General Information

Catalog Number: CSCI 5446-001 grad
                 CSCI 4446-001 undergrad

Time/Place: Tuesdays & Thursdays 9:30-10:45am
            in ECCR 1B40 and/or via zoom

Webpage: www.cs.colorado.edu/~lizb/chaos-course.html

Instructor: Liz Bradley
            ECOT 747
            lizb@cs.colorado.edu
            303-492-5355

Office Hours: by appointment at the zoom link on the course home page;
              please email me to set up a time.

TA Help Hours: Wednesday 1-3 and Friday 1-4
               Please check the course webpage for locations
               (virtual or physical, depending on the state of the world)

Texts: Nonlinear Dynamics and Chaos, [required]
       S. Strogatz, Addison-Wesley.

       Nonlinear Time-Series Analysis, [required]
       H. Kantz and T. Schreiber

Description:
This course explores dynamical systems and the various ways to use a computer to investigate
their behavior. It covers the standard computational and analytical tools used in nonlinear dy-
namics, together with their underlying theory, and concludes with a brief review of leading-edge
chaos research. Examples of important topics and techniques are: state-space representation, in-
terpretation, and surfaces of section; steady-state solutions and limit sets; numerical integration;
time and frequency domain analysis; bifurcation diagrams; fractals, fractal dimension, and the
link between fractals and chaos; etc. Students construct their own computational tools and use
them to explore interesting chaotic systems, ranging from mechanical pendulums to biological
populations to electronic circuits.

Strogatz’s book will be the primary text. It is well-written and thorough, but gets mathemati-
cally dense now and then. The reading assignments at the beginning of each problem set will
identify these places and lectures will guide you through them. The text will be supplemented
by xeroxed material and current research papers. A running bibliography of other interesting (but optional) material will be given in the problem sets. The Kantz/Schreiber book is a great source of both background material and algorithms for time-series analysis. Most of the algorithms described in that book are instantiated in the TISEAN package.

This year, we will also be using some online materials from a MOOC offered through the Santa Fe Institute’s Complexity Explorer platform. This will include a couple of short videos associated with each lecture, together with an (ungraded) online quiz about each one, and a series of ten “unit tests,” which will be part of your grade for the course. You may take the unit tests whenever you wish—any time before the end of classes—but previous students have found that they’re useful in studying for the final. There are a couple of problems here & there on the unit tests that aren’t applicable because our homework is different than the MOOC assignments (e.g., the question about the trapezoidal solver on unit test 6). Just skip those; I’ll normalize that out of the grades.

**Note:** this is an up-to-the-minute current-topics course, and a substantial percentage of the material that we will discuss is not covered in any textbook or paper. **Do not take this class unless you plan to attend all the lectures.** Really. You won’t be able to pass the final exam if you don’t. The MOOC videos can help, but they’re at a much lower level than CSCI 4446/5446.

### Assignments, workload, and expectations:

The heart of this course is a sequence of twelve problem sets, submitted and graded via Canvas. People who are registered for CSCI 5446 will do a month-long final project instead of the last three homework sets.

Speaking of space: you’ve doubtless heard about the “spring pause” effort across the College of Engineering. For a variety of reasons, I’ve decided to do our pause a bit earlier than the coordinated one in March. To that end, we will back way off during the week of February 15th. We will still have class on the 16th and 18th, with attendance taken, but with more interactive activities and likely shorter sessions, and there will be no assignments due that week. February 17th is a wellness day so you should have a three-plus day head break to rest and recharge. Please please please don’t take this opportunity to jet off to Crested Butte or Cancun and make yourself into a COVID vector.

A cumulative final exam will be held for everyone. If we are still in virtual mode, that will happen via one-on-one interview grading during finals week. If we’re in person, it will happen on paper, during the scheduled final exam period (Monday 3 May from 4:30-7pm). If you have three exams scheduled on May 3rd, *I need to know before the tenth week of the semester* in order to make accommodations. You can find the exam schedules here:

[www.colorado.edu/registrar/calendars-schedules/final-exams-schedule](http://www.colorado.edu/registrar/calendars-schedules/final-exams-schedule)

As mentioned above, there will also be one or two short videos associated with each lecture, along with an online quiz about the material covered in those videos due at the end of every week. These will not be graded—there are solution videos online as well—but they will prepare you to absorb and/or process the in-class material more easily, and to pass the ten online “unit tests” that are part of your grade. All of these materials will be listed on the problem-set pdfs posted on the course webpage and also on [www.cs.colorado.edu/~lizb/chaos/videos.html](http://www.cs.colorado.edu/~lizb/chaos/videos.html). It’s
your choice on when to watch these (before or after the associated lecture...whatever works best for you).

You should expect to spend at least 8-10 hours per week of prep time—outside of lecture—on this class. Roughly a quarter of that time will be spent writing code, about half playing with your code and figuring out the results, and the other quarter reading source materials and thinking about the concepts that were presented in class.

An important point about the assignments: each one builds upon the previous ones. That means that you can’t punt a problem set; you have to get the code for every assignment at least mostly working or you’ll be stalled on later ones. The final exam will also depend critically upon successful completion of the assignments.

You are free to work together on homework during the initial problem-solving stages, but you should finish, polish, interpret, and write up your work on your own. You should also feel free to consult me or the other class members for clarifications, corroboration, suggestions, debugging help, etc., at any point in any assignment. Please do not carry this to the point where anyone avoids learning from the assignments. In particular, the final, turned-in version of all assignments should be your own work. That includes words, code, ideas, etc. Identical material will garner a zero grade for that assignment, and possibly a discussion with the Honor Code Council\(^1\), for all of the people involved, regardless of who copied from whom. If you are in any doubt about where the academic honesty boundaries lie for this class, please ask me.

One final note about expectations: because of the logistical and communication hurdles under which we’re operating this semester, I really need you all to keep on top of your email and the announcements on the Canvas page. I will check my email several times daily and reply within 24 hours or on the next business day, at the latest.\(^2\) The best way to reach me in real time is via my office phone, which forwards to my cell.

Computers:

The most critical of this course’s prerequisites, besides independence and motivation, is functional computer literacy. If you are not totally comfortable hacking code, you may still enroll in this course, but be prepared to spend 15+ hours per week on it for the first couple of weeks instead of the 8-10 hours cited above.

You may use any computer, language, and graphics package that you want. The graphics need not be whizzy, just good enough to plot a bunch of points on a scaled, labeled axis. Please email me if you do not have access to adequate computer facilities and I will make arrangements.

Note that there is very little canned software for this course, and for a very important reason: I want you to understand the details of the algorithms, which only happens when you write them yourself from scratch. Almost all of what you turn in will be graphics output, sketches, and written analysis and interpretation of the patterns and trends you see in the pictures. I will not grade your code for style; I’m interested in what comes out of it, not how well-commented or well-written it is.

Grades:

Grades will be based on attendance, the homework, the online unit tests, and the final exam;

\(^1\)http://www.colorado.edu/academics/honorcode/

\(^2\)And you should also take some time off during the weekends!
for those enrolled in 5446, the final project also factors in. Here are the operative formulae:

CSCI 5446: 40% homework + 35% project + 10% final exam + 10% attendance + 5% unit tests
CSCI 4446: 70% homework + 15% final exam + 10% attendance + 5% unit tests

You must get all the programs to work at a basic level, understand and explain the results, and turn in all problem sets to pass this course. You must do so thoughtfully and elegantly to get an A.

Regarding attendance and participation: we’ll mark you present if you’re in class (physically or in zoom with your camera on). If you contribute actively to class discussions, I will bump your grade upwards, up to a full letter grade. This kicks in only above the passing threshold: I will not use class participation to change Fs into Ds. And note that “participation” is not the same as “attendance”—although, in my experience, there is a very strong correlation between attendance and final-exam performance.

It is very difficult to pass this class, let alone do well, if you do not attend the lectures. Again, much of the course material is not in any textbook, webpage, video, or slide deck. Please plan accordingly.

If I can manage it, I’m going to try to set up one-on-one zoom meetings with everyone during first few weeks and again mid-term for CSCI 4446 people. These are not required or graded; they’re just so we are not just talking zoom heads to one another. Feel free to opt out.

Syllabus:

- General introduction to chaos (1 1/2 lectures)
- Dynamics of iterated maps (2 1/2 lectures)
- Fractals and fractal dimension (1-2 lectures)
- Continuous-time dynamics (3 lectures)
- Applications (1 lecture)
- Poincaré sections (2 lectures)
- Attractor characterization (6 lectures)
- Hamiltonian chaos (3 lectures)
- Prediction, modeling, and noise (1-2 lectures)
- Stability (2-3 lectures)
- Current topics (1 lecture)
- Project presentations (1-2 lectures)
Accommodations and other policies, beginning with COVID-19...

As a matter of public health and safety due to the pandemic, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements, and public health orders in place to reduce the risk of spreading infectious disease. Required safety measures at CU Boulder relevant to the classroom setting include: maintain 6-foot distancing when possible, wear a face covering in public indoor spaces and outdoors while on campus consistent with state and county health orders, clean local work area, practice hand hygiene, follow public health orders, and if sick and you live off campus, do not come onto campus (unless instructed by a CU Healthcare professional), or if you live on campus, please alert CU Boulder Medical Services.

Students who fail to adhere to these requirements will be asked to leave class. Students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct and Conflict Resolution. For more information, see the policies on COVID-19 Health and Safety and classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please see the “Accommodation for Disabilities” statement below.

(I doubt that this applies to any of you, but all students who are new to campus must complete the COVID-19 Student Health and Expectations Course. And as you certainly know, before coming to campus each day, all students are required to complete the Buff Pass.)

Students who have tested positive for COVID-19, have symptoms of COVID-19, or have had close contact with someone who has tested positive for or had symptoms of COVID-19 must stay home. If you are sick or quarantined, please email me before the next class, if possible, but at least within 24 hours, so that I can make arrangements to work around the situation (e.g., special zoom office hours, someone to take notes for you, etc.) You do not need to document this with any kind of doctor’s note; what’s important here is that we all take care of each other.

Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. For more information, see the policies on classroom behavior and the Student Code of Conduct (www.colorado.edu/osccr).

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to me within the first three weeks of the semester so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition or injury, email me as soon as you can so we can figure out how to address your needs. (The “Temporary Medical Conditions” guidelines under the Students tab on the Disability Services website may also be useful in these situations.)

---

3 www.colorado.edu/policies/student-classroom-and-course-related-behavior
CU Boulder recognizes that students’ legal information doesn’t always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors’ class rosters. In the absence of such updates, the name that appears on the class roster is the student’s legal name. That’s what they send me but I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I can make appropriate changes to my own records. It will help me remember if you also use the “Rename” feature to tell Zoom to use the proper name.

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. If you have religious obligations that will cause logistical issues in this class (e.g., with turning in an assignment or attending a lecture), please let me know at least two weeks in advance so that we can work out alternatives.

CU Boulder is committed to fostering a positive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct (including sexual assault, exploitation, harassment, dating or domestic violence, and stalking), discrimination, and harassment by members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or cureport@colorado.edu. Information about the OIEC, university policies, anonymous reporting, and the campus resources can be found on the OIEC website\(^4\).

Please know that faculty and instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about options for reporting and support resources.

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. \textit{Please note: “plagiarism” includes turning in code that you copied from somewhere on the web, even if you made some cosmetic changes in order to conceal that fact.} All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu; 303-492-5550). Students who are found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found at the Honor Code Office website.

In an ideal world, science and mathematics would be completely objective. In reality, however, these fields are to at least some extent subjective, and they are built on a small subset of privileged voices. I have made an effort to diversify the sources from which I draw, but the possibilities were limited and the material may contain overt or covert biases, even though the material is primarily scientific and/or mathematical. Please contact me, in person or electronically, if you have any suggestions as to how I could improve the quality of the course materials. We’ll figure out some sort of channel for anonymous feedback and announce it ASAP.

\(^4\)www.colorado.edu/institutionalequity/
I really want to create a learning environment for my students that supports a diversity of thought, perspectives, and experiences, and honors your identities (race, gender, class, sexuality, religion, ability, ...). As a participant in this class, you should strive to honor the diversity of your classmates. And if something was said in class—by anyone—that made you feel uncomfortable, please talk to me about it. Again, anonymous feedback is always an option.