TOPICS IN COMPLEX ADAPTIVE SYSTEMS

UNM CS-591, Section 008

Spring Term, 2006
Mon, Wed 1:00 - 2:15 pm
Dane Smith Hall 232

Professor: Stephanie Forrest

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Office Hours: Mon. 2:30 - 4:30, Thu. 12:30 - 2:30 (or by appointment)

Textbook:

The Computational Beauty of Nature by G. Flake. MIT Press, 1999.

Recommended: *How the Immune System Works* by Lauren Sompayrac. Blackwell Science, 1999.

Recommended: *An Introduction to Genetic Algorithms* by M. Mitchell. MIT Press, 1996.

Selected Readings.

Course Description:

A graduate level introduction to selected topics in the field of complex adaptive systems, including: Definitions of complexity, cellular automata, genetic algorithms, computer immune systems, and artificial life. Regular programming projects are required.

Course Assignments and Grading:

The course will consist of lectures and class discussions based on assigned readings. There will be a significant amount of reading (plan on one or two scientific papers per week), and two or three programming assignments. A significant fraction of the course will involve reading research papers, asking critical questions about the readings, and summarizing and discussing them in class. 40% of the course grade will be based on class participation and individual presentations.

Programming maturity is expected as a pre-requisite. This means that you can choose your favorite programming language in which to complete your assignments **and** you are responsible for debugging your own computer programs. 60% of the course grade will be based on the projects.

Course Topics

I. Introduction (1 week)

Lecture: What is a complex system? How do we measure the complexity of a system?
Discussion: Flake Ch. 1; Lansing article
Discussion: Levin article

Readings:

S. Lansing "Complex adaptive systems" *Annual Rev. of Anthropology* (2003)
S. Levin "Complex adaptive systems: Exploring the known, the unknown, and the unknowable" *Bulletin of the American Mathematical Society* (2002)

II. Evolution and genetic algorithms (4 weeks)

Biological underpinnings

Lecture: Introduction to genetics (no assigned reading)
Discussion: Origin of Species

Genetic algorithms

Lecture: The simple GA and example applications (Flake, Ch. 20; Mitchell, Ch. 1, Ch. 2 recommended)
Discussion: Major Transitions in Evolution
Lecture: What is a model? Homomorphic theory of modeling (no assigned reading)

Programming assignment: Evolutionary games

Lecture: Non-zero sum games and the iterated Prisoner's Dilemma (Flake, Ch. 17)
Discussion: Assignment details
Discussion: Assignment details cont.

Readings:

Origin of Species by C. Darwin (Ch. 1 - 3)
An Introduction to Genetic Algorithms by M. Mitchell (Ch. 1, 2)
The Major Transitions in Evolution by J. Maynard Smith and E. Szathmary (Ch. 1)
Y. Sato et al. "Chaos in learning a simple two-person game" *PNAS* (2002)
M. Nowak and K. Sigmund "Bacterial game dynamics" *Nature* (2002)
B. Kerr et al. "Local dispersal promoted biodiversity in real-life game of rock-paper-scissors" *Nature* (2002)

III. Cellular automata and artificial life (3 weeks)

Cellular Automata and artificial life:

Lecture: Cellular automata and the game of life (Flake, Ch. 15)
Lecture: Tierra (no assigned reading)
Discussion: Definitions of life (Smith and Szathmary)

Modeling applications

Lecture: Modeling cancer (Hallmarks of Cancer)
Discussion: Assignment details (Abbott, Gerety)

Mathematical underpinnings

Discussion: The importance of being discrete

Readings:

J. Maynard Smith and E. Szathmary *The Major Transitions in Evolution*, Ch. 2-3.
D. Hanahan and R. Weinberg "The hallmarks of cancer" *Cell* (2000).
R. Abbott et al. "Simulating the hallmarks of cancer." *Journal of Artificial Life* (in press)

R. Gerety et al. "Modeling somatic evolution in tumorigenesis." *PLOS* (submitted)
R. Durrett and S. Levin "The importance of being discrete (and spatial)" *Theoretical Population Biology* 46:3 (1994)

IV. Scaling(1 week)
Lecture: Introduction to power laws and metabolic scaling (no assigned reading)
Discussion: Small worlds and social networks (Newman)
Readings:
M. Newman "The structure and function of networks." *Computer Physics Comm.*

V. Computational immunology (2 weeks)
Biological underpinnings
Lecture: Overview of the adaptive immune system.
Lecture: Immunology as information processing.
Applications:
Presentations: Disease modeling
Variable efficacy of repeated annual influenza vaccination"
"Probing the Effects of the Well-mixed Assumption on Viral Infection Dynamics"
Presentations: Security and privacy applications
Presentations: Immune modeling and epidemiology

Readings:
Recommended: *How the Immune System Works*, Ch. 1-5
S. Hofmeyr "An interpretative introduction to the immune system." In L. Segel and I. Cohen Ed. *Design Principles for the Immune system and Other Distributed Autonomous Systems* (2001).
Choose one of:
S. Hofmeyr and S. Forrest "Architecture for an artificial immune system." *Evolutionary Computation Journal* 8:4 (2000).
F. Esponda et al. "Negative representations of information" *Int. Jour. of Information Security* (in press)
A. Somayaji and S. Forrest "Automated response using system-call delays." Usenix 2000.
G. Barrantes, et al. "Randomized instruction set emulation to disrupt binary code injection attacks." *ACM CCS* (2003).
J. Kephart and S. White "Directed Graph Epidemiological Models of Computer Viruses," Proc. IEEE Symposium on Security and Privacy (1991).
J. Balthrop, et al. "Technological networks and the spread of computer viruses." *Science* (2004).
D. Smith et al. "Variable efficacy of repeated annual influenza vaccination" PNAS (1999)
C. Beauchemin "Probing the effects of the well-mixed assumption on viral infection dynamics" *J. Theoretical Biology* (in press).
D. Chao et al. "The effects of thymic selection on the range of T cell cross-reactivity" *European Journal of Immunology* (2005).

VI. Course Conclusion and Presentations (1 week)

Presentations and Discussion

Readings:

Choose one of:

P. Bak *How Nature Works* Ch. 1 Springer-Verlag (1996)

H. Hendreiks-Jansen *Catching Ourselves in the Act* Ch. 1 MIT Press (1996).

S. Forrest "Emergent Computation" *Physica D* 42:1-3 (1990)