Topics in Complexity

Biology 131

Stanford University, Fall Quarter 2011
Thursdays, 2:15-4:05pm, Building 240, room 110

Seminar Leaders

Mark D. Longo
PhD Candidate, Biology
mlongo@stanford.edu

Rebecca Wilbanks
PhD Student, Modern Thought and Literature
rrw@stanford.edu

Diamantis Sellis
PhD Candidate, Biology
dsellis@stanford.edu

I. TOPICS: A survey of the tools, findings, and philosophical and cultural implications associated with the study of complex systems.

II. READINGS: All required readings will be available on Coursework.

III. COURSE REQUIREMENTS: There are no prerequisites. This is a one credit satisfactory/no credit course. Credit will depend on attendance and class participation. One class absence is allowed; others must be excused. Each student will be responsible for 1) a short (5-10 minute) presentation on one of our foundational definitions, 2) a short presentation (in teams) on one of our assigned readings, and 3) a short (1-3 page) essay applying the concepts that we learn in class to the system of your choice.

IV. FORMAT: Classes will include discussions of readings as well as guest lectures by faculty. Our first three sessions will focus on building our Complexity lexicon. The next part of our course will involve the application of these concepts to understand specific complex systems. Three sessions will be devoted to cognitive science and mind, one to social science applications, one to evolution, one to language, and one to political philosophy.

V. SCHEDULE OF TOPICS/DISCUSSIONS (subject to change based on student interest)

Week 1, Sept. 29

Complexity in Context

In this class we will discuss our objectives for this course, introduce ourselves to one another, and trace the development of the field of Complexity.

Lecturer(s): Rebecca Wilbanks, PhD student in Modern Thought and Literature, Stanford

Lecture title: *Complexity in context: An introduction and historical perspective*

Readings:

- Stanford Complexity Group (SCG) Foundational Definitions (to be handed out during class).

Week 2, October 6

Discussion of Foundational Concepts

In this class we will review one-paragraph summaries of the following twenty terms:

- Attractors
- Autopoiesis
- Chaos
- Complexity
- Decentralized Control
- Developmental Systems
- Dissipative Structures
- Edge of Chaos
- Emergence
- Fractals
- Generation History
- Holons
- Networks
- Nonlinear Dynamics
- Order for Free
- Phase Changes
- Phase Portraits/State Space
- Robustness
- Self-Organization
- Simulation

Every student will be responsible for presenting on one concept. This discussion may extend to our next class session.

Lecturer(s): Discussion led by Mark Longo, PhD Candidate in Biology, Stanford

Lecture title:

Readings:

- SCG Foundational Definitions (and their associated references, optional)

Week 3, October 13

Methods in the Study of Complexity

In this class we will discuss some mathematical and computational methods that are used in different fields to study complex systems and others that have been influential in the development of our understanding of Complexity concepts (graph theory, networks, cellular automata, boids and emergence, agent based simulations).

Lecturer(s): Diamantis Sellis, PhD candidate in Biology, Stanford
Craig Reynolds (inventor of "boids" simulation), Sony Computer Entertainment

Lecture title: *A demonstration of agent-based modeling*

Readings:

- "The mathematics of complexity." Chapter 6 in Capra, Fritjof. 1996. *The web of life: a new scientific understanding of living systems*. New York: Anchor Books.
- "The origins of a 'new' science." Chapter 2 in Watts, Duncan J. 2003. *Six degrees: the science of a connected age*. New York: Norton. (optional)

NOTE: We may devote this class to further exploration of foundational concepts, depending on our progress.

Week 4, October 20

Neural Networks

Professor James "Jay" McClelland is to a large extent responsible for the "connectionist" revolution of the 1980's. In this view, cognitive processes arise from the interactions of neurons through their synaptic connections. Research in his lab revolves around efforts to develop explicit computational models based on these ideas; to test, refine, and extend the principles embodied in the models; and then to apply the models to substantive research questions through behavioral experiment, computer simulation, functional brain imaging, and mathematical analysis. In this class, he will discuss how semantic knowledge may emerge from neural network dynamics.

Lecturer(s): James (Jay) McClelland, Chair, Department of Psychology, Stanford

Lecture title: *Emergent semantics in neural networks*

Readings:

- McClelland, J. L. & Rogers, T. T. (2003). The parallel distributed processing approach to semantic cognition. *Nature Reviews Neuroscience, 4*, 310-322

Week 5, October 27 **SEE IMPORTANT NOTE BELOW

Neurodynamics

Professor Walter Freeman's laboratory develops data-driven brain theory by analysis of action potentials and brain waves recorded with high-density electrode arrays fixed on or in animal and human subjects who are engaged in goal-directed behavior. The objective is to understand the ways in which the immense numbers of neurons in the human brain cooperate and coordinate their activities in creating intelligent behavior. It was the tools and concepts of Complexity, notably ideas of self-organization and chaos theory, which led Dr. Freeman to a number of breakthroughs in his understanding of neurodynamics. This session will consist of a noon lecture by Dr. Freeman followed by discussion during our seminar.

NOTE: **Class will meet at 3:00pm this day. Professor Freeman will give his talk from 12:00-1:15pm (Location TBD). Students are welcome to join us for lunch afterwards. Our speaker will discuss his work with us during class from 3:00-4:05pm.

Lecturer(s): Walter Freeman, Division of Neurobiology, University of California at Berkeley
Lecture title: *How brains create knowledge and meaning from fragments of information*
Readings:

- Pages 515-532 of Hosek, J. R., & Freeman, W. J. (2001). Osmetic Ontogenesis, or Olfaction Becomes You: The Neurodynamic, Intentional Self and Its Affinities with the Foucaultian/Butlerian Subject. *Configurations, 9,* 3, 509-542.
- Freeman WJ (2001) How brains make up their minds. New York: Columbia (optional)

Week 6, November 3

Intuitive Artificial Intelligence

Monica Anderson's company, Syntience Inc., focuses on creating computer based systems capable of learning human languages using a proprietary algorithm called Artificial Intuition. In the course of Ms. Anderson's work, she has thought deeply about current limitations in artificial intelligence research. Her lecture will focus on such limitations, which she believes are largely due to the inappropriate application of models, and how Complexity concepts may help move research forward in the artificial intelligence domain.

Lecturer(s): Monica Anderson, Founder, Syntience Incorporated
Lecture title: *Model free methods for bizarre domains*
Readings:

- Anderson, Monica (2011) Reduction considered harmful. Hplusmagazine.com < http://hplusmagazine.com/2011/03/31/reduction-considered-harmful/>
- Chapter 3 in Eisenstein, C. (2007). *The ascent of humanity*. Harrisburg, Penn: Panenthea Press. (optional)

Week 7, November 10

Networks and Institutional Evolution

Professor Woody Powell's interdisciplinary interests span the fields of Education, Sociology, Organizational Behavior, Management Science and Engineering, and Communication. A forthcoming book deals with the emergence of novel organizational forms within and between institutions. In this lecture he will talk about his research on the evolution of collaborative connections among the biomedical industry and universities using a network-based approach.

Lecturer(s): Woody Powell, Professor of Education, Stanford
Lecture title: *Practicing Polygamy with Good Taste: The Dynamics of Collaboration in the Life Sciences.*
Readings:

- Powell, W., et al. (2005) Network Dynamics and Field Evolution: The Growth of Interorganizational Collaboration in the Life Sciences. *American Journal of Sociology* 110(4):1132-1205

Week 8, November 17

Biological Evolution and Complexity

How the philosophical concepts of parts, wholes and their dialectical relationship are applied to biological systems. Individuality. Definition of evolution through natural selection. Objects and levels of selection. Causality and routes of inheritance.

Lecturer(s): Discussion led by Diamantis Sellis

Lecture title:

Readings:

- Oyama, S., Griffiths, P.E., Gray, R. 1. Introduction: What is Developmental Systems Theory? in Oyama, S., Griffiths, P.E., Gray, R. (eds.) 1991. Cycles of contingency. Developmental systems and evolution. MIT Press
- Chapter VI. section 6. Part and Whole. System (pp178-183) in Spirkin, A. 1990. (tr. Syrovatkin) Fundamentals of Philosophy. Progress Publishers. Moscow.

Week 9, December 1

Complexity in Language and Literature

We will explore the ways in which language and meaning have been conceptualized as complex systems from Saussure (who replaced the one-to-one relationship between sign and signifier with a network of signs that gain meaning from their relationship with each other) to Derrida, and beyond. How have scholars in literary studies and philosophy reacted to these changing conceptualizations and what are the implications?

Lecturer(s): Discussion led by Rebecca Wilbanks

Lecture title:

Readings:

- Cilliers, Paul. "Post Structuralism, connectionism, and complexity." Complexity and Postmodernism. London: Routledge, 1998. (p. 37-47)
- Wolfe, Cary. "Meaning and Event: or, Systems Theory and 'The reconstruction of deconstruction." What is Posthumanism. Minneapolis: University of Minnesota Press, 2010. (p. 3-29)

Week 10, December 8

Towards an Embodied Political Philosophy

An exploration of recent applications of Complexity in the realm of political philosophy. We will discuss John Protevi's "political physiology," and Manuel Delanda's concept of the "assemblage."

Lecturer(s): Discussion led by Rebecca Wilbanks

Lecture title:

Readings:

- Chapters 1, 2, & 7 from Protevi, J. (2009). *Political affect: Connecting the social and the somatic*. Minneapolis, MN: University of Minnesota Press.
- Delanda, Manuel. "Deleuzian Social Ontology and Assemblage Theory." Chapter 13 in Fuglsang, M., & Sørensen, B. M. (2006). *Deleuze and the social*. Edinburgh: Edinburgh University Press.