Semester projects

Principles of Complex Systems
Course 300, Fall, 2008

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Outline

Semester projects

Requirements:

1. $\approx$ 5 minute introduction to project (fourth week)
2. 15 to 20 minute final presentation
3. Report: $\geq$ 5 pages (single space), journal-style

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,
- . . .

project topics:

Investigate the self-similarity of complex networks:

- “Self-similarity of complex networks”
  Song et al. (2005a) [16]
- “Origins of fractality in the growth of complex networks”
  Song et al. (2006a) [17]
- “Skeleton and Fractal Scaling in Complex Networks”
  Go et al. (2006a) [8]
- “Complex Networks Renormalization: Flows and Fixed Points”
  Radicchi et al. (2008a) [15]

project topics:

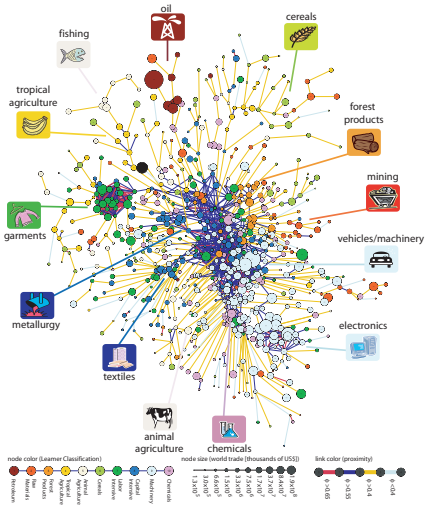
- Develop and elaborate an online experiment to study some aspect of social phenomena
- e.g., cheating, cooperation, influence, decision-making, etc.

project topics:

- 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:

- Study Hidalgo et al.’s “The Product Space Conditions the Development of Nations” [9]
- How do products depend on each other, and how does this network evolve?



project topics:

- Explore proposed measures of system complexity.

project 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) [10].

project topics:

- Investigate and review Cybernetics, a forerunner to Complex Systems.

project topics:

- Read and review Herbert Simon's "Sciences of the Artificial" (or more Simon's work more generally).

project topics:

- Investigate the life and work of Frank Harary (⊞), graph theory champion.

project topics:

- Investigate and report on General Systems Theory.

project topics:

- Vague/Large: Study spreading of anything where influence can be measured.

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." [14]
- 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 [7]

project topics:

- Investigate Service Science, which doesn't sound very good but IBM believes will be bigger than computer science.
- Definition: "Service Science, Management, and Engineering (SSME) is an interdisciplinary approach to the study, design, and implementation of service systems—complex systems in which specific arrangements of people and technologies take actions that provide value for others."

project topics:

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

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
- This method has been applied to the study of international relations networks.

project topics:

- Study Stuart Kauffman's *nk* boolean networks which model regulatory gene networks [11]

project topics:

- Engineering: Read and critically explore 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. [18]
- 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? [3]

project topics:

- Study Michael Kearns and others' work on Cobot. Very cool.
- See `http://cobot.research.att.com/`.

project topics:

- Study Kearns et al.'s experimental studies of people solving classical graph theory problems [12]
- "An Experimental Study of the Coloring Problem on Human Subject Networks"
- (Possibly) Run some of these experiments for our class.

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 [4, 5, 6]

project topics:

- Biology: Study leaf network patterns.
- Key on very interesting work by Xia.
- Classic Monge problem: how to move stuff from one place to another.
- Bulk flow versus network flow.

project topics:

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

project topics:

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

project topics:

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

project topics:

- Vague/Large:
  Study social networks as revealed by email patterns, Facebook connections, etc.
- "Empirical analysis of evolving social networks" Kossinets and Watts, Science, Vol 311, 88-90, 2006. [13]
- "Community Structure in Online Collegiate Social Networks"
  Traud et al., 2008.
  http://arxiv.org/abs/0809.0690 (⊞)

project topics:

- Vague/Large:
  How do countries depend on each other for water, energy, people (immigration), investments?

project topics:

- Vague/Large:
  How is the media connected? Who copies whom?

project topics:

- Vague/Large:
  Investigate memetics, the ‘science’ of memes.

project topics:

Sport...

project topics:

- Vague/Large:
  How does advertising work collectively? For example, does one car manufacturers’ ads indirectly help other car manufacturers?

project topics:

- Vague/Large:
  Anything interesting to do with evolution, biology, ethics, religion, history, influence, food, international relations, . . .

project topics:

- Vague/Large:
  Study spreading of neologisms.

project topics:

- Vague/Large:
  Study spreading of anything where influence can be measured.

References I

A. Bejan.
Shape and Structure, from Engineering to Nature.
Cambridge Univ. Press, Cambridge, UK, 2000.

L. M. A. Bettencourt, J. Lobo, D. Helbing, Kühnhert, and G. B. West.
Growth, innovation, scaling, and the pace of life in cities.
Proc. Natl. Acad. Sci., 104(17):7301–7306, 2007.
pdf (⊞)

E. Castronova.
Synthetic Worlds: The Business and Culture of Online Games.
University of Chicago Press, Chicago, IL, 2005.

References II

S. Douady and Y. Couder.
Phyllotaxis as a dynamical self organizing process Part I: The spiral modes resulting from time-periodic iterations.
J. Theor. Biol., 178:255–274, 1996. pdf (⊞)

S. Douady and Y. Couder.
Phyllotaxis as a dynamical self organizing process Part II: The spontaneous formation of a periodicity and the coexistence of spiral and whorled patterns.
J. Theor. Biol., 178:275–294, 1996. pdf (⊞)

S. Douady and Y. Couder.
Phyllotaxis as a dynamical self organizing process Part III: The simulation of the transient regimes of ontogeny.
J. Theor. Biol., 178:295–312, 1996. pdf (⊞)

References III

R. Ferrer i Cancho and R. Solé.
The small world of human language.
Proc. R. Soc. Lond. B, 26:2261–2265, 2001. pdf (⊞)

K.-I. Goh, G. Salvi, B. Kahng, and D. Kim.
Skeleton and fractal scaling in complex networks.
Phys. Rev. Lett., 96:Article # 018701, 2006. pdf (⊞)

C. A. Hidalgo, B. Klinger, A.-L. Barabási, and R. Hausman.
The product space conditions the development of nations.
Science, 317:482–487, 2007. pdf (⊞)

R. A. Hill, R. A. Bentley, and R. I. M. Dunbar.
Network scaling reveals consistent fractal pattern in hierarchical mammalian societies.
Biology Letters, 2008. pdf (⊞)

References IV

S. Kauffman.
The Origins of Order.
Oxford, 1993.

M. Kearns, S. Suri, and N. Montfort.
An experimental study of the coloring problem on human subject networks.
Science, 313:824–827, 2006. pdf (⊞)

G. Kossinets and D. J. Watts.
Empirical analysis of evolving social networks.
Science, 311:88–90, 2006. pdf (⊞)

M. A. Nowak.
Five rules for the evolution of cooperation.
Science, 314:1560–1563, 2006. pdf (⊞)

References V

F. Radicchi, J. J. Ramasco, A. Barrat, and S. Fortunato.
Complex networks renormalization: Flows and fixed points.
Phys. Rev. Lett., 101:Article # 148701, 2008. pdf (⊞)

C. Song, S. Havlin, and H. A. Makse.
Nature, 433:392–395, 2005. pdf (⊞)

C. Song, S. Havlin, and H. A. Makse.
Origins of fractality in the growth of complex networks.
Nature Physics, 2:275–281, 2006. pdf (⊞)

P. Turchin.
Historical Dynamics: Why States Rise and Fall.
Princeton University Press, Princeton, NJ, 2003.