Course Introduction and Overview

Networked Life
Networked and Social Systems Engineering (NETS) 112
Fall 2014
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A Little Experiment
An Artificial Social Network

• Consider yourself “connected” to everyone in this room who:
  - Was born within a few hundred miles of the city or town you were born in
  - Or shares one of your favorite hobbies/interests/activities
  - Network is the aggregate of all these pairwise connections

• Some observations
  - Network is artificial, yet not unrelated to reality --- you really might meet people due to proximity or shared interests
  - Network definition has “knobs” or “parameters” we can fiddle with
    • Radius around your birthplace, strength of interest
    • But might expect certain qualitative properties to remain invariant (NYC density)

• Seems hard to guess at global structure
  - Might be quite complicated
  - None of us has a bird’s eye view

• Let’s experiment with navigation or search in this network
  - Communal goal: route a “message” from one part of the network to another
  - Try to do it in as few “hops” as possible
  - The Catch: everyone has only local information about the network

• Existence of short paths (structure) vs. finding them (algorithm)
• What happens when we go from 100 to 100 million to 7 billion?
Networks
(Social and Otherwise)
Internet, Router Level

- “Points” are physical machines
- “Links” are physical wires
- Interaction is electronic
- A purely technological network?
• Points are *people*
• Links are *social*
• Interactions: relationships, professional, virtual...
• How and why does *structure* form?
• Points are machines... but are associated with people
• Links are physical... but may depend on human preferences
• Interaction: content exchange
• Food for thought: free riding

Gnutella Peers
• Points are neurons
• Links are axons
• Interaction is electrical, but...
• New field: “Connectomics”
• Food for thought:
  - Do neurons cooperate or compete?
The Premise of Networked Life

• It makes sense to study these diverse networks together.

• Commonalities:
  - Formation (distributed, bottom-up, “organic”,…)
  - Structure (individuals, groups, overall connectivity, robustness…)
  - Decentralization (control, administration, protection,…)
  - Strategic Behavior (economic, competition, free riding,…)

• An Emerging Science:
  - Examining apparent similarities (and differences) between many social, economic, biological and technological networked systems & organizations
  - Importance of network effects in such systems
    • How things are connected matters greatly
    • Details of interaction matter greatly
    • The metaphor of contagion in networks
    • Dynamics of economic and strategic interaction
  - Quantitative and qualitative; experimental and theoretical
  - Enabled by the revolution of instrumentation and measurement
Who’s Doing All This?

• **Computer Scientists**
  - Understand and design complex, distributed networks
  - View “competitive” decentralized systems as economies

• **Social Scientists, Behavioral Psychologists, Economists**
  - Understand human behavior in “simple” settings
  - Revised views of economic rationality in humans
  - Theories and measurement of social networks

• **Biologists**
  - Neural networks, gene regulatory networks,…

• **Physicists and Mathematicians**
  - Interest and methods in complex systems
  - Theories of macroscopic behavior (phase transitions)

• **Communities are interacting and collaborating**
Course Mission

• A *network-centric* examination of a wide range of social, technological, biological, financial and political systems

• Examined via the tools and metaphors of:
  - computer science
  - economics and finance
  - psychology and sociology
  - biology
  - mathematics and physics

• Emphasize the common themes

• Develop a new way of examining the world
A Communal Experiment

- Few similar undergraduate courses
  - (e.g. Cornell)
- No formal technical prerequisites
  - greatly aided by recent books
- class demographics:
  - majors: cog sci, communications, linguistics, history, econ, finance, psych,...
  - freshmen through graduate students
- Extensive web visualizations and demos
- Participatory in-class and out-of-class social experiments
- Course was initial inspiration and basis for the new Networked and Social Systems Engineering (NETS) program
What is a Network?

- Networks as a collection of pairwise relationships
- Measures: degree, diameter, clustering, centrality, expansion...
- Examples of (un)familiar and important types of networks
  - social networks
  - content networks
  - technological networks
  - biological networks
  - economic networks
- What makes a network interesting?
- The distinction between structure and dynamics
Contagion and Tipping in Networks

• The dynamics of transmission
• Viral spread and epidemic as metaphor
• Amplification of the incremental
• Connectors, hubs, and small worlds
• Travers and Milgram’s famous experiment
• *Loosely* based on Gladwell’s “The Tipping Point”
Network Structure

• “Universal” structural properties of networks
  - small diameter
  - clustering
  - mixtures of local and long-distance connectivity
  - heavy-tailed distributions

• Models of network formation
  - random graph models
  - preferential attachment
  - small-world models
  - affiliation networks
  - all will be stochastic or randomized... for now

• Loosely based on Watts’ “Six Degrees”
The Web as Network

• Empirical structure of the web
  - connected components and directionality
  - diameter
  - robustness measures
• Web and blog communities
• Web search:
  - hubs and authorities
  - the PageRank algorithm and organic search
  - gaming Google and the SEO industry
  - later: sponsored search
• Web trust and network structure
Towards Rational Dynamics

- Moving beyond the dynamics of contagion
- Dynamics of self-interest and optimization
- Introduction to equilibrium concepts
- Emergence of the global from the local
- The wisdom/madness of crowds:
  - thresholds and cascades
  - mathematical models of tipping
  - the market for lemons
  - private preferences and global segregation
- Loosely based on Schelling’s “Micromotives and Macrobehavior”
Game Theory and Networks

- The mathematical language of strategic and economic behavior
- Notions of equilibrium
  - Nash, correlated, cooperative, market, bargaining
- Multi-player games and markets
- Evolutionary game theory
  - mimicking vs. optimizing
- Games and markets on networks
- How does network structure influence strategic behavior?
- Behavioral game theory and human subject studies
  - classic example: the Ultimatum game
Behavioral Experiments in Social Networks

- Analyses of recent years’ experiments...
- ... and hopefully some new ones of your own.
Strategic Network Formation

• Network Science: stochastic models of formation
• But networks form for a reason...
• Examine game-theoretic formation:
  - players must purchase the edges...
  - ...but accrue “participation benefits”
Sponsored Web Search

- Web as Network: PageRank and “organic” search
- **Sponsored search:** formal markets in search phrases
- Mechanism design and auctions
- Competitive landscape (GOOG vs. MSFT vs. YHOO vs...)
- Equilibrium studies
- The economics of sponsored search
- SEO vs. SEM
Internet Economics

- Internet basics
- Selfish routing and The Price of Anarchy
- Peer-to-peer as competitive economy
- Paris Metro Pricing for QoS
- Economic views of network security and spam
Course Mechanics

• Will make heavy use of course web page:
  - www.cis.upenn.edu/~mkearns/teaching/NetworkedLife
  - You will need good Internet access!

• No technical prerequisites!!!

• Lectures:
  - slides provided; emphasis on concepts
  - frequent demos, visualizations, and in-class experiments
  - please be on time to lectures! (10:30)

• No recitations

• Readings: mixture of general audience writings and articles from the scientific literature

• Three required texts:
  - “The Tipping Point”, Gladwell
  - “Six Degrees”, Watts
  - “Micromotives and Macrobehavior”, Schelling

• Assignments (~1/3 of grade)
  - computer/web exercises, short essays, quantitative problems
  - collaboration is not permitted

• Midterm (~1/3 of grade)

• Final exam (~1/3 of grade)

• Possible we’ll throw in a project/paper assignment
First Assignment

• Due *next lecture* (Thursday 9/4)
  - Simple background questionnaire
  - Last-names exercise