SYLLABUS

Instructor: Dr. Charles E. Hughes
Contact: charles.hughes@ucf.edu; Use Subject COT6410
Class: TR 9:00AM – 10:15AM; HEC-103
Zoom link when we meet virtually: https:tinyurl.com/4drwcssj
Office Hours: TR 10:45AM – 12:00PM and by appointment
Zoom link: https://tinyurl.com/49sx2mde
GTA: Wei Zhang; Contact: we991015@knights.ucf.edu; Use Subject COT6410
Office Hours: MW 2:30PM – 4:00PM
Zoom Link: https://ucf.zoom.us/j/2408121701
Texts: Course notes and associated slides and other online material, also at Webcourses
http://www.cs.ucf.edu/courses/cot6410/Spring2023/Notes

Course Description:

Catalog Description:

Computational Complexity: PR: COT 5405. Properties of algorithms, computational equivalence of machines, time-space complexity measures, examples of algorithms of different complexity, classification of algorithms, classes P and NP.

Full Scope: This is really a Theory of Computation Course. It involves three major components:

- Formal Languages and Automata Theory – This is in part a review, but it also introduces context for the remainder of the course, e.g., introducing problems about formal languages that we later prove are unsolvable or computationally very hard. Additionally, we cover some topics in this area that are rarely covered in undergraduate courses, e.g., Arden's Theorem and Myhill-Nerode's Theorem, and the applications of these theorems to problems that are often complex to solve when presented in other formalism.
- Computability Theory – This part of the course focuses on varying equivalent models of computation and absolute limits on the capabilities of any model of computation. As regards models, we will present some very disparate ones that can be shown equivalent, giving credence to the hypothesis that these models are as good as any we will ever discover. Once we have looked at various models, we will look at problems that cannot be solved by procedures described in these models. After showing the "Halting Problem" and Uniform Halting Problem" to be unsolvable we will develop two methods of showing open problems to be unsolvable. These are reduction and Rice's Theorem, the latter of which shows that interesting problems about the behaviors of computer programs are generally not just hard but rather unsolvable. We will also present various techniques to bound the complexities of open problems above and below with the clear goal of finding the precise inherent complexity, as surprisingly hierarchies of complexities exist even in unsolvable domains. In fact, there is an infinite hierarchy of unsolvable problems. We will then show that unsolvability raises its ugly head in surprising places.
- Complexity Theory – The focus here is mostly on problems in the class NP – those decision problems that can be solved in polynomial time if we are allowed to take advantage of non-determinism or, equivalently, unbounded parallelism. We will present concepts such as NP-Hard and NP-Complete, the former being those problems for which a deterministic polynomial time solution implies one for all NP problems, and the latter being NP-Hard and also in the class NP. As with unsolvablity, we will develop a canonical example of an NP-Complete problem. We will use reduction and some clever "widgets" to show many other problems are also

NP-Complete. We will discuss low-complexity heuristics that are good approximations to the precise solutions to some hard problems. We will then look at a variety of variants of complexity

- Straightforward Assignments – You will be expected to complete a variety of assignments that are aligned with the course topics. You will be given sample problems as well with keys that help you understand the requirements of each assignment and broaden your knowledge of the topics.
- Presentation – The culminating experience will be your reading, understanding, developing a summary, and doing a presentation on a very current research paper, usually one published in the last 12 months.
- Exams – There will be a midterm and final. The final is somewhat cumulative in that material every stage of the course builds on material from the early stages. However, the emphasis on the midterm is Formal Languages/Automata Theory and Computability, and of the final is Computability and Complexity Theory.

Recommended Reading:

Sipser, *Introduction to the Theory of Computation 3rd Ed.*, Cengage Learning, 2013. (used in COT4210)
Hopcroft, Motwani&Ullman, *Intro to Automata Theory, Languages and Computation 3rd Ed.*, Prentice-Hall, 2006.
Garey&Johnson, *Computers and Intractability: A Guide to the Th. of NP-Completeness*, W. H. Freeman & Co., 1979.
Papadimitriou & Lewis, *Elements of the Theory of Computation*, Prentice-Hall, 1997.
Davis, Sigal&Weyuker, *Computability, Complexity and Languages 2nd Ed.*, Acad. Press (Morgan Kaufmann), 1994.
Oded Goldreich, *Computational Complexity: A Conceptual Approach*, Cambridge University Press, 2008.
Arora&Barak, *Computational Complexity: A Modern Approach*, Cambridge University Press, 2009.

Rules to Abide by

- **Do Your Own Work**
  - When you turn in an assignment, you are implicitly telling me that these are the fruits of your labor. Do not copy anyone else's homework or let anyone else copy yours. In contrast, working together to understand lecture material and solutions to problems not posed as assignments is encouraged. Cheating on an assignment will result in an F on that assignment for the first infraction and an F for the course on the second. This can also lead to administrative action at the university level.
- **Late Assignments**
  - I will accept no late assignments, except under very unusual conditions, and those exceptions must be arranged with me or the GTA in advance unless associated with some tragic event.
- **Exams**
  - No communication during exams, except with me or a designated proctor, will be tolerated. A single offense will lead to termination of your participation in the class, the assignment of a failing grade and probable administrative action at the university level.

Grading Policy:

- Midterm – 125 points; Final Exam – 125 points
- Extra – 50 points used to increase **weight** of better exam, always to your benefit
- Assignments – 75 points
- Paper, Video and Presentation – 125 points
  This will likely be an individual project, See course website for details
- Total Available: 500
- Grading will be A >= 90%, B+ >= 85%, B >= 80%, C+ >= 75%, C >= 70%, D >= 50%, F < 50%
  Minus grades might also be used if deemed appropriate.
  Grading of Exams and Assignments
  We will endeavor to return each exam with a week of its taking place and each assignment within a week of its due date.

Attendance:

This is a Mixed Mode class. Thus, all lectures will be posted on-line as well as being presented either in-person or via Zoom. Exams will be in-person and so plan on being on campus those class periods. Reviews will also be in-person., although they will be recorded. However, in-person attendance at reviews is highly recommended as I tend not to be tight-lipped about my topic biases.

Expected Outcomes

- You will gain an understanding of various types of computational models and their relation to each other.
- You will have a strong sense of the limits that are imposed by the very nature of computation, and the ubiquity of unsolvable problems throughout CS.
- You will understand the notion of computational complexity and especially of the classes of problems known as P, NP, co-NP, NP-complete, NP-Hard, PSPACE, and PSPACE-complete.
- You will (hopefully) come away with stronger formal proof skills and a better appreciation of the importance of discrete mathematics to all aspects of CS.
- And I hope you have fun – if you come with an open mind, you may find the course to be enjoyable.

Brief Outline

Introduce Theory of Computation, including

- Notion of decision problems
  - Sets of natural numbers
  - Sets of strings over some finite alphabet (language)
  - Grammars as language generators (Chomsky Hierarchy)
- Various models of computation
  - Weak models such as finite, pushdown, and linear bounded automata
  - Review of major results from automata and formal language theory
  - Turing Machines and other equivalent models
  - Deterministic versus non-deterministic models
  - Relation of models to sets/languages they recognize
- Limits of computation
  - Undecidable problems
  - Enumerable/semi-decidable problems
  - The technique of reducibility
  - The ubiquity of undecidability, including Rice's Theorem (reducibility)
  - The notion of semi-decidable (re) and of co-re sets
- Complexity theory
  - Order notation (just a quick review)
  - Polynomial reducibility
  - Time complexity, the sets P, NP, co-NP, NP-complete, NP-hard, etc., and the question does P=NP?
  - Space complexity, the sets PSPACE, PSPACE-complete, NPSPACE
  - Various NP complete problems via gadgets and reducibility
- Other Topics
  - TBD

Important dates

- Midterm – Tuesday, March 7 in HEC-101 (I hope)
- Withdraw Deadline – Friday, March 24
- Spring Break – March 13-19
- Final – Thursday, April 27, 7:00AM–9:50AM in HEC-101 (I hope)

Academic Honesty:

Plagiarism and cheating of any kind on an examination, quiz, or assignment will result at least in an "F" for that assignment (and may, depending on the severity of the case, lead to an "F" for the entire course) and may be subject to appropriate referral to the Office of Student Conduct for further action. See the U CF Golden Rule for further information. Students should familiarize themselves with UCF's Rules of Conduct at <https://scai.sdes.ucf.edu/student-rules-of-conduct/> (Section 1).

I will assume for this course that you will adhere to the academic creed of this University and will maintain the highest standards of academic integrity. In other words, don't cheat by giving answers to others or taking them from anyone else. I will also adhere to the highest standards of academic integrity, so please do not ask me to change (or expect me to change) your grade illegitimately or to bend or break rules for one person that will not apply to everyone. Do not cheat. NOTE: As graders, we reserve the right to compare content submitted by students to alternative content (either students' or otherwise) by any means necessary (automated or non-automated).

The use of cell phones and talking during class, which results in the disruption of other students, is not allowed. Please silence cell phones before class. Laptops are highly encouraged. Students should follow the instructor lessons and refrain from inappropriate material. Decorum is expected in class. (This should not have to be said formally but here we are - if you have a complaint - see the instructor after class in private, via email, or via office hours.).

If you do "google", "google" right - use websites from reliable sources. You cannot ask for help online to write solutions for assignments. Popular forums are monitored by instructors and bots to ensure academic integrity.

Responses to Academic Dishonesty, Plagiarism, or Cheating

Students should also familiarize themselves with the procedures for academic misconduct in UCF's student handbook, The Golden Rule <https://goldenrule.sdes.ucf.edu/>. UCF faculty members have a responsibility for students' education and the value of a UCF degree, and so seek to prevent unethical behavior and respond to academic misconduct when necessary. Penalties for violating rules, policies, and instructions within this course can range from a zero on the exercise to an "F" letter grade in the course. In addition, an Academic Misconduct report could be filed with the Office of Student Conduct, which could lead to a disciplinary warning, disciplinary probation, or deferred suspension or separation from the University through suspension, dismissal, or expulsion with the addition of a "Z" designation on one's transcript.

Being found in violation of academic conduct standards could result in a student having to disclose such behavior on a graduate school application, being removed from a leadership position within a student organization, the recipient of scholarships, participation in University activities such as study abroad, internships, etc.

Let's avoid all of this by demonstrating values of honesty, trust, and integrity. No grade is worth compromising your integrity and moving your moral compass. Stay true to doing the right thing: take the zero, not a shortcut.

Campus Safety Statement for Students

Emergencies on campus are rare, but if one should arise during class, everyone needs to work together. Students should be aware of their surroundings and familiar with some basic safety and security concepts. Though most emergency situations are primarily relevant to courses that meet in person, such incidents can also impact online students, either when they are on or near campus to participate in other courses or activities or when their course work is affected by off-campus emergencies. The following policies apply to courses in online modalities.

- In case of an emergency, dial 911 for assistance.
- Every UCF classroom contains an emergency procedure guide posted on a wall near the door.
- To stay informed about emergency situations, students can sign up to receive UCF text alerts by going to <https://my.ucf.edu> and logging in. Click on "Student Self Service" located on the left side of the screen in the toolbar, scroll down to the blue "Personal Information" heading on the Student Center screen, click on "UCF Alert", fill out the information, including e-mail address, cell phone number, and cell phone provider, click "Apply" to save the changes, and then click "OK."
- Students with special needs related to emergencies should speak with their instructors outside of class.

Deployed Active-Duty Military Students

Students who are deployed active-duty military and/or National Guard personnel and require accommodation should contact their instructors as soon as possible after the semester begins and/or after they receive notification of deployment to make related arrangements.

Religious Observances

Students must notify their instructor in advance if they intend to miss class for a religious observance. For more information, see the UCF policy at <http://regulations.ucf.edu/chapter5/documents/5.020ReligiousObservancesFINALJan19.pdf> This is just so we can provide you with the material you will miss and adjust any relevant assignment dates.

Accessibility Statement:

The University of Central Florida is committed to providing access and inclusion for all persons with disabilities. Students with disabilities who need access to course content due to course design limitations should contact the professor as soon as possible. Students should also connect with Student Accessibility Services (SAS) <http://sas.sdes.ucf.edu/> (Ferrell Commons 185, sas@ucf.edu, phone 407-823-2371). For students connected with SAS, a Course Accessibility Letter may be created and sent to professors, which informs faculty of potential course access and accommodations that might be necessary and reasonable. Determining reasonable access and accommodations requires consideration of the course design, course learning objectives, and the individual academic and course barriers experienced by the student. Further conversation with SAS, faculty, and the student may be warranted to ensure an accessible course experience.

Changes/Announcements:

Though I try to plan for everything, life will surprise us and we may have to make adjustments. In the event that anything in this syllabus changes (e.g., classroom moves, changes in due dates, contact information), I will use a broad CANVAS announcement so that all students are informed immediately. It is critically important that you set your CANVAS announcements so that you receive all notifications and be sure to check the class site at least twice a week. Notices of announcements are automatically sent to your Knights mail as a backup communication method.

Copyright:

This course may contain copyright-protected materials such as audio or video clips, images, text materials, etc. These items are being used in accordance with the Fair Use doctrine to enhance the learning environment. Please do not copy, duplicate, download or distribute these items. The use of these materials is strictly reserved for this online classroom environment and your use only. All copyright materials are credited to the copyright holder.

Third-Party Software and FERPA:

During this course, you might have the opportunity to use public online services and/or software applications sometimes called third-party software such as a blog or wiki. While some of these could be required assignments, you need not make any personally identifying information on a public site. Do not post or provide any private information about yourself or your classmates. Where appropriate use a pseudonym or nickname. Some written assignments posted publicly may require personal reflection/comments, but assignments will not require you to disclose any personally identity-sensitive information. If you have any concerns, please contact your instructor.

*COVID-19 Accommodations:

During this course, I expect there to be major uncertainty and change this semester. We will all do what we can to accommodate changes based on feedback from the CDC, state, and University. Students are expected to follow all guidance provided by the university. The instructor will be flexible with office hours given the uncertainty in people's daily schedules. (For Spring 2022 - we may need to be especially flexible). We organized the course material into weekly modules to minimize confusion and provide this flexibility.

University-Wide Face Covering Policy for Common Spaces and Face-to- Face Classes

To protect members of our community, everyone is expected to wear a facial covering inside all common spaces including classrooms (https://policies.ucf.edu/documents/PolicyEmergencyCOVIDReturnPolicy.pdf). Follow CDC guidelines regarding vaccination. Consistent with CDC guidelines, we expect that individuals who are able to get vaccinated, get vaccinated to protect themselves and others. Faculty have the right to cancel the class if the safety and well-being of class members are in jeopardy. Students will be responsible for the material that would have been covered in class as provided by the instructor.

Notifications in Case of Changes to Course Modality

Depending on the course of the pandemic during the semester, the university may make changes to the way classes are offered. If that happens, please look for announcements or messages in Webcourses@UCF or Knights email about changes specific to this course.

COVID-19 and Illness Notification

Students who believe they may have a COVID-19 diagnosis should contact UCF Student Health Services (407-823-2509) so proper contact tracing procedures can take place.

Students should not come to campus if they are ill, are experiencing any symptoms of COVID-19, have tested positive for COVID, or if anyone living in their residence has tested positive or is sick with COVID-19 symptoms. CDC guidance for COVID-19 symptoms is located here: (https://www.cdc.gov/coronavirus/2019-ncov/symptoms-testing/symptoms.html)

Students should contact their instructor(s) as soon as possible if they miss class for any illness reason to discuss reasonable adjustments that might need to be made. When possible, students should contact their instructor(s) before missing class.

In Case of Faculty Illness

If the instructor falls ill during the semester, there may be changes to this course, including having a backup instructor take over the course. Please look for announcements or mail in Webcourses@UCF or Knights email for any alterations to this course.

Course Accessibility and Disability COVID-19 Supplemental Statement

Students with disabilities should speak with their instructor and should contact sas@ucf.edu to discuss specific accommodations for this or other courses.