Semester projects

Principles of Complex Systems
CSYS/MATH 300, Fall, 2010

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Outline

The Plan

Suggestions for Projects

References

Semester projects

Requirements:

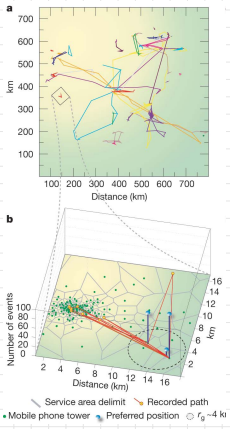
1. 3 minute introduction to project (fourth week)
2. 10 minute final presentation
3. Report: $\geq$ 5 pages (single space), journal-style
4. Goal: seed papers or help papers along.

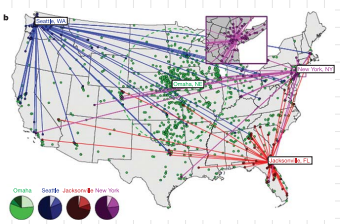
Narrative hierarchy

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,
- . . .

topics:





- Study movement and interactions of people.
- Brockmann *et al.* [4] "Where's George" study.
- Barabasi's group: tracking movement via cell phones [18].

topics:

Explore Sugarscape.

topics:

Explore "Catastrophic cascade of failures in interdependent networks" Buldyrev et al., Nature 2010 [5].

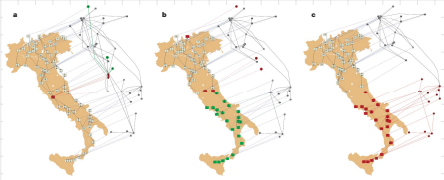


Figure 1 | Modelling a blackout in Italy. Illustration of an iterative process of a cascade of failures using real-world data from a power network (located on the map of Italy) and an Internet network (shifted above the map) that were implicated in an electrical blackout that occurred in Italy in September 2003[29]. 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).

topics:

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

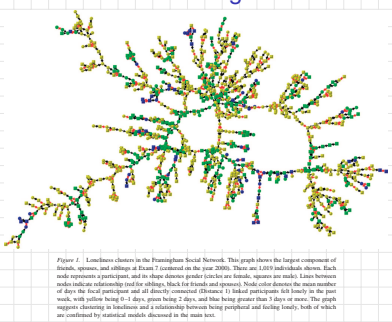


Figure 1. Loneliness clusters in the Framingham Social Network. This graph shows the largest component of friends, spouses, and siblings at Exam 7 (centered on the year 2000). There are 1,019 individuals shown. Each node represents a participant, and its shape denotes gender (circles are female, squares are male). Lines between nodes indicate relationship (red for siblings, black for friends and spouses). Node color denotes the mean number of days the focal participant and all directly connected (Distance 1) linked participants felt lonely in the past week, with yellow being 0–1 days, green being 2 days, and blue being greater than 3 days or more. The graph suggests clustering in loneliness and a relationship between being peripheral and feeling lonely, both of which are confirmed by statistical models discussed in the main text.

- Obesity [8]
- Smoking cessation [9]
- Happiness [16]
- Loneliness [6]

One question: how does the (very) sparse sampling of a real social network affect their findings?

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. [29]
- "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

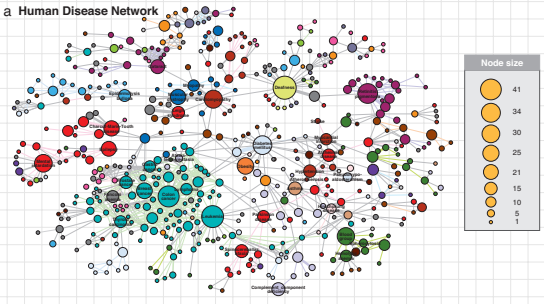
topics:

The problem of missing data in networks:

- Clauset et al. (2008)
  "Hierarchical structure and the prediction of missing links in networks" [10]
- Kossinets (2006)
  "Effects of missing data in social networks" [24]

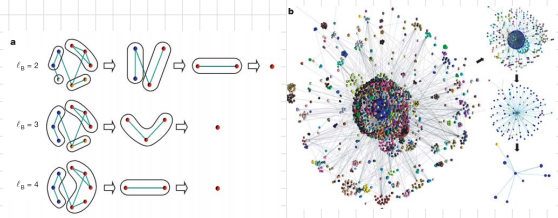
topics:

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



topics:

- Explore "self-similarity of complex networks" [30, 31] First work by Song *et al.*, Nature, 2005.
- See accompanying comment by Strogatz [32]
- 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) [31]
- "Skeleton and Fractal Scaling in Complex Networks"
  Go et al. (2006a) [17]
- "Complex Networks Renormalization: Flows and Fixed Points"
  Radicchi et al. (2008a) [28]

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:

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

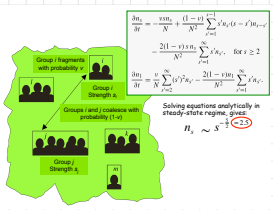
topics:

- 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" [2]

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.com/2010/09/17/the-geometry-of-sprawl/)

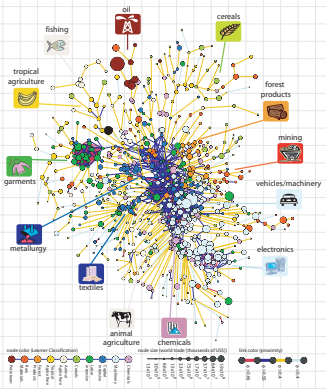
topics:



- 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 [11, 21, 3] 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" [19]
- 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:

- Study scientific collaboration networks.
- Mounds of data + good models.
- See seminal work by De Solla Price [27].
  plus modern work by Redner, Newman, *et al.*
- We will study some of this in class...

topics:

- Explore proposed measures of system complexity.

topics:

- Study Kearns et al.'s experimental studies of people solving classical graph theory problems [23]
- "An Experimental Study of the Coloring Problem on Human Subject Networks"
- (Possibly) Run some of these experiments for our class.

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) [20].

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:

- 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."[26] 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.
- More general: Explore language evolution
- One paper to start with: "The small world of human language" by Ferrer i Cancho and Solé[15]
- Study spreading of neologisms (also: baby names)
- Study models/theories/data re the origin and evolution of language.

topics:

- Study Stuart Kauffman's *nk* boolean networks which model regulatory gene networks[22]

topics:

- Critically explore Bejan's Constructal Theory.
- See Bejan's book "Shape and Structure, from Engineering to Nature."[1]
- Bejan asks why we see branching network flow structures so often in Nature—trees, rivers, etc.

topics:

- Read and critique "Historical Dynamics: Why States Rise and Fall" by Peter Turchin.[33]
- Can history Clyodynamics (⊞), Psychohistory, ...
- 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).

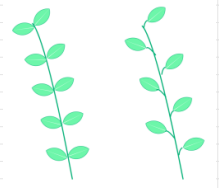
topics:

- Review: Study Castronova's and others' work on massive multiplayer online games. How do social networks form in these games? [7]
- 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 [12, 13, 14]

http://andbug.blogspot.com/ (⊞)



Wikipedia (⊞)

topics:

- Vague/Large:
  Study how the Wikipedia's content is interconnected.

topics:

- 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. [25]
- "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 (⊞)

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:

- 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:

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

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