CS 470, Cellular Automata and Complexity Syllabus

Instructor: David Bahr (answers to Dave, David, Mr. Bahr, Dr. Bahr, yo, hey you, and others). Work Phone: 964-5147. Home phone: 303-449-9179 (before 9:30pm). Cell: 303-249-7468 (spotty reception at my house). dbahr@regis.edu.

Schedule: T Th, 10:50am-12:05pm.

Office Hours: Carroll Hall room 241, unless I specify a particular pool table in advance. T Th, 12:30pm-1:30pm. Fri by appointment, 10:30am-12:00pm and 1:00pm-3:30pm. But feel free to drop by or call at any time.

Summary: We will use the beautiful behavior of cellular automata (CA) to explore theories of computation and complexity. CA are lattices of cells that interact through simple rules -- crazy simple rules. Each cell has a value of 0 or 1, and the cells update their number based on their neighbors' values. A typical update rule is "sum modulo 2". That's it.

But even with these simple rules, we'll show that CA can model complex physics like fluid flow, social interactions like rioting, and biological behaviors like herding. Even more profound, we'll prove that some CA are capable of "universal computation". In other words, despite their simple rules, some CA can mimic the computer on your desk and are every bit as powerful!

At a purely aesthetic level, CA produce beautiful and mesmerizing patterns reminiscent of Escher gone mad. Fractals describe many of these intricate designs, and group theory can explain their structure, but you may find yourself drawn and inspired by their artistic potential.

This is a junior/senior level class, though there are few pre-requisites. We will do some full-on, no-holds-barred, math proofs, so linear algebra would be helpful. We will also do some basic programming. The more advanced your mathematics and programming skills, the more you will get out of the class.

Please Note: This class has a more “theoretical” flavor than your typical computer science class. It explores the science of computer science rather than the technology. As such, Cellular Automata is not an essential class for someone who just wants to write code for a living. However, if you want to understand more about how your universe works, and if you want a glimpse at the deep and very cool connections between math, computer science and physics, then this class is for you! We address the applications of cellular automata to many other disciplines like biology, sociology and medicine – so this class has a very practical component for anyone thinking of graduate school, and it offers an exciting new way to think about your other studies. Just be open to exploring the theoretical side of computer science, and we will have a lot of fun!
Learning Objectives:
(1) Understand how surprisingly simple rules can lead to phenomenally complex and beautiful behaviors.
(2) Understand universal computation from a mathematical point of view, and how very simple cellular automata rules can reproduce computers as powerful as any desktop or super computer.
(3) Understand the close theoretical relationship between computer science and other disciplines, particularly mathematics and physics.
(4) Understand applications of theoretical computer science to physical and social sciences, particularly sociology, biology (including medical applications), and physics (including fluid flow).
(5) Understand the important distinctions between class I, II, III, and IV, and why class IV behavior is rare but inevitable. At both a mathematical and philosophical level, understand why this implies “life” (self-reproducing phenomena) is inevitable in our universe.
(6) Understand from a mathematical point of view why, in theory, cellular automata can be used to solve any problem and model any system. Also understand why it is difficult to implement cellular automata to solve many particular problems.

Exams: Mid-term exam, final project

Homework: Weekly assignments. Late homework is not accepted and the grade will be a zero. But don’t panic! Your lowest homework grade will not be considered in the final grade. Note: Most assignments will be turned in by email. If your homework gives me a virus (causing untold hours of pain, anguish, and despair) then your grade will be a zero. No one wants to see me in anguish (right?), so invest in a good anti-virus program and keep it up to date!

Grade: Class participation (aka attendance): 10%
        Homework: 30%
        Midterm: 30%
        Final Project: 30%
Note that class participation counts for a full letter grade.

Computer Required: Seems obvious, but you absolutely must have your own computer for this class. No exceptions. See me if this is a problem.

Online Notes: I know you are begging for more, so I’ve posted my lecture notes online at http://academic.regis.edu/dbahr/. They are great for review, and even better as a class preview (just imagine how impressed everyone will be with your knowledge of the day’s topic). The online notes do have some occasional typos and outright errors (after all, these are nothing more than my scribbled notes). I’m going to eventually publish these notes as a CD, so I’ll grant extra credit to the first person that points out and corrects an online typo or error. The amount of credit depends on the subtlety and magnitude of the error. I’ll also credit you on the CD, making your name live forever in “print”.

Topics:
Week 1: Introduction and general principles of CA – beauty and so much more
Week 2: Details of one-dimensional CA – fractals, cycle lengths, algebraic properties.
Week 3: Details of one-dimensional CA continued. Totalistic CA. Additive CA.
Week 4: Classes of CA (I, II, III, IV). Langton’s lambda.
Week 5: Two-dimensional CA and classes I, II, III, IV
Week 6: Universal computation in CA and theory of computation
Week 7: Review and midterm (Thursday, March 4; subject to change)
Week 8: Spring break
Week 9: Theory of computation – NAND, OR, etc., and Turing machines.
Week 10: General principles of complexity (statistical mechanics)
Week 11: Applications in physics – fluid flow, phase transitions
Week 12: Applications in sociology, biology – bird flocks, zebra stripes, voting, etc.
Week 13: Designing your own CA experiment/application
Week 14: Review
Week 15: Final project presentations

Special needs: If you have a disability requiring academic adjustments for this class, please contact Disability Services (303-458-4941). They will help determine appropriate accommodations. I recommend that you make arrangements as soon as possible because accommodations cannot be provided retroactively.

Ethics: It hardly needs to be said, but Regis takes a very dim view of cheating. Students who cheat, plagiarize, copy, fake, bootleg, or attempt to con, defraud, swindle, bamboozle, fleece, dupe, fool, trick, or deceive will fail the course. Other synonyms are also prohibited. For clarity, copying homework is considered cheating. If you have any questions about proper conduct please come talk to me.

Consistent with the College's Academic Integrity Policy, I will report all violations to the Dean's office. Students who have committed multiple instances of academic dishonesty can be subject to institutional penalties like probation, suspension, or expulsion, in addition to the penalties for this course. The Academic Integrity policy is described in the Bulletin; detailed information about the policy and the appeals process can be found in the Dean's office.

Dr. Bahr’s Grading Policy (in gory detail)

My goal is to produce graduates that I would hire if I was running my own business. I also want to produce graduate students that I would accept into a PhD program. This means, of course, that I can’t pass out A’s like free candy. However, it does mean that I am invested in your progress, and I very much want all of my students to do well.

In the past, I have worked as a manager at various “.coms”. I have also worked with graduate students on complex research at the cutting edge of science. I know what is necessary to succeed in the workplace and in graduate school. Therefore, my grading is
not designed to penalize but instead to prepare you with important and necessary skills. Ideally, this preparation will pay off with the best possible job after graduation and place you into the best possible graduate school.

To that end, the following might help you to understand my homework assignments and grading.

(1) My assignments typically have some problems that will reinforce what you have learned in the classroom and in any assigned reading. Each assignment will also have one or more problems designed to “push your envelope” and to see if you can stretch your newfound knowledge into a situation that was not covered explicitly in the classroom.

(2) In some classes, the assignments are “cumulative” with a build-up to the final project. Initial assignments develop skills that are used later in the semester.

(3) Students that do the assigned reading almost always get a better grade. The required reading, if any, is at the top of each assignment.

(4) I always drop your lowest homework score for the semester. In other words, you get one “freebie”. Why? Because everyone has a bad hair day. You might get the flu, you might have a family emergency, or you might just have trouble with the assignment. I remove that lowest score, no questions asked. But *please*, consider saving that freebie for a rainy day. Don’t blow off an assignment early in the semester, or you might not have the freebie later in the semester when you really need it. That’s a rookie mistake.

(5) I don’t accept late homework. All assignments are due at the beginning of the class hour. That includes any written, emailed, and/or oral portions of the assignment. It is not acceptable to print or email your work an hour after class. This policy is uniform and fair to all concerned.

By the way, I am MOST interested in having you learn the material, so if your assignment is late, you may still turn it in. I will grade the late work, but I won’t give you credit. Remember, if your *job* assignment is late, then they just fire you. In that light, my policy seems downright lenient. 😊

(6) I do not grade on a curve. In some semesters, I have had every student in my class get an A for the semester. Awesome! However, I am not afraid to pass out low grades, and I occasionally have to fail a student. I hate doing that, and if you are struggling please seek my assistance early. I have never had to fail anybody that sought help on a regular basis.

(7) I do not tolerate cheating or copying. It’s an automatic fail for the class. You may always work together on assignments, but I recommend sitting face to face so that you cannot actually copy your partner’s work. (By the way, it is a
common misconception that your code will be identical to everybody else’s. Everyone has different code, even for the simplest assignments.)

(8) 10% of your final grade at the end of the semester is for “participation”. This is not an attendance score. Instead, I’m looking for interaction, interest, questions, and positive contributions inside the classroom. If you are contributing and asking questions regularly, I almost always give the full 10%.

(9) Please note that I do not give credit for “effort” on individual assignments – some folks just have to put in more time than others. That’s neither a positive nor negative assessment of your skills, so homeworks are graded strictly on merit. But any extra effort will certainly count towards the 10% participation grade!

(10) I am neither the easiest nor the toughest grader on campus, but I am reasonable and open to questions. If you are ever puzzled by your grade, you should feel free to ask. On some occasions, I will give back points if you can explain your motivation.

(11) I can be very particular about the details. This is not because I hate you, I promise. Instead, I’m trying to encourage good habits that will make you a star on the job. So I will frequently take off a small number of points for poor spelling, poor grammar, poor formatting, poor commenting, poor exception handling, etc. With atrocious grammar, would you expect to keep a job as a journalist? No. Similarly, you can’t expect to keep a job as a programmer with atrocious formatting, commenting, etc. So, after four years of careful critique, most of my students do an excellent job at “getting the details right”.

(12) Finally, I return assignments promptly. If you have not received your graded assignment after one week, that would be very odd. So come to see me and make sure that (1) my dog didn’t eat your assignment, and (2) the world hasn’t ended.

For your effort on the assignments, I promise that you will have a better understanding of the material, and that this will translate to confidence on the job. Talk to some of my graduates, and they will tell you that the homework really pays off! My students have been very successful in the workplace, and some employers call me each year to ask specifically for my graduating seniors.