PHYS 615: Nonlinear Dynamics of Extended Systems

2 – 3:15pm TuTh, PHY 4221 (Toll building)

Instructor:

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Please include "PHYS615" in the subject heading of your email so that your message receives high priority.

Phone: x5-1610

Office Hours: Thurs 11am-12pm, A.V. Williams 3341, or by appointment

Website:

Accessible via www.elms.umd.edu

Description:

This is a topics course in complex extended systems aimed at the level of first year graduate students. Broadly speaking, a complex system is a set of interacting elements that are nonlinearly coupled to give rise to emergent behavior. This course primarily focuses on how a physics perspective coupled with a computational approach can lend insights into complex systems. The course has no explicit prerequisites. A strong undergraduate math background that includes differential equations, linear algebra, and basic probability and statistics is assumed. A knowledge of statistical physics at the undergraduate level is also valuable, but the course is designed to be accessible to graduate students from non-physics disciplines. Some experience with computer programming is necessary. Problem sets will include numerical calculations and simple simulations, which means either writing code in a scientific programming language or using a standard software package such as Matlab or Mathematica. The course will work primarily from a series of research papers. Links to these papers will be posted to the website.

Grading:

Problem sets: 40% (4 problem sets, best 3 count toward your grade); literature presentation: 15% (Research papers will be assigned to students individually or in pairs. The task is to convey the main ideas in the assigned paper in a 35-40 minute presentation, including discussion); class discussion: 5%; final project: 40% (Students will identify a line of original research in the area of complex systems and write a report which includes: motivation of the problem, relevant background, an outline for the proposed work, and some preliminary investigations)

A note about class discussions:

You are expected to do review the assigned readings before class. This is essential for quality discussion which is a key component of the course. You are not expected to understand the readings in their entirety. If you have trouble understanding the readings, you should come to class with specific questions about what was unclear or confusing.

Topics and Tentative Schedule:

Course Overview*:* 1/25

Topic Area 1: A Physics Approach to Biological and Social Systems: Some Examples

- Scaling in biological systems: 1/30
- Econophysics: 2/1

- Sociophysics: 2/6
- Two student literature presentations: 2/13
    - Scaling student literature presentation:

      J. F. Gillooly, J. H. Brown, G. B. West, V. M. Savage, and E. L. Charnov, "Effects of Size and Temperature on Metabolic Rate," Science 293, 2248 -2251 (2001).
    - Econophysics student literature presentation:

      M. H. R. Stanley, L. A. N. Amaral, S. V. Buldyrev, S. Havlin, H. Leschhorn, P. Maass, M. A. Salinger, and H. E. Stanley, "Scaling Behavior in the Growth of Companies," Nature 379, 804-806 (1996).

Topic Area 2: Simple Models of Complex Systems

- Intro to agent-based modeling 2/8
- Cellular automata 2/15, 2/20
- More agent-based modeling 2/20, 2/22
    - Agent-based modeling student literature presentation: 2/22

      Couzin, I.D., Krause, J., Franks, N.R. and Levin, S.A.(2005), "Effective leadership and decision making in animal groups on the move," Nature 433, 513-516 (2005)

Topic Area 3: Power Law Distributions in Natural Systems

- Simple mechanisms for generating power law distributions: 2/27, 3/1
    - Power law student literature presentation: 3/6

      A. Clauset, C.R. Shalizi, and M.E.J. Newman, "Power-law distributions in empirical data" SIAM (2009).
- Critical phenomena in percolation: 3/6, 3/8
- Self-organized criticality (SOC): 3/8, 3/13
    - SOC Student literature presentation: 3/15

      O. Peters and J. D. Neelin, "Critical phenomena in atmospheric precipitation," Nature Physics 2, 393 - 396 (2006)
- Highly-optimized tolerance (HOT): 3/15, 3/27
    - HOT student literature presentation: 3/27

      Zhou, T., Carlson, J.M., and Doyle, J., "Evolutionary Dynamics and Highly Optimized Tolerance," J. Theor. Bio. 236 , 438-447 (2005).

Topic Area 4: Complex Networks

- Network measures: 3/29
- Network models: 4/3, 4/5
- Network algorithms: 4/5, 4/10
    - Student literature presentation: 4/10

      Watts, D. J, Dodds P.S., and Newman M.E.J., "Identity and search in social networks," Science 296:1302 (2002).
- Network dynamics: 4/12, 4/17

Topic Area 5: Computational Tools for Complex Systems

- Simulated Annealing and Genetic Algorithms: 4/19, 4/24
- Computational Mechanics: 4/24, 4/26, 5/1
    - Student literature presentation: 5/1

D. P. Varn, G. S. Canright and J. P. Crutchfield, "Discovering planar disorder in close-packed structures from x-ray diffraction: Beyond the fault model," Physical Review B 66, 174110 (2002).

Due Dates:

1/30	-	ranked choices for student literature presentations due
2/27	-	1st problem set (on cellular automata) due
3/13	-	1 page description of proposed final project due
4/3	-	2nd problem set (on power laws) due
4/19	-	3rd problem set (on complex networks) due
5/3	-	Final project report due. Presentations on (27, 28, 29) 5/3 , 5/8, 5/10
5/10	-	4th problem set (on computational tools) due

Readings:

A more complete list including dates for the various readings will be kept on the website under PHYS615>Pages>Readings. The dates listed there are approximate and subject to minor changes. In the case that a reading date is changed, a notice will be posted on the announcements page (PHYS615>Announcements).

BOOKS:
Lectures on Complex Networks, S. N. Dorogovstev
Modeling Complex Systems by Nina Boccara,
Complex Systems Dynamics by Gerard Weisbuch
SCALING IN BIOLOGICAL SYSTEMS: West *et al., Science* **276**, 122 (1997).
ECONOPHYSICS:
J. D. Farmer, M. Shubik, and E. Smith, *Phys. Today*, Sept 37-42 (2006) .
Daniels*, et al*., *PRL* **90**, 108102 (2003).
A. Dragulescu and V. M. Yakevenko, *Euro Phys J B* **17**, 723-729 (2000).
CELLULAR AUTOMATA: *Cellular Automata Modeling of Physical Systems* by Chopard and Droz
POWER LAWS:
http://www-personal.umich.edu/~mejn/courses/2006/cmplxsys899/powerlaws.pdf by Mark Newman
PERCOLATION THEORY: *Introduction to Percolation Theory* by Stauffer and Aharony
SELF-ORGANIZED CRITICALITY: *Self-Organized Criticality* by Jensen
HIGHLY OPTIMIZED TOLERANCE:
J.M. Carlson, J. Doyle*, PRE* **60**, 1412 - 1427 (1999)
J.M. Carlson, J. Doyle, *PRL* **84**, 2529 - 2532 (2000)
COMPLEX NETWORKS
S. H. Strogatz, *Nature* **410**, 268-276 (2001)
M. E. J. Newman, *SIAM Review* **45**, 167-256 (2003).
R. Albert and A.-L Barabasi, Rev. Mod. Phys. **74**, 47 –97 (2002)
SIMULATED ANNEALING: S. Kirkpatrick *et al, Science*, **220**, 671-680 (1983) see also Weisbuch

COMPUTATIONAL MECHANICS:

http://hornacek.coa.edu/dave/Tutorial/notes.pdf by Dave Feldman

C. R. Shalizi and J. P. Crutchfield. *Journal Statistical Physics* **104**, 819-881 (2001)