 embeddings and representation learning

- Network dynamics
  - Cascading behaviors
  - Information diffusion
  - Epidemic models
  - Influence maximization

- Temporal networks
  - Models
  - Algorithms
  - Applications

List may be updated later
Books

• Frequent 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

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

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

Reasonable programming experience:
Python, R, C/C++, Java
Course work

- Three assignments + a few exercises (30%)
  - Individual
- One semester project (50%)
  - Collaborative (a team of two or three)
- Mid-term exam (18%)
- Class participation (2%)
  - Discussions in class, in-class exercise

- Project breakdown: 50%
  - Reaction paper: 7%
  - Project proposal: 7%
  - Presentation: 8%
  - Final report: 28%
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

• Course website: everything will be on Canvas
  • Slides, reading materials, announcements, and other resources

• Canvas will also be used to handle assignment and project submissions

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

• Check the Canvas page of the course regularly for info and updates
Related courses elsewhere

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

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

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

• Yale (Dan Speilman, Spectral Graph Theory, Fall 2015)
  • http://www.cs.yale.edu/homes/spielman/561/
A few words on policies

• Classroom conduct
  • Mute when not speaking
  • Arrive on time and remain throughout the class

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

• Class participation
  • Required

• Late work or missing work
  • 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 COVID-19 policy and other statements
Thanks!

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