CSCI 410/CSIS 616 Automata Theory Syllabus (Spring 2024)

Contents

1 Logistics

1.1 Instructional Staff

Instructor: Michael Levet (He/Him/His); lastnamefirstinitial (at) cofc (dot) edu.

1.2 Key Dates

Last Day to Drop Before Grade of 'W' Is Recorded: Wednesday, January 17.
Last Day to Drop Before with Grade of 'W': Friday, February 9.
Breaks: March 3-9 (Spring Break)

1.3 Course Website

All announcements will be posted to the course website: **TODO**. Students are responsible for checking the course website daily. Assignments and other course materials will be posted to OAKS.

1.4 Lecture

Lectures: Wednesday, 5:30-8:15, HWEA 300.

We will take breaks. My intent is to partition class time, so it is closer to three 50-minute sections.

1.5 Office Hours

There will be a mix of in-person (HWEA 312) and Zoom office hours. The Zoom link and days/times for office hours will be posted to my course homepage. Your success is my top priority- if any of these times don't work, please do not hesitate to email me to schedule an appointment! **If you have COVID or another contagious illness, please do not attend my office hours in-person. I will be happy to facilitate remote participation.**

2 Course Description

2.1 Prerequisites for CSCI 410

The prerequisites include:

- Math 307 (Grade of D- or Better), OR
- CSCI 310 (Grade of C- or Better), OR
- Math 295 (Grade of C- or Better).

The department has voted to change the prerequisite for Math 307 to require a C-. This will go into effect in future iterations of this course.

It is dangerous to take this class without one of these prerequisites, and in particular it is dangerous to take this class if you earned a D+ or lower in Math 307. If you are comfortable formulating mathematical proofs, but do not have one of these prerequisites, please talk to me.

2.2 Prerequisites for CSIS 616

The official prerequisite is graduate standing. If you have not taken undergraduate coursework in Algorithms or Discrete Math, or if you are rusty on your proofs-based math, then I recommend taking CSIS 605 Applied Algorithms before this class.

2.3 Workload

CSCI 410 is an intensive 3-credit course. Well-prepared students should expect to spend on average 10-14 hours/week outside of class. Students who have significant gaps in their backgrounds may find that they need to carve out additional time to review the prerequisite material. I am happy to discuss prerequisite content in office hours- please do not hesitate to reach out!

2.4 Course Content

CSCI 410/CSIS 616 is an advanced undergraduate/introductory graduate course in theoretical computer science, which is divided into three key areas: Automata theory, Computability theory, and Computational Complexity theory. The goal is to ascertain the power and limits of computation. To this end, it is necessary to define precisely what constitutes a model of computation as well as what constitutes a computational problem. This is the purpose of Automata theory. Computability theory studies which problems can (and cannot) be solved by computers. Finally, Computational Complexity theory seeks to classify computational problems based on how efficiently they can be solved.

We will discuss several models of computation and the classes of computational problems they solve, including finite state automata and regular languages, pushdown automata and context-free languages, and Turing machines and recursively enumerable languages. Once the basic framework from automata theory is established, we will move into more interesting material from computability and complexity theory including the undecidability of the halting problem, reducibility, the Church-Turing thesis, and the P vs. NP problem. Should time allow, we may delve further into computability and complexity theory.

Ultimately, this course is mathematical in nature. The obvious connections are with combinatorics and graph theory. However, theoretical computer science also has deep connections to algebra, topology, analysis, and logic. These deep interlays with other areas of mathematics provide deep insights, such as the undecidability of the halting problem, Primes is in P, and the breakthrough result exhibiting a quasi-polynomial time algorithm to decide if two graphs are isomorphic. In order to appreciate such results in theoretical computer science, formal proofs and the underlying ideas will be examined in great detail. Therefore, a key objective in this course is to develop your mathematical maturity; that is, your ability to understand mathematical statements and formulate rigorous mathematical proofs. This will ultimately be the best indicator for success (outside of hard work). I will rigorously prove mathematical statements in class and discuss proof strategy throughout this course. Every student will be expected to formulate proofs on homework and assessments. We will begin with a brief survey of discrete mathematics and proof techniques.

2.5 Learning Objectives

The obvious course objective is learning the material outlined above. Beyond that, the development of rigorous mathematical thought, mathematical maturity, and sharpness of proof writing will be emphasized. The underlying goal is for you to improve your ability to read and write mathematics, as well as appreciate the design and usage of axioms in a theoretical discipline. A third goal is to provide a solid preparation for subsequent courses in Theoretical Computer Science, such as one might encounter at the graduate level, as well as theoretical courses in other departments (including, but certainly not limited to: Math, Economics, Physics).

Note: I am not assuming that everyone in the class feels comfortable writing mathematical proofs. There will be considerable emphasis on teaching you all how to write (better) proofs. If you find the material interesting and *want* to get better at writing proofs, then I encourage you to take this class!

Our formal learning objectives include:

- Students will prove theorems by induction.
- Students will prove two sets are equal.
- Students will prove theorems about functions, relations, and graphs.
- Students will solve enumeration problems.
- Students will construct regular expressions, finite state machines, and convert between the two.
- Students will prove that languages are not regular.
- Students will construct context-free grammars.
- Students will construct Turing machines.
- Students will solve problems in Computability Theory and Computational Complexity Theory.

2.6 Course Text

Course lecture notes will be provided, which will serve as the official course text.

3 Course Structure and Grading

Homework/Quizzes: Your learning in this class will ultimately come from making a good faith attempt to answer the homework questions. You should write up your problems formally and correctly, as if you were explaining the material to someone else. Proofs should be rigorous and flow logically. Homework will be assigned regularly, and will be submitted via OAKS. Each homework problem will be graded according to the following scale: Outstanding/Proficiency/Progress/Attempted/No Attempt. Grades of Outstanding and Proficiency count equally for full credit, but are included to signal that a perfect solution is not required for full credit (Proficiency). For each homework assignment, you may revise and resubmit any (and every) question on which you did not receive a grade of Proficiency or Outstanding. Such revisions should be accompanied by reflections and will be due within two weeks of receiving your homework grade or the day before Reading Day (whichever comes first). Your homework score will be:

$$(\#\text{Outstanding} + \#\text{Proficiency})/(\#\text{Possible Problems}).$$

I will also regularly assign quizzes, mainly to check your understanding. Quizzes will be administered asynchronously via OAKS, timed at 45 minutes (scaled for students with disability accommodations). These are mainly to check your understanding of the content and for me to provide timely feedback. Quizzes will be graded according to the same scale as homework. Grades of Outstanding and Proficiency on quizzes will contribute positively to the numerator, but not to the denominator (number of possible problems). Thus, attempting quizzes can help you, but will not hurt you.

There will be two midterms, where each midterm question will be administered as its own OAKS quiz. Each midterm will be available for a period of several days; you do not have to complete everything all in one day. Midterm questions will be graded according to the same scale as homework. However, unlike quizzes, the midterm questions will count towards the denominator (the number of possible problems). In my experience, students who keep up with the homework and quizzes are not surprised by the midterms and do quite well on them. There will not be revisions on quizzes or midterms.

Final: Instead of a traditional final exam, there will be a final reflection.

Challenge Problems: I will post challenge problems throughout the semester. These are more involved than standard homework problems and are designed to both deepen your understanding of the course content and be rewarding problem solving experiences. There will be suggested due dates for the challenge problems (mainly to help you plan your time), but these will not be strictly enforced. You will be able to turn in challenge problems up to a week before Reading Day (so that I have time to grade them). You will be able to revise your solutions to challenge problems as necessary (and up to the deadline), provided your revisions demonstrate a good faith effort at incorporating the feedback. Challenge problems are not required to pass the class, but are necessary to earn a grade of B+ or better (for 410 students), or B- or better (for 616 students).

Final Grades: Final grades will be issued according to the following cutoffs. Note that you must satisfy all of the conditions in a given row to earn a grade (e.g., a CSCI 410 student must earn an 87% on HW, submit a satisfactory final reflection, and demonstrate proficiency on at least two challenge problems to earn an A). I reserve the right to adjust these cutoffs downwards (more favorably) as I find is warranted, based on the interests of learning and fairness.

Grade	CSCI 410			CSIS 616		
	HW	**Final**	**Challenge**	**HW**	**Final**	**Challenge**
A	87%	Satisfactory	2	90%	Satisfactory	5
A-	84%	Satisfactory	1	87%	Satisfactory	4
B+	80%	Satisfactory	1	84%	Satisfactory	3
B	77%	Satisfactory	0	80%	Satisfactory	2
B-	74%	Satisfactory	0	77%	Satisfactory	1
C+	70%	Satisfactory	0	74%	Satisfactory	0
C	67%	Satisfactory	0	70%	Satisfactory	0
C-	64%	Not Satisfactory	0			
D+	60%	Not Satisfactory	0			
D	55%	Not Satisfactory	0			
D-	50%	Not Satisfactory	0			

For students considering enrolling in CSIS 616, please note that the College of Charleston does not have grades between D- and C- for graduate classes.

Grades in the **C-/C/C+** range indicate a solid command of the mechanics (e.g., working through procedures, coming up with basic examples/counterexamples). Grades in the **B-/B/B+** range indicate a solid command of the mechanics and a moderate understanding of the theoretical underpinnings. Grades in the **A-/A** range indicate a strong proficiency with both synthesis-based problem solving and formulating mathematical proofs, and this is a very solid indicator of preparedness for taking subsequent courses in Theoretical Computer Science and Math.

As a remark for students considering applying for PhD programs in Computer Science: depending on the program, it may be possible to count an undergraduate course for graduate credit provided that your graduate program deems it reasonable that the courses are equivalent. If you enroll in CSCI 410 and earn an A- or A at the graduate level (the CSIS 616 cutoffs), I can make note of this (with your permission) in a letter of recommendation or in discussion with the graduate program director wherever you land. Therefore, it may be worth pursuing an A- or A under the CSIS 616 cutoffs.

3.1 Homework

Homework will be assigned regularly, with clearly posted deadlines. Late homework will not be accepted, unless prior arrangements are made or in emergency situations. Please discuss with me as soon as possible if you have a situation that may warrant an extension. Please submit your homework via OAKS.

- Homework must be **typed** using the provided LaTeX template. Diagrams (e.g., graphs, trees) may be hand-drawn and embedded in the LaTeXdocument as an image and **oriented so that we do not have to rotate our screens to grade your work.** Please note that **handwritten solutions or those prepared without LaTeXwill not be graded.** Similarly, **if we have to rotate our screens to grade your work, then your work will not be graded.**

- You are welcome to discuss the problems with your classmates, as well as reference outside resources. **Anything you submit must be in your own words and reflect your understanding of the material.** If there are any questions about this, it is your responsibility to contact me reasonably ahead of the submission deadline. **Looking up solutions or copying from other sources (including your classmates) is an honor code violation.** You must **cite** any resource (other than the course text or the instructor) that you use. This includes any classmates with whom you collaborate. Failure to cite your sources will be treated as an **honor code violation.** See Section 3.3.

- Posting to online forums for help (e.g., Chegg, Reddit, StackExchange, etc.) is an **honor code violation.** See Section 3.3.

- Individual assignments may have additional instructions beyond the syllabus. Students are responsible for adhering to those instructions.

3.2 Quizzes

There will be regular quizzes covering the given standards. Each quiz will have 1 question and will be timed for 45 minutes. The intent is that students will have 30 minutes (scaled for students with extra time accommodations) to take the quiz and 15 minutes to submit to OAKS. In practice, students are welcome to allocate the 45 minutes as they see fit. As we have allocated 15 minutes to prepare the quizzes for submission, late quizzes will **not** be accepted. If your internet goes out, you may take a picture (such as with Cam Scanner) and send a **legible** picture (in JPEG, PNG, or PDF formats) within the 45 minute window to the instructor. **I am unable to accept HEIC files.**

A LaTeXtemplate will be provided for the quiz. You may either type your work using the LaTeXtemplate, or you may handwrite your work and embed it as an image in the LaTeXtemplate. If you choose to handwrite your work, the image must be **legible** and **oriented so that we do not have to rotate our screens to grade your work.** If your work is illegible or we have to rotate our screens, your work will not be graded.

Quizzes are open-book and open-note, but are individual efforts. Consulting anyone who is not a member of the instructional staff about a quiz, which includes your classmates, tutors, and posting online (e.g., Chegg, Reddit, Discord, StackExchange, etc.) constitutes an **honor code violation.** See Section 3.3. You are welcome to email the instructor with clarification questions, with the understanding that doing so counts against your allotted time and that I may not respond to you in time.

3.3 Honor Code

I expect students are familiar with policies pertaining to academic integrity, outlined in the Student Handbook. Much of what you will learn about mathematics and theoretical computer science will come from your discussions with your peers. You are welcome and encouraged to discuss the homework problems with each other and with me. It is expected that you work the problems by yourself first, so that you can contribute to the discussion. This policy will be changed, reluctantly, if I find it is being abused. **Your submissions must be written in your own words and reflect your understanding of the material.** Note that you are responsible for citing any resource (including other people) that are not members of the course staff, the course lecture notes, or the lectures. Posting to online forums for help (e.g., Chegg, Reddit, StackExchange, etc.) is an **honor code violation.** If there are any questions regarding this policy, please ask the instructor.

4 Course Policies

4.1 Late Work

Late work will **not** be accepted, unless prior arrangements have been made or in case of emergency situations. Extensions can be requested using the following **TODO: Google form**. I recognize that you all will frequently have competing deadlines, including for your other classes as well as personal obligations. There is not always time to meet all of one's deadlines. The way to handle these situations is to communicate reasonably in advance. In general, I encourage you to ask for what you need. While I will in general try to be flexible for short-term extensions, do note that that requesting an extension does not guarantee that you will receive one. For long-term emergencies, please talk to me.

Note that missing the homework or quiz deadlines by a couple minutes is not a valid reason for late work to be accepted. Homework due dates and times will be clearly posted, and students will have 15 minutes to submit their quizzes (on top of 30 minutes to take their quizzes). Please plan accordingly.

4.2 Late Enrollments

Students who enroll in the course after the first day of class are subject to the same deadlines as the rest of the class.

4.3 Attendance

Attendance is not required and will only be taken during the first two weeks, for the purpose of attendance verification as required by CofC. Students who have not engaged with class by attending, completing assignments, or emailing me may be reported as having "never attended." If you are sick, please stay home– let me know if this is in the first two weeks, so that you do not get dropped. In particular, if you have COVID, please quarantine until such time as you are not contagious. I will be happy to facilitate remote participation in these instances. In the event that any member of the class (myself included) contracts COVID, I reserve the right to move the entire class online.

Note that ≥ 0 class sessions will be recorded via both voice and video recording. By attending and remaining in this class, the student consents to being recorded. Recorded class sessions are for instructional use only and may not be shared with anyone who is not enrolled in the class.

4.4 Modifications to the Syllabus

The instructor reserves the right to modify any of the policies in the syllabus at any time, particularly as dictated by the interests of learning and fairness. Students will not be graded any harsher than as outlined in Section 3.

4.5 Student Feedback

Student feedback regarding this course is welcome at any time. Those who wish to leave feedback anonymously are welcome to do so using this Google form: **TODO**. Students are also welcome to reach out to the instructor via email or in office hours to discuss their concerns.

5 Required Syllabus Statements

5.1 Religious Holidays

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. In this class, please contact the instructor within the first two weeks to discuss any conflicts with religious events.

5.2 Students with Disabilities

The Center for Disability Services/SNAP is committed to assisting qualified students with disabilities achieve their academic goals by providing reasonable academic accommodations under appropriate circumstances. If you have a disability and anticipate the need for an accommodation in order to participate in this class, please connect with the Center for Disability Services/SNAP. They will assist you in getting the resources you may need to participate fully in this class. You can contact the Center for Disability Services/SNAP office at 843.953.1431 or at snap@cofc.edu. You can find additional information and request academic accommodations at the Center for Disability Services/SNAP website.

If you are not registered with SNAP and believe you may need a disability accommodation, please do not hesitate to contact me.

5.3 Inclement Weather, Pandemic or Substantial Interruption of Instruction

In the event of inclement weather, I will communicate a detailed plan for how class will proceed (if at all). Please prioritize your safety in these situations, including any need to evacuate. If there is a need to evacuate, I will also be prioritizing my own evacuation. The university has allocated make-up days on the weekends to be used if class is canceled for inclement weather. I will communicate in a timely manner for if/how these days will be used.

In the event of a surge in the ongoing COVID pandemic, I reserve the right to make adjustments to the structure of the class. In particular, if there exists at least one member of the class with COVID, I reserve the right to move the course online.

6 Schedule (Tentative)

Note that this schedule is subject to change, including the dates of Midterm 1 and Midterm 2.

Class	Date	Topics
1	Jan. 10	Syllabus, Set Equality Proofs, Proof by Induction, Functions.
2	Jan. 17	Relations, Combinatorics, Graph Theory
3	Jan. 24	Countability, Regular Expressions, DFAs
4	Jan. 31	NFAs, Kleene's Theorem, Product Machines
		Midterm 1 (Tentative– Will be open for several days)
5	Feb. 7	Algebraic Structure of Regular Languages Converting Regular Expressions to ϵ-NFAs Removing ϵ-transitions Converting NFAs to DFAs
6	Feb. 14	Derivatives of Regular Expressions Brzozowski Algebraic Method Pumping Lemma Closure Properties
7	Feb. 21	Myhill–Nerode, DFA Minimization, Context-Free Languages (CFLs)
8	Feb. 28	Finish CFLs, Turing Machines, Decidability, Halting Problem
	March 6	No Class (Spring Break)
		Midterm 2 (TBD– We can decide later if this will be before or after break)
9	March 13	Reducibility, Rice's Theorem, P vs. NP
10	March 20	NP-completeness, Closure Properties
11	March 27	Space Complexity, PSPACE and PSPACE-completeness
12	April 3	L, NL, Immerman–Szelepcsényi, Circuits and Measures of Circuit Complexity
13	April 10	Ladner's Theorem, Oracles, Boolean Normal Forms, Parallel Prefix Circuits
14	April 17	Baker–Gill–Solovay (Relativization Barrier), Parallel Prefix Addition
15	April 24	Time and Space Hierarchy Theorems, Symmetric and Threshold Circuits