Semester projects
Principles of Complex Systems
CSYS/MATH 300, Fall, 2011

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

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

Semantic 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 (III) we’ve covered in our weekly Complex Systems Reading Group at UVM.

Sociotechnical phenomena—Foldit:

- Also: zooniverse (III), ESP game (III), captchas (III).


Score-based voting versus rank-based voting:
- Balinski and Laraki[2]

topics:

- Study movement and interactions of people.
- Barabasi’s group: tracking movement via cell phones[21].

topics:

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. [33]
- “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

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**The problem of missing data in networks:**

- Clauset et al. (2008) “Hierarchical structure and the prediction of missing links in networks” [12]

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**One of many questions:**

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

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**Topics:**

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

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**Topics:**

- See accompanying comment by Strogatz [36]
- See also “Coarse-graining and self-dissimilarity of complex networks” by Itzkovitz et al. [7]
“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/the-geometry-of-sprawl/
Semester projects

The Plan
Suggestions for Projects
References

25 of 53

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) [23].

topics:

▶ Study scientific collaboration networks.
▶ Mounds of data + good models.
▶ We will study some of this in class...

topics:

▶ Study Kearns et al.’s experimental studies of people solving classical graph theory problems [26]
▶ “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;”[30] 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.
- Explore proposed measures of system complexity.
- Study Stuart Kauffman's *nk boolean networks* which model regulatory gene networks.\(^{[25]}\)

- 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.\(^{[37]}\)
- Can history *Clyodynamics* (Ⅱ), *Psychohistory* (Ⅲ), ... *“Big History”* (Ⅲ)
- Arbesman: *“The life-spans of Empires”*\(^{[1]}\)
- Also see *“Secular Cycles”* (Ⅲ).

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

- 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!).

- Study *phyllotaxis* (Ⅲ), 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\(^{[15, 16, 17]}\)

- 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!).

- Social networks:
  - Study social networks as revealed by email patterns, Facebook connections, tweets, etc.
  - *“Community Structure in Online Collegiate Social Networks”* Traud et al., 2008.
### Semester projects

### The Plan

### Suggestions for Projects

### References

#### topics:

**Vague/Large:**

- Study Amazon's recommender networks.
  
  See work by Sornette et al.

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

- 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.

- 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...

#### References

The life-spans of empires.

A theory of measuring, electing, and ranking.

Shape and Structure, from Engineering to Nature.
References II

Growth, innovation, scaling, and the pace of life in cities.

Common ecology quantifies human insurgency.

The scaling laws of human travel.

References III

Catastrophic cascade of failures in interdependent networks.

Alone in the crowd: The structure and spread of loneliness in a large social network.

Synthetic Worlds: The Business and Culture of Online Games.

References IV

The spread of obesity in a large social network over 32 years.

The collective dynamics of smoking in a large social network.

Hierarchical structure and the prediction of missing links in networks.

References V

On the Frequency of Severe Terrorist Events.

Predicting protein structures with a multiplayer online game.

Phyllotaxis as a dynamical self organizing process Part I: The spiral modes resulting from time-periodic iterations.

References VI

Phyllotaxis as a dynamical self organizing process Part II: The spontaneous formation of a periodicity and the coexistence of spiral and whorled patterns.

Phyllotaxis as a dynamical self organizing process Part III: The simulation of the transient regimes of ontogeny.

The small world of human language.

References VII

Dynamic spread of happiness in a large social network: longitudinal analysis over 20 years in the Framingham Heart Study.
BMJ, 337:article #2338, 2008. pdf

Skeleton and fractal scaling in complex networks.

Understanding individual human mobility patterns.
References VIII

The product space conditions the development of nations.

Network scaling reveals consistent fractal pattern in hierarchical mammalian societies.

Universal patterns underlying ongoing wars and terrorism, 2006. pdf

References IX

The Origins of Order.

An experimental study of the coloring problem on human subject networks.

[27] G. Kossinets.
Effects of missing data in social networks.

Empirical analysis of evolving social networks.

References X

Controllability of complex networks.

Five rules for the evolution of cooperation.

Networks of scientific papers.

Complex networks renormalization: Flows and fixed points.

References XI

Early-warning signals for critical transition.

[34] C. Song, S. Havlin, and H. A. Makse.
Self-similarity of complex networks.

Origins of fractality in the growth of complex networks.

Romanesque networks.

References XII

Historical Dynamics: Why States Rise and Fall.