Complex Adaptive Systems
UNM CS 591, Section 3, Spring 2009
MWF 12 – 12:50
Woodward Hall 147
cs.unm.edu/~melaniem/courses/CAS09.html

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Course Description: A graduate level introduction to selected topics in complex adaptive systems focusing on computational tools to simulate and measure complexity, and analysis of biological and social complex adaptive systems. Topics include definitions of complexity, cellular automata, evolution and genetic algorithms, dynamical systems, scaling and fractals, ant colonies and ant colony algorithms.

Course Assignments and Grading: The course will be based on readings, discussions, lectures and programming assignments. In addition to the primary textbook, students will read one or two papers from the primary scientific literature or chapters from supplemental textbooks each week. 40% of the course grade will be based on class participation, including leading and participating in discussions of assigned readings and participation in in-class exercises. One class day per week will be a discussion period. Every student should come prepared to give a 3-5 minute summary of the paper(s) to be discussed and 2-3 questions to facilitate discussion. 60% of the grade will come from approximately 4 programming projects. Sample Matlab code will be provided to get you started on some projects. You can turn in projects written in whatever language you choose, but you are responsible for getting your programs running. You will often work in pairs. For each project you will turn in a report describing how to run your program, what your code does, its outputs and answers to specific questions.

Topics:
I. Introduction: What is a complex system? (1.5 weeks)
   a. Biological\Social\Economic Complex Adaptive Systems
   b. Computational definitions of complexity
   c. Reading & Discussion to include:
      2. “What is Complexity?” Gell Mann, 1995
      3. Flake, Chapter 1 (p. 1-8) and Chapter 9 (p. 129-136)
II. Cellular Automata (2 weeks)
   a. Computational foundations of CAs
   b. Applications in Social science, biology, physics, computer science
   c. Reading and Discussion to include:
      i. Flake, Ch 15
ii. Excerpts from *A new kind of Science*, S. Wolfram

d. **Assignment 1: Cellular Automata**

III. Dynamical Systems (1-2 weeks)
   a. Nonlinear dynamics and chaos
   b. Complexity in physical systems
   c. Biological system: predator prey interactions
   d. Computational tools: Stability analysis, iterative maps, liapunov exponents
   e. Readings to include:
      i. Flake, chapters 10-12
      ii. *Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry and Engineering* by Steven H. Strogatz

IV. Evolution and Genetic Algorithms (2 weeks)
   a. Biological system: Genetics and evolution Discussion and Reading to include excerpts from
      i. *Origin of Species*. Charles Darwin, Ch 1-3
      ii. *Major Transitions in Evolution*. John Maynard-Smith, Ch 1
      iii. *Evolution of Complexity*. John Tyler Bonner, selected reading
   b. Computational Tools: Genetic Algorithms. Discussion & Readings to include
      i. Flake, Ch 20
      ii. Mitchell, *An Introduction to Genetic Algorithms*, Ch 1 and 2

c. **Assignment 2: Genetic Algorithms**

V. Networks, Scaling and Fractals (1-2 weeks)
   a. Computational tools: L-systems, complex network theory
   b. Mathematical tools: measuring power laws
   c. Readings to include
      i. Flake, chapters 5-8

VI. Modeling (1-2 weeks)
   a. Homomorphic theory of models
   b. Discussion: Science *in silico*: what is the role of modeling in science?
   c. Discrete versus continuous models
   d. Agent based models
      i. Social Systems
      ii. Immune System
   e. Readings to include
      i. Flake, chapter 16

f. **Assignment 3: TBD**

VII. Decentralized search and communication in ant colonies (2 weeks)
   a. Colony organization (lecture and field trip)
   b. Ant Colony Optimization
   c. Readings and discussion to include excerpts from
      i. Ant Fugue, Hofstadter 1979

d. **Assignment 4: ACO project and final written report**