Semester projects
Principles of Complex Systems
Course CSYS/MATH 300, Fall, 2009

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Outline

The Plan

Suggestions for Projects

References
Semester projects

Requirements:

1. ≈ 5 minute introduction to project (fourth week)
2. 15 to 20 minute final presentation
3. Report: ≥ 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,
► ...
Study movement and interactions of people.


Barabasi’s group: tracking movement via cell phones [12].
System robustness

Are there universal signatures that presage system failure?:

“Early-warning signals for critical transitions”

Abstract: Complex dynamical systems, ranging from ecosystems to financial markets and the climate, can have tipping points at which a sudden shift to a contrasting dynamical regime may occur. 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.

Scheffer et al., Nature 2009[24]
(We will talk about work by Doyle et al. on robust-yet-fragile systems)
Study the human disease and disease gene networks (Goh et al., 2007):

- Asthma
- Atherosclerosis
- Blood group
- Breast cancer
- Complement component deficiency
- Cardiomyopathy
- Cataract
- Charcot-Marie-Tooth disease
- Colon cancer
- Deafness
- Diabetes mellitus
- Epidermolysis bullosa
- Epilepsy
- Fanconi anemia
- Gastric cancer
- Hypertension
- Leigh syndrome
- Leukemia
- Lymphoma
- Mental retardation
- Muscular dystrophy
- Myocardial infarction
- Myopathy
- Obesity
- Parkinson disease
- Prostate cancer
- Retinitis pigmentosa
- Spherocytosis
- Spinocerebellar ataxia
- Stroke
- Thyroid carcinoma
- Zellweger syndrome
project topics:

The problem of missing data in networks:

- Clauset et al. (2008)  
  “Hierarchical structure and the prediction of missing links in networks”[5]

- Kossinets (2006)  
  “Effects of missing data in social networks”[18]
Explore “self-similarity of complex networks” [25, 26]
See accompanying comment by Strogatz [27]
project topics:

Related papers:

▶ “Origins of fractality in the growth of complex networks”
  Song et al. (2006a) [26]

▶ “Skeleton and Fractal Scaling in Complex Networks”
  Go et al. (2006a) [11]

▶ “Complex Networks Renormalization: Flows and Fixed Points”
  Radicchi et al. (2008a) [22]
project topics:

- Develop and elaborate an online experiment to study some aspect of social phenomena
- e.g., cheating, cooperation, influence, decision-making, etc.
project topics:

▶ **Statistics**: Study Peter Hoff’s (and others’) work on latent variables.

▶ **Idea**: explain connection pattern in a network through hidden individual or dyadic variables.

▶ **Method**: has been applied to the study of international relations networks.
project 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].
project topics:

- Physics/Society—Wars: Study work that started with Lewis Richardson’s “Variation of the frequency of fatal quarrels with magnitude” in 1949. [23, 29]
- Specifically explore Clauset et al. and Johnson et al.’s work on terrorist attacks and civil wars. [6, 15]
project topics:

- 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?
project topics:

- Explore proposed measures of system complexity.
project topics:

- Explore Dunbar’s number ([link](http://www.lifewithalacrity.com))
- See [here](http://www.lifewithalacrity.com) and [here](http://www.lifewithalacrity.com) for some food for thought regarding large-scale online games and Dunbar’s number. [http://www.lifewithalacrity.com](http://www.lifewithalacrity.com)
- Recent work: “Network scaling reveals consistent fractal pattern in hierarchical mammalian societies” Hill et al. (2008) [14].
Study scientific collaboration networks.
Mounds of data + good models.
See seminal work by De Solla Price\textsuperscript{[21]}. 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\textsuperscript{[17]}
- “An Experimental Study of the Coloring Problem on Human Subject Networks”
- (Possibly) Run some of these experiments for our class.
Semester projects

Suggestions for Projects

▶ Vague/Large:
Study amazon’s recommender networks.

Customers Who Bought This Item Also Bought

Harry Potter Schoolbooks: Fantastic Beasts and... by J.K. Rowling
$10.19

The Tales of Beedle the Bard, Collector's Ed... by J. K. Rowling
$10.88

Harry, A History: The True Story of a Boy Wizar... by Melissa Anelli

Inkdeath (Inkheart) by Cornelia Funke
$15.49

See work by Sornette et al..

▶ Vague/Large:
Study Netflix’s open data (movies and people form a bipartite graph).
Project topics:

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

- Study games (as in game theory) on networks.
- For cooperation: Review Martin Nowak’s recent piece in Science: “Five rules for the evolution of cooperation.” [20]
- Much work to explore: voter models, contagion-type models, etc.
project 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 [10]
- Study spreading of neologisms (also: baby names)
- Study models/theories/data re the origin and evolution of language.
project topics:

- Investigate safety codes (building, fire, etc.).
- What kind of relational networks do safety codes form? How have they evolved?
project topics:

- Study Stuart Kauffman’s *nk boolean networks* which model regulatory gene networks [16]
project 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.
project topics:

- Read and critique “Historical Dynamics: Why States Rise and Fall” by Peter Turchin. [28]
- Can history Clyodynamics (🗹), Psychohistory, ...
- Also see “Secular Cycles” (🗹).
project topics:

▶ Explore work by Doyle, Alderson, et al. as well as Pastor-Satorras et al. on the structure of the Internet.
project topics:

- Review: Study Castronova’s and others’ work on massive multiplayer online games. How do social networks form in these games? [4]
- See work by Johnson et al. on gang formation in the real world and in World of Warcraft (really!).
project 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 [7, 8, 9]
project topics:

- Vague/Large: Study how the Wikipedia’s content is interconnected.
project topics:

- Study social networks as revealed by email patterns, Facebook connections, tweets, etc.
- “Community Structure in Online Collegiate Social Networks” Traud et al., 2008.
project 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?
- Investigate memetics, the ‘science’ of memes.
- Sport...
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.
project 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, . . .
References I

A. Bejan.  
*Shape and Structure, from Engineering to Nature.*  

Growth, innovation, scaling, and the pace of life in cities.  
[PDF](pdf)

D. Brockmann, L. Hufnagel, and T. Geisel.  
The scaling laws of human travel.  
[PDF](pdf)
E. Castronova.  
*Synthetic Worlds: The Business and Culture of Online Games.*  

Hierarchical structure and the prediction of missing links in networks.  

A. Clauset, M. Young, and K. S. Gleditsch.  
On the Frequency of Severe Terrorist Events.  
pdf (查看全文)
References III


References IV

R. Ferrer i Cancho and R. Solé.
The small world of human language.  

Skeleton and fractal scaling in complex networks. 

Understanding individual human mobility patterns. 

The product space conditions the development of nations.  
References V


References VI


References VII


References VIII

Early-warning signals for critical transition.  

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

C. Song, S. Havlin, and H. A. Makse.  
Origins of fractality in the growth of complex networks.  

S. H. Strogatz.  
Romanesque networks.  
References IX

- **P. Turchin.**
  *Historical Dynamics: Why States Rise and Fall.*

- **D. Wilkinson.**
  *Deadly Quarrels: Lewis F. Richardson and the Statistical Study of War.*