

**CS 420/594: Advanced Topics in Machine Intelligence****Fall 2007: Biologically-Inspired Computation****Instructor:**

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Classes: 2:10–3:25 TR in HSS 110

Course web page: <http://www.cs.utk.edu/~mclennan/Classes/420>

**Description**

CS 420 covers advanced topics in machine intelligence with an emphasis on faculty research; CS 594 is similarly focused on faculty research. In the Fall semester of 2007 the topic for my CS 420/594 will be *biologically-inspired computation*, including recent developments in computational methods inspired by nature, such as neural networks, genetic algorithms and other evolutionary computation systems, ant swarm optimization, artificial immune systems, swarm intelligence, cellular automata, and multi-agent systems.

Fundamental to the understanding and implementation of massively parallel, distributed computational systems is an investigation of the behavior and self-organization of a variety of systems in which useful work emerges from the interaction of many simple agents. The question we address is: How should a multitude of independent computational (or robotic) agents cooperate in order to process information and achieve their goals, in a way that is efficient, self-optimizing, adaptive, and robust in the face of changing needs, damage, and attack?

Fortunately, nature provides many models from which we can learn. In this course we will discuss natural computational systems that solve some of the same problems that we want to solve, including adaptive path minimization by ants, wasp and termite nest building, army ant raiding, fish schooling and bird flocking, pattern formation in animal coats, coordinated cooperation in slime molds, synchronized firefly flashing, soft constraint satisfaction in spin glasses, evolution by natural selection, game theory and the evolution of cooperation, computation at the edge of chaos, and information processing in the brain.

You will learn about specific computational applications of these ideas, including artificial neural networks, simulated annealing, cellular automata, ant colony optimization, artificial immune systems, particle swarm optimization, and genetic algorithms and other evolutionary computation systems. These techniques are

also used in computer games and computer animation.

Since the goal of this course is for you to gain an intuitive understanding of adaptive and self-organizing computational systems, the lectures make extensive use of videos, simulations, and other computer demonstrations. Your grade will be based on four moderate-sized projects, and I will consider group projects (but you will have to do more!).

### **Prerequisites**

This is a project-oriented course and therefore all students will be expected to have basic programming skills. However, for non-EECS students (e.g., those in biology, ecology, psychology, etc.) I will provide alternate non-programming assignments. If you have any questions about whether you should take this course, please send me mail.

### **Grading**

Your grade will be based on four projects, in which you will conduct and write up experiments using the software associated with Flake's book, as well as conducting experiments with software that you program yourself. (Non-EECS students can do alternative, non-programming assignments.)

Students taking CS 594 (i.e. the course for graduate credit) will be expected to do specified additional work. For example, you will be required to run additional experiments, to do mathematical derivations, or to propose and evaluate new methods of system analysis.

### **Text**

CS 420 & 594: Flake, Gary William. *The Computational Beauty of Nature*. MIT Press, 1998.

### **Tentative List of Topics**

Chapter numbers refer to Flake unless otherwise specified. Slides for each lecture will be posted in the course of the semester.

1. Overview: course description, definition of biologically-inspired computing, why it is important
2. Cellular Automata: Wolfram's classification, Langton's lambda, CA models in nature, excitable media (ch. 15)
3. Autonomous Agents and Self-Organization: termites, ants, flocks, herds, and schools (ch. 16)
4. Competition and Cooperation: zero- and nonzero-sum games, iterated prisoner's dilemma, stable strategies, ecological & spatial models (ch. 17)
5. Natural and Analog Computation: artificial neural nets, associative memory, Hebbian learning, Hopfield networks (ch. 18)
6. Complex Systems & Phase Transitions: summary (ch. 19)
7. Genetics and Evolution: biological adaptation & evolution, genetic algorithms, schema theorem (ch. 20)
8. Neural Networks and Learning: pattern classification & linear separability, single- and multilayer perceptrons, backpropagation, internal representation (ch. 22)
9. Adaptation: summary (ch. 23)

As time permits:

10. Nonlinear Dynamics in Simple Maps (ch. 10)
11. Strange Attractors (ch. 11)
12. Producer-Consumer Dynamics (ch. 12)
13. Controlling Chaos (ch. 13)
14. Chaos, Randomness, and Computability (ch. 14)

We will do about one topic every week or so.