

University of Colorado
Department of Computer Science
Chaotic Dynamics
Spring 2023

General Information

Catalog Number:	CSCI 5446-001 CSCI 4446-001	grad undergrad
Time/Place:	Tuesdays & Thursdays 9:30-10:45am in ECCR 151	
Webpage:	www.cs.colorado.edu/~lizb/chaos-course.html (i.e., not the standard Canvas course page!)	
Instructor:	Liz Bradley lizb@cs.colorado.edu	ECOT 747 303-492-5355
Office Hours:	Mondays 2-3pm by zoom, thursdays 11:30-12:30 in person (ECOT 747), and at other times by appointment; please email me to set up a time. <i>It's a good idea to check my webpage before you stop by in case a conflict has come up with one of the regular times.</i>	
TA Help Hours:	Mondays 10am - noon in ECCS 114J.	
Texts:	<i>Nonlinear Dynamics and Chaos</i> , S. Strogatz, Addison-Wesley.	[required]
	<i>Nonlinear Time-Series Analysis</i> , H. Kantz and T. Schreiber	[required]

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 dynamics, 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, interpretation, 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 mathematically 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 current research papers and other materials. 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, I've arranged for you to receive access to these two textbooks digitally, on the first day of classes, through the course Canvas page. This is an **opt-out** thing: if you don't want to take advantage of this, use the link in the reminder email that you will receive with the subject heading "Day 1 Digital Access." You must do this no later than their deadline or you will see a "Day 1 Digital Access" charge on your tuition and fee bill!

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 thirteen 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.

A cumulative final exam will be held for everyone—on paper, during the scheduled session during final exam period. As soon as the schedule is announced, I will let you know. If you have three exams scheduled on the day of our exam, I need to know *before spring break* in order to make accommodations.

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 handouts that are posted on the course webpage and also on 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 Council¹, 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.

Computers:

The most critical of this course's prerequisites, besides independence and motivation, is functional computer literacy. If you are not totally comfortable putting mathematical ideas into the form of functional 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 the homework, the unit tests, and the final exam. For those enrolled in CSCI 5446, the final project also factors in. Here are the operative formulae:

- CSCI 5446: 40% homework + 15% final exam + 5% + unit tests + 40% project
- CSCI 4446: 75% homework + 20% final exam + 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.

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.

¹<http://www.colorado.edu/academics/honorcode/>

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.

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

Electronic versions of these paragraphs, complete with embedded hyperlinks, are available at the link in the footnote at the bottom of this page (since the url is too long for the textwidth of this document)².

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. 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 (also in a footnote to avoid breaking the margins)³, the Student Code of Conduct (www.colorado.edu/osccr), and the Office of Institutional Equity and Compliance (www.colorado.edu/oiec/.)

As a matter of public health and safety, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements and all public health orders in place to reduce the risk of spreading infectious disease. CU Boulder currently requires COVID-19 vaccination and boosters for all faculty, staff and students. Students, faculty

²www.colorado.edu/academicaffairs/policies-customs-guidelines/required-syllabus-statements

³www.colorado.edu/policies/student-classroom-and-course-related-behavior

and staff must upload proof of vaccination and boosters or file for an exemption based on medical, ethical or moral grounds through the MyCUHealth portal.

The CU Boulder campus is currently mask-optional. However, if public health conditions change and masks are again required in classrooms, students who fail to adhere to masking requirements will be asked to leave class, and 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 policy on classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please follow the steps in the “Accommodation for Disabilities” paragraph below.

If you feel ill and think you might have COVID-19, if you have tested positive for COVID-19, or if you are unvaccinated or partially vaccinated and have been in close contact with someone who has COVID-19, you should stay home and follow the further guidance of the Public Health Office (contacttracing@colorado.edu). If you are fully vaccinated and have been in close contact with someone who has COVID-19, you do not need to stay home; rather, you should self-monitor for symptoms and follow the further guidance of the Public Health Office (contacttracing@colorado.edu).

If you have a temporary medical condition or injury, 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.* The “Temporary Medical Conditions” guidelines under the Students tab on the Disability Services website may also be useful in these situations.

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner 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.

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. 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.

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code academic integrity policy. Violations of the Honor Code may include, but are not limited to: 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. *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.

CU Boulder is committed to fostering a positive and welcoming learning, working, and living environment. University policy prohibits sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, protected-class discrimination and harassment, and related retaliation by or against members of our community on- and off-campus. These behaviors harm individuals and our community. The Office of Institutional Equity and Compliance (OIEC) addresses these concerns, and individuals who believe they have been subjected to misconduct can contact OIEC at 303-492-2127 or email cureport@colorado.edu. Information about university policies, reporting options, and support resources can be found on the OIEC website.

Please know that faculty and graduate instructors have a responsibility to inform OIEC when they are made aware of any issues related to these policies, regardless of when or where they occurred, to ensure that individuals impacted receive information about their rights, support resources, and resolution options. To learn more about reporting and support options for a variety of concerns, visit www.colorado.edu/dontignoreit.

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.

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. If you'd like your feedback to be anonymous, please slip it under my office door.

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.