Dr. Charles Rocca
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http://sites.wcsu.edu/roccac

MAT/CS 359 - 71: Theory of Computation
On Ground: Higgins 104, M 5:30-8pm
Credits: 3 credit
Grading: Standard A-F

Office Hours:

Office hours are on ground for the Spring 2024 Semester. If you need to meet virtually we can make an appointment to do so via my WebEx Virtual Office:
Higgins 101-DV (https://wcsu.webex.com/meet/roccac)

- Monday, Tuesday, Thursday, & Friday: 12:45pm - 1:45pm
- Tuesday & Thursday: 3:30pm - 4:30pm
- or by appointment

Course Materials:

- *"Introduction to the Theory of Computation, 3rd ed."* by Michael Sipser

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Course Description:

Basic theoretical principles embodied in formal languages, automata and computability.

Student Learning Outcomes:

After successful completion of this course students will be able to:

- Describe the differences between finite automata, pushdown automata, and Turing machines and the hierarchy of formal languages (regular, context-free, recursively enumerable, recursive) recognizable by these classes of machines.
- Describe the correspondence of the above hierarchy of formal languages with levels of the Chomsky hierarchy of formal grammars (regular, context-free, unrestricted), and Describe/ perform algorithms to convert a grammar to the appropriate kind of automaton, and vice-versa.
- Describe/perform algorithms to convert non-deterministic finite automata to equivalent deterministic finite automata, and non-deterministic Turing machines to equivalent deterministic Turing machines.
- Perform algorithms to convert regular expressions to finite automata and vice-versa, and explain the role of these algorithms in proving that a language is regular if and only if it is represented by a regular expression.
- Demonstrate a language's place in the Chomsky hierarchy by constructing an appropriate automaton, grammar, or regular expression, and by using pumping theorems or other means to show that a language is not regular or not context-free.
- Describe the halting problem and explain why it is undecidable
- Describe the Church-Turing thesis and supporting evidence

Course Content:

In this course we will cover the material on automata, languages, and computability theory from chapters 0 through 6 in *"Introduction to the Theory of Computation, 3rd ed."* by Michael Sipser.

The author of your text, Michael Sipser, has made material from his version of this course available at https://ocw.mit.edu/courses/18-404j-theory-of-computation-fall-2020/. The material in this course *roughly* corresponds to lectures 1 through 11 in Sipser's course; this course spends time on review (chapter 0) and on advanced topics in computability theory (chapter 6), as well as spending more time in general on the overlapping topics. I encourage you to look at Sipser's Lecture Notes and Video Lectures in order to get a perspective different from my own.

Grading:

- 40% Weekly Quizzes
- 45% Three Unit Exams
- 15% Text Assignments

Quizzes: You will have eight quizzes this semester. These will be at the start of class on days when you don't have an exam and will check how well you understood the material from the previous class. These will focus on basic knowledge and skills. The lowest three quizzes will be dropped.

Exams: You will have three exams which, like the quizzes, will focus on knowledge and skills. These will be comprehensive exams covering all the content in a unit. For the first two exams which will be during the regular semester you will be allowed to redo some of the questions you get wrong in order to regain up to 33% of the points you lost. ***Since redos are out of class work, they must be typed, in complete sentences, and in your own words.***

Assignments: There will be one assignment from each of chapters 1 through 4, and one for 5 & 6 combined for a total of 5, assuming we get through the desired material. Unlike quizzes and exams, these will focus on problem solving and, as such, will be more time consuming. I expect you to make every effort to complete these on your own or by working with others in the class. As long as you are trying to solve these yourself you will be allowed to turn in second drafts of assignments. If you cheat on any question on an assignment you will receive a zero on the assignment and will not be allowed to redo any of the work. The lowest assignment grade will be dropped. ***All assignments must be typed, in complete sentences, and in your own words.***

Course Calendar:

Monday	
1/22 Syllabus, Review Sections 0.1 - 0.4	**1**
1/29 Sections 1.1 & 1.2 & Quiz 1	**2**
2/5 Sections 1.3 & 1.4 & Quiz 2	**3**
2/12 Sections 2.1 & 2.2 & Quiz 3	**4**
2/19 ***Presidents Day - No Class***	
2/26 Sections 2.3 & 2.4 & Quiz 4, ***Chapter 1 Assn.:*** p.83 - 1.3, 1.4c, 1.5c, 1.6ej, 1.12, 1.18ej, 1.21b, 1.22, 1.28a, 1.29b	**5**
3/4 ***Exam: Automata and Languages (Chapters 1& 2)***	**6**
3/11 ***Spring Break - No Class***	
3/18 Sections 3.1 & 3.2	**7**
3/25 Sections 3.3 & 4.1 & Quiz 5 ***Chapter 2 Assn.:*** p. 154: 2.1, 2.2, 2.4bc, 2.5bc, 2.11, 2.13, 2.14, 2.15, 2.16	**8**
4/1 Sections 4.2 & Clean Up & Quiz 6	**9**
4/8 ***Exam: Computability Theory Part 1(Chapters 3 & 4)***	**10**
4/15 Sections 5.1-5.3 ***Chapter 3 Assn.:*** p.187: 3.1cd, 3.2cd, 3.8b, 3.9, 3.15bc, 3.16bc	**11**
4/22 Sections 6.1 & 6.2 & Quiz 7	**12**
4/29 Sections 6.3 & 6.4 & Quiz 8 ***Chapter 4 Assn.:*** p.210: 4.3, 4.4, 4.6 4.7 4.11, 4.13	**13**
5/6 ***Exam: Computability Theory Part 2 (Chapters 5 & 6)***	**14**

Chapter 5 & 6 Assn.: p.239 - 5.1 (use Theorem 5.13 and show that $ALL_{CFG} \leq_m EQ_{CFG}$), 5.2 (Show, directly, that $\overline{EQ_{CFG}}$ is recognizable); p.270 - 6.1, 6.11 (look at 6.10), 6.28 (look at 6.12). Due 5/10/23 by 3pm

Course Outline:

I. Introduction to formal languages and automata

1. Strings and languages over a finite alphabet
2. Automata for language recognition purposes

II. Finite Automata and regular languages

1. Deterministic Finite Automata (DFAs)
   (a) Deterministic Finite Automata (DFAs) and definition of regular language
   (b) Non-deterministic Finite Automata (NFAs)
   (c) Equivalence of NFAs and DFAs.
2. Regular Grammars (RGs)
   (a) Definition and examples
   (b) Equivalence of RGs and NFAs
3. Some operations on languages which preserve regularity
   (a) complement
   (b) union and intersection
   (c) reversal
   (d) concatenation
   (e) Kleene star
4. Regular Expressions
   (a) Recursive definition of regular expression
   (b) Regular expressions determine languages
   (c) Equivalence of regular expressions with NFAs
5. Non-regular languages
   (a) There are uncountably many languages over a given alphabet but only countably many DFAs
   (b) Pumping theorem for regular languages
   (c) Examples of languages that are not regular

III. Pushdown automata and context-free languages

1. Pushdown Automata (PDAs)
   (a) definition and examples
   (b) definition of context-free language, and examples
   (c) every regular language is context-free but not conversely
   (d) optional: Some PDAs are necessarily non deterministic
2. Context-free Grammars (CFGs)
   (a) Definition and examples
   (b) Equivalence of CFGs and PDAs
3. Some closure properties of the set of context-free languages
   (a) Union
   (b) Concatenation

   (c) Star
   (d) Reversal
   (e) Intersection and complement do not preserve context-free languages

4. Non-context-free languages
   (a) Pumping theorem for context-free languages
   (b) Examples of languages that are not context-free

IV. Turing machines, Turing-acceptable languages, and Turing-decidable languages

1. Turing machines (TMs)
   (a) Definition and examples of TMs
   (b) Modular construction of TMs from basic building blocks
   (c) Examples which demonstrate that TMs can calculate
2. TMs (and variations of TMs) for language recognition
   (a) Turing-recognizable (TR) and Turing-decidable (TD) languages
   (b) Multitape TMs accept TR languages
   (c) Nondeterministic TMs accept TR languages
   (d) Context-free languages are TD
   (e) A language is TD if and only if both it and its complement are TR
3. Unrestricted grammars
   (a) Examples
   (b) Unrestricted grammars generate precisely the TR languages
4. Universal TMs and the halting problem
   (a) Encoding TMs as binary strings
   (b) Self-terminating TMs
   (c) The Halting Problem and existence of undecidable lnguages.
5. The Church-Turing Thesis and supporting evidence
   (a) Turing-computable functions
   (b) the Church-Turing Thesis
   (c) Notion of recursive functions and equivalence with Turing-computable functions
   (d) Recursively enumerable languages and recursive languages, and equivalence of these with TR languages and TD languages
   (e) More supporting evidence for the Church-Turing thesis

You and Your Grades:

- "A" (Exceptional) range 90% to 100%:
  The student has demonstrated significant mastery of the appropriate knowledge and skills relevant to the course. The student is able to solve standard formulaic exercises and most nonstandard problems which require deeper insight.
  - "A" $\iff 92.5\% \leq Grade \leq 100\%$
  - "A-" $\iff 90\% \leq Grade < 92.5\%$
- "B" (Good) range 80% to 90%:
  The student has demonstrated mastery of the appropriate knowledge and skills relevant to the course. The student is able to solve standard formulaic exercises and some nonstandard problems which require deeper insight.
  - "B+" $\iff 87.5\% \leq Grade < 90\%$
  - "B" $\iff 82.5\% \leq Grade < 87.5\%$
  - "B-" $\iff 80\% \leq Grade < 82.5\%$
- "C" (Adequate) range 70% to 80%:
  The student has demonstrated adequate mastery of the appropriate knowledge and skills relevant to the course. The student is able to solve most standard formulaic exercises but struggles with nonstandard problems which require deeper insight.
  - "C+" $\iff 77.5\% \leq Grade < 80\%$
  - "C" $\iff 72.5\% \leq Grade < 77.5\%$
  - "C-" $\iff 70\% \leq Grade < 72.5\%$
- "D" (Inadequate) range 60% to 70%:
  The student has demonstrated inadequate or incomplete mastery of the appropriate knowledge and skills relevant to the course. The student is able to solve some standard formulaic exercises but few if any nonstandard problems which require deeper insight.
  - "D+" $\iff 67.5\% \leq Grade < 70\%$
  - "D" $\iff 62.5\% \leq Grade < 67.5\%$
  - "D-" $\iff 60\% \leq Grade < 62.5\%$
- "F" (Unacceptable) below 60%:
  The student has demonstrated essentially no mastery of the appropriate knowledge and skills relevant to the course. The student is unable to solve most standard formulaic exercises and essentially no nonstandard problems which require deeper insight.

End User Agreement:

General Expectations: As a student in this class you are expected to:

- attend class and take notes,
- actively read material in each section, taking notes,
- review your notes on a regular basis,
- check your university email every day,
- check the class site ***at least*** every other day,
- begin studying for exams in a timely fashion,
- ask questions early and often,
- attend office hours,
- seek help in the math clinic or tutoring center, and
- complete assignments and readings on time.

Assignment Guidelines: (These apply to ***all out of class work***.)

- Work handed in must always look neat, legible, and professional. Work must be very neatly written or preferably typed. The quality of your work will be factored into your grade, up to 10%, in extreme cases work may be rejected and then counted as late.
- Answers on all assignments should be given in complete sentences. I should be able to tell what your answer means without re-reading the problem. This does not mean you simply rewrite the question.
- An assignment is considered late after I have handed it back or gone over it in class. Late assignments are accepted but may receive at most 75% credit. Late assignments go to the absolute bottom of the stack of papers to be graded; ***all on time work is graded before any late work.***
- If you work on an assignment as part of a group, then there may be no more than three individuals in the group and all your names must be on the assignment. You should hand in only one copy of the work.
- All work must be submitted in the manner directed.

Email Etiquette Guidelines: When sending an email you must include the course number and semester in the subject line. For example, if you are taking MAT 314 in Fall 1592 then the the subject line should begin with "[MAT 314 Fall 1592]." Also, you should always begin with a salutation such as "Dear Dr. Rocca" and end with a closing such as "Sincerely, I. Newton."

Exam Makeup Policy: To qualify for a makeup exam you must have a valid reason for missing the exam and, if at all possible, let me know ahead of time that you are missing the exam. You will need to meet with me in order to arrange a time for the make up exam. If you do not have a valid reason, do not give prior notice when possible, or simply do not show up for an exam, you are not entitled to a makeup and will not be given one. If you fail to show up for your makeup exam, you will not be given a second opportunity.

The 2% Exception: Any quiz or class work which is ultimately worth no more then 2% of your final grade can not be made up.

Time on Task: As a 3 credit class you should expect to average 7.5 to 8.5 hours of work a week including class time. Some weeks you may get away with less and some may require more.

Attendance: There is no specific policy for attendance in this course. However, if you have ***three consecutive unexcused absences*** within the first half of the semester I am required to report to the University that you have ***stopped attending***.

Academic Honesty: If on any assignment, quiz, or exam you turn in someone else's work, regardless of the source, as if it were your own you will receive a zero on that assignment, quiz, or exam. If you are caught doing this three times you will receive an F in the course and the Dean will be informed of your academic dishonesty.
(https://www.wcsu.edu/faculty-handbook/2019-2020/policies-pertaining-to-students/academic-honesty-policy/)

Accommodations: If you have need of an accommodation for testing or note taking, please visit AccessAbility Services, located in the HAAS Library room 406 (http://www.wcsu.edu/accessability).