Semester projects

Principles of Complex Systems
CSYS/MATH 300, Spring, 2013

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Outline

Semester projects

Requirements:

1. 3 minute introduction to project (5th week).
2. 5-10 minute final presentation.
3. Report: ≥ 5 pages (single space), journal-style

Goals:

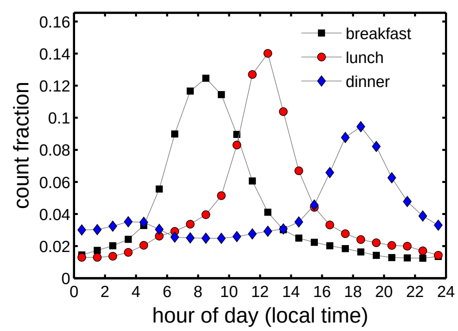
- Understand, critique, and communicate published work.
- Seed research papers or help papers along.

Narrative hierarchy

Presenting at many scales:

- 1 to 3 word encapsulation, a soundbite,
- a sentence/title,
- a few sentences,
- a paragraph,
- a short paper,
- a long paper,
- ...

Twitter—living in the now:



- Research opportunity: be involved in our socio-info-algorithmo-econo-geo-technico-physical systems research group studying Twitter and other wordful large data sets.

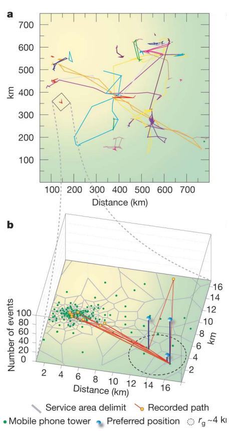
topics:

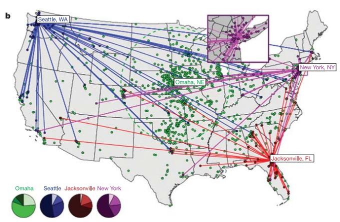
- Develop and elaborate an online experiment to study some aspect of social phenomena
- e.g., collective search, cooperation, cheating, influence, creation, decision-making, etc.
- Part of the PLAY project.

topics:

Rummage round in the papers (⊞) we've covered in our weekly Complex Systems Reading Group at UVM.

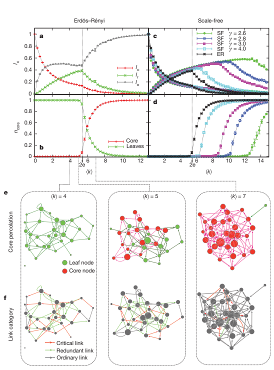
topics:





- Study movement and interactions of people.
- Brockmann *et al.*[6] "Where's George" study.
- Barabasi's group: tracking movement via cell phones[21].

topics:



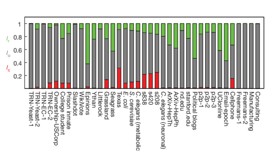


Figure 4 | Link categories for robust control. The fractions of critical (red, l_c), redundant (green, l_r) and ordinary (grey, l_o) links for the real networks named in Table 1. To make controllability robust to link failures, it is sufficient to double only the critical links, formally making each of these links redundant and therefore ensuring that there are no critical links in the system.

"Controllability of complex networks"[30] Liu et al., Nature 2011.

Sociotechnical phenomena—Foldit:

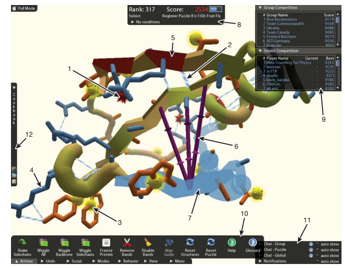


Figure 1 | Foldit screenshot illustrating tools and visualizations. The visualizations include a clash representing atoms that are too close (arrow 1); a hydrogen bond (arrow 2); a hydrophobic side chain with a yellow blob because it is exposed (arrow 3); a hydrophilic side chain (arrow 4); and a segment of the backbone that is red due to high residue energy (arrow 5). The players can make modifications including 'rubber bands' (arrow 6), which add constraints to guide automated tools, and freezing (arrow 7), which prevents degrees of freedom from changing. The user interface includes information about the player's current status, including score (arrow 8); a leader board (arrow 9), which shows the scores of other players and groups; toolbars for accessing tools and options (arrow 10); chat for interacting with other players (arrow 11); and a 'cookbook' for making new automated tools or 'recipes' (arrow 12).

- "Predicting protein structures with a multiplayer online game." Cooper et al., Nature, 2010.[14]
- Also: zooniverse (⊞), ESP game (⊞), captchas (⊞).

topics:

Explore "Catastrophic cascade of failures in interdependent networks"[7]. Buldyrev et al., Nature 2010.

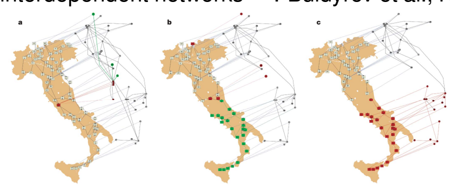


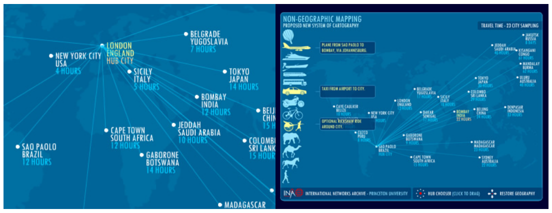
Figure 1 | Modelling a blackout in Italy. Illustration of an iterative process of a cascade of failures using real-world data from a power network (located on the map of Italy) and an Internet network (shifted above the map) that were implicated in an electrical blackout that occurred in Italy in September 2003[20]. The networks are drawn using the real geographical locations and every Internet server is connected to the geographically nearest power station. **a**, One power station is removed (red node on map) from the power network and as a result the Internet nodes depending on it are removed from the Internet network (red nodes above the map). The nodes that will be disconnected from the giant cluster (a cluster that spans the entire network) at the next step are marked in green. **b**, Additional nodes that were disconnected from the Internet communication network giant component are removed (red nodes above map). As a result the power stations depending on them are removed from the power network (red nodes on map). Again, the nodes that will be disconnected from the giant cluster at the next step are marked in green. **c**, Additional nodes that were disconnected from the giant component of the power network are removed (red nodes on map) as well as the nodes in the Internet network that depend on them (red nodes above map).

Voting

Score-based voting versus rank-based voting:

- Balinski and Laraki[2]
  "A theory of measuring, electing, and ranking"
  Proc. Natl. Acad. Sci., pp. 8720–8725 (2007)

The madness of modern geography:



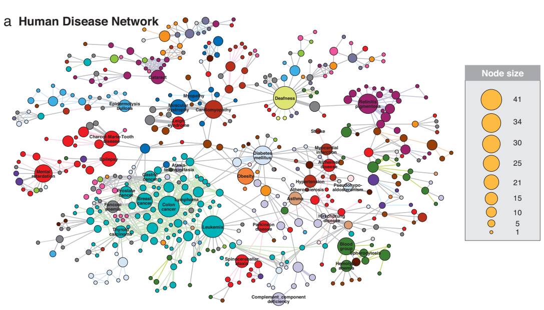
- Explore distances between points on the Earth as travel times.
- See Jonathan Harris's work here (⊞) and here (⊞).

topics:

- Explore general theories on system robustness.
- Are there universal signatures that presage system failure?
- See "Early-warning signals for critical transitions" Scheffer et al., Nature 2009. [35]
- "Although predicting such critical points before they are reached is extremely difficult, work in different scientific fields is now suggesting the existence of generic early-warning signals that may indicate for a wide class of systems if a critical threshold is approaching."
- Later in class: Doyle et al., robust-yet-fragile systems

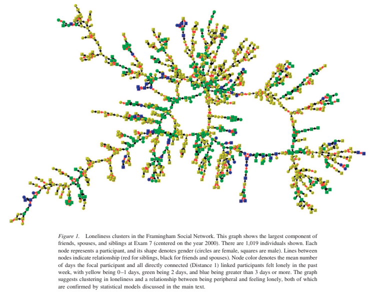
topics:

- Study the human disease and disease gene networks (Goh *et al.*, 2007):



topics:

Explore and critique Fowler and Christakis et al. work on social contagion of:



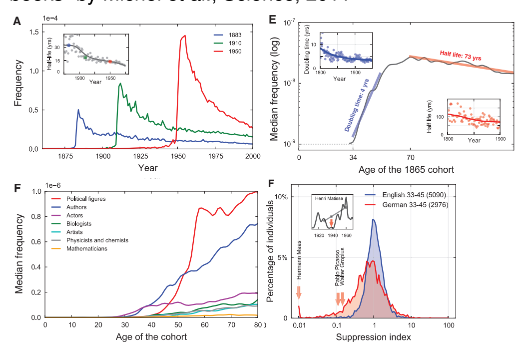
- Obesity [10]
- Smoking cessation [11]
- Happiness [19]
- Loneliness [8]

One of many questions:

How does the (very) sparse sampling of a real social network affect their findings?

Culturomics:

"Quantitative analysis of culture using millions of digitized books" by Michel et al., Science, 2011 [31]



http://www.culturomics.org/ (⊞)
Google Books ngram viewer (⊞)

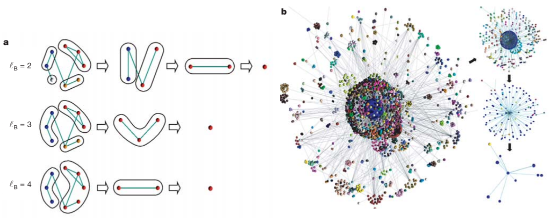
topics:

The problem of missing data in networks:

- Clauset et al. (2008)
  "Hierarchical structure and the prediction of missing links in networks" [12]
- Kossinets (2006)
  "Effects of missing data in social networks" [28]

topics:

- Explore "self-similarity of complex networks"[36, 37] First work by Song *et al.*, Nature, 2005.
- See accompanying comment by Strogatz[38]
- See also "Coarse-graining and self-dissimilarity of complex networks" by Itzkovitz et al.[?]



topics:

Related papers:

- "Origins of fractality in the growth of complex networks"
  Song et al. (2006a)[37]
- "Skeleton and Fractal Scaling in Complex Networks"
  Go et al. (2006a)[20]
- "Complex Networks Renormalization: Flows and Fixed Points"
  Radicchi et al. (2008a)[34]

topics:

- Explore patterns, designed and undesigned, of cities and suburbs.

topics:

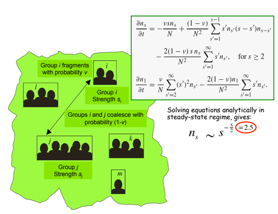
"Looking at Gielen's work, it's tempting to propose a new branch of the human sciences: geometric sociology, a study of nothing but the shapes our inhabited spaces make. Its research agenda would ask why these forms, angles and geometries emerge so consistently, from prehistoric settlements to the fringes of exurbia. Are sites like these an aesthetic pursuit, a mathematical accident, a calculated bending of property lines based on glitches in the local planning code or an emergent combination of all these factors? Or are they the expression of something buried deep in human culture and the unconscious, something only visible from high above?"

http://opinionator.blogs.nytimes/..../the-geometry-of-sprawl/ (⊞)

topics:

- Study collective creativity arising out of social interactions
- Productivity, wealth, creativity, disease, etc. appear to increase superlinearly with population
- Start with Bettencourt et al.'s "Growth, innovation, scaling, and the pace of life in cities"[4]

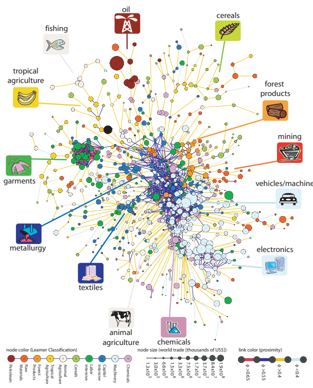
topics:



- Physics/Society—Wars: Study work that started with Lewis Richardson's "Variation of the frequency of fatal quarrels with magnitude" in 1949.
- Specifically explore Clauset et al. and Johnson et al.'s work[13, 25, 5] on terrorist attacks and civil wars
- Richardson bonus: Britain's coastline, turbulence, weather prediction, ...

topics:

- Study Hidalgo et al.'s "The Product Space Conditions the Development of Nations" [23]
- How do products depend on each other, and how does this network evolve?
- How do countries depend on each other for water, energy, people (immigration), investments?



topics:

- Explore Dunbar's number (⊞)
- See here (⊞) and here (⊞) for some food for thought regarding large-scale online games and Dunbar's number. [http://www.lifewithalacrity.com (⊞)]
- Recent work: "Network scaling reveals consistent fractal pattern in hierarchical mammalian societies" Hill et al. (2008) [24].

Study networks and creativity:

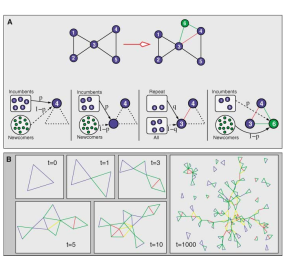


Fig. 2. Modeling the emergence of collaboration networks in creative enterprises. (**A**) Creation of a team with $m = 3$ agents. Consider, at time zero, a collaboration network comprising five agents, all incumbents (blue circles). Along with the incumbents, there is a large pool of newcomers (green circles) available to participate in new teams. Each agent in a team has a probability p of being drawn from the pool of incumbents and a probability $1 - p$ of being drawn from the pool of newcomers. For the second and subsequent agents selected from the incumbents' pool: (i) with probability q, the new agent is randomly selected from among the set of collaborators of a randomly selected incumbent already in the team; (ii) otherwise, he or she is selected at random among all incumbents in the network. For concreteness, let us assume that incumbent 4 is selected as the first agent in the new team (leftmost box). Let us also assume that the second agent is an incumbent, too (center-left box). In this example, the second agent is a past collaborator of agent 4, specifically agent 3 (center-right box). Lastly, the third agent is selected from the pool of newcomers; this agent becomes incumbent 6 (rightmost box). In these boxes and in the following panels and figures, blue lines indicate newcomer-newcomer collaborations, green lines indicate newcomer-incumbent collaborations, yellow lines indicate new incumbent-incumbent collaborations, and red lines indicate repeat collaborations. (**B**) Time evolution of the network of collaborations according to the model for $p = 0.5$, $q = 0.5$, and $m = 3$.

- Guimerà et al., Science 2005: [22] "Team Assembly Mechanisms Determine Collaboration Network Structure and Team Performance"
- Broadway musical industry
- Scientific collaboration in Social Psychology, Economics, Ecology, and Astronomy.

topics:

- Study scientific collaboration networks.
- Mounds of data + good models.
- See seminal work by De Solla Price [33]. plus modern work by Redner, Newman, *et al.*
- We will study some of this in class...

topics:

- Study Kearns et al.'s experimental studies of people solving classical graph theory problems [27]
- "An Experimental Study of the Coloring Problem on Human Subject Networks"
- (Possibly) Run some of these experiments for our class.

topics:

- Study collective tagging (or folksonomy)
- e.g., del.icio.us, flickr
- See work by Bernardo Huberman et al. at HP labs.

topics:

- Study games (as in game theory) on networks.
- For cooperation: Review Martin Nowak's piece in Science, "Five rules for the evolution of cooperation."[32] and related works.
- Much work to explore: voter models, contagion-type models, etc.

topics:

- Semantic networks: explore word-word connection networks generated by linking semantically related words.
- Also: Networks based on morphological or phonetic similarity.
- More general: Explore language evolution
- One paper to start with: "The small world of human language" by Ferrer i Cancho and Solé[18]
- Study spreading of neologisms.
- Examine new words relative to existing words—is there a pattern? Phonetic and morphological similarities.
- Crazy: Can new words be predicted?
- Use Google Books n-grams as a data source.

topics:

- Explore proposed measures of system complexity.
- Study Stuart Kauffman's *nk* boolean networks which model regulatory gene networks[26]

topics:

- Critically explore Bejan's Constructal Theory.
- See Bejan's book "Shape and Structure, from Engineering to Nature."[3]
- Bejan asks why we see branching network flow structures so often in Nature—trees, rivers, etc.
- Read and critique "Historical Dynamics: Why States Rise and Fall" by Peter Turchin.[39]
- Can history Clyodynamics (⊞), Psychohistory (⊞), ...
- "Big History" (⊞)
- Arbesman: "The life-spans of Empires"[1]
- Also see "Secular Cycles" (⊞).

topics:

- Explore work by Doyle, Alderson, et al. as well as Pastor-Satorras et al. on the structure of the Internet(s).

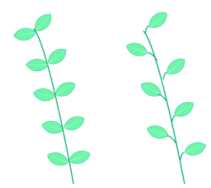
topics:

- Review: Study Castronova's and others' work on massive multiplayer online games. How do social networks form in these games?[9]
- See work by Johnson et al. on gang formation in the real world and in World of Warcraft (really!).

topics:

- Study phyllotaxis (⊞), how plants grow new buds and branches.
- Some delightful mathematics appears involving the Fibonacci series.
- Excellent work to start with: “Phyllotaxis as a Dynamical Self Organizing Process: Parts I, II, and III” by Douady and Couder [15, 16, 17]

http://andbug.blogspot.com/ (⊞)



Wikipedia (⊞)

topics:

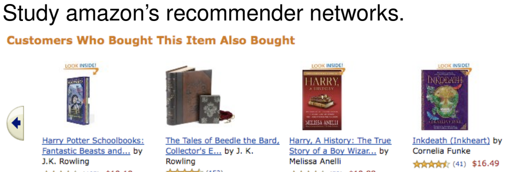
Social networks:

- Study social networks as revealed by email patterns, Facebook connections, tweets, etc.
- “Empirical analysis of evolving social networks” Kossinets and Watts, Science, Vol 311, 88-90, 2006. [29]
- “Inferring friendship network structure by using mobile phone data” Eagle, et al., PNAS, 2009.
- “Community Structure in Online Collegiate Social Networks”
  Traud et al., 2008.
  http://arxiv.org/abs/0809.0690 (⊞)

topics:

Vague/Large:

- Study amazon’s recommender networks.



  See work by Sornette *et al.*.
- Vague/Large:
  Study Netflix’s open data (movies and people form a bipartite graph).

topics:

Vague/Large:

- Study how the Wikipedia’s content is interconnected.

topics:

More Vague/Large:

- How do countries depend on each other for water, energy, people (immigration), investments?
- How is the media connected? Who copies whom?
- (Problem: Need to be able to measure interactions.)
- Investigate memetics, the ‘science’ of memes.
- http://memetracker.org/ (⊞)
- Sport...

topics:

More Vague/Large:

- How does advertising work collectively?
- Does one car manufacturers’ ads indirectly help other car manufacturers?
- Ads for junk food versus fruits and vegetables.
- Ads for cars versus bikes versus walking.

topics:

More Vague/Large:

- Study spreading of anything where influence can be measured (very hard).
- Study any interesting micro-macro story to do with evolution, biology, ethics, religion, history, food, international relations, ...
- Data is key.

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