Introduction to Mathematical Approaches to Language

LING 123

(fulfills *Foundations Mathematics Requirement*)

Manuel Pacheco ILC, room 119, MW 11:00-12:15

Revisions to Nondiscrimination and Anti-harassment policy, and to Additional Resources for Students, approved by Faculty Senate, 12/8/20.

Revisions to Campus Safety information and links 4/7/23.

Revision to Nondiscrimination and Anti-Harassment policy link 8/19/24.

Description of Course

The goal of this course is to ***equip you with conceptual and mathematical tools to analyze and formally model language***.

Humans use complex language, and this is one of the fundamental characteristics that makes us human. In this course, we will learn how to think mathematically by analyzing the structure underlying the languages we all speak and use to reason. We will learn concepts from formal language theory, discrete mathematics, set theory, and basic logic to explore and understand puzzling properties of language that we encounter in everyday contexts. Although the concepts we'll use require attention to detail, we'll see that not only are they very powerful, they're also intuitive to work with. This course is an excellent opportunity to learn about symbolic, mathematical tools that have virtually no numbers, but have the power and precision to model accessible and intriguing data in the domain of natural human language.

Course Prerequisites or Co-requisites

None

Instructor and Contact Information

Eric Jackson, COMM 114A, ejackson1@arizona.edu

Office Hours: Mondays 2pm-4pm in COMM 114A and on Zoom,
https://arizona.zoom.us/j/85678652639?pwd=6y6wZSHJ7GWxgpD8UU2Ag7gTeNdJPL.1
Meeting ID: 856 7865 2639
Password: 816071
Office hours on Monday holidays will be moved to the following Tuesday and be *only on Zoom*
(9/1 moved to 9/2)

Teaching Assistant and Contact Information

Hannah Smith, hnsmith1@arizona.edu

Office Hours: Tuesdays 3om-4pm in the Main Library room B413, or by appointment

Course Format and Teaching Methods

This class will primarily involve in-person sessions for discussion and practice, and tests (mid-term and final) will be in person. Additionally, we'll have resources in a D2L course site where students will submit assignments, access grades, and find supplementary course materials:

https://d2l.arizona.edu/d2l/home/1656950

Course Objectives

This course introduces students to concepts used to formally model natural human language, including:

- Thinking precisely about language, viewing all human language as a system with regular (but possibly very complex!) patterns linking forms, meanings, and contexts
- Formal language theory: the Chomsky Hierarchy, regular languages and grammars, and context-free languages and grammars
- Automata theory and finite state automata
- Semantics (meaning) in natural language, including entailment, presupposition, and implicature
- Propositional logic
- Naive set theory

Expected Learning Outcomes

At the end of the course, successful students will be able to:

- demonstrate the ability to analyze patterns in language.
  (Relates to Linguistics UG Program outcome #1)
- describe and address common misconceptions about language.
  (Relates to Linguistics UG Program outcome #3)
- communicate knowledge about linguistics orally or through writing.
  (Relates to Linguistics UG Program outcome #4)
- create a formal definition for a language and characterize that language by a formalism like a *rule-based grammar* or a *finite-state automaton*.
- determine if an expression is properly part of a formal language.
- frame arguments using propositional logic, and distinguish between valid and invalid arguments.
- represent the meaning of some kinds of simple propositions using set theory.
- explain the differences between entailment, presupposition, and implicature.
- define and manipulate sets, and perform set-theoretic reasoning.
- discuss the advantages and limitations of available formal tools in given situations.

Absence and Class Participation Policy

Participating in the course and attending lectures and other course events are vital to the learning process. As such, attendance is required at all class meetings. The benefit you gain from this course is directly related to the time and effort that you put into it. Absences may affect a student's final course grade. If you anticipate being absent, are unexpectedly absent, or are unable to participate in class activities, please contact the instructor as soon as possible so we can find a way to make up the learning you missed.

To request a disability-related accommodation to this attendance policy, please contact the Disability Resource Center at (520) 621-3268 or disability@arizona.edu.

If you are experiencing unexpected barriers to your success in your courses, the Dean of Students Office is a central support resource for all students and may be helpful. The Dean of Students Office is located in the Robert L. Nugent Building, room 100, or call 520-621-7057.

The UA's policy concerning Class Attendance and Participation is available at: https://catalog.arizona.edu/policy/courses-credit/courses/class-attendance-participation.

The UA policy regarding absences for any sincerely held religious belief, observance, or practice will be accommodated where reasonable, http://policy.arizona.edu/human-resources/religious-accommodation-policy.

Absences pre-approved by the UA Dean of Students (or Dean Designee) will be honored. See: https://deanofstudents.arizona.edu/policies/attendance-policies-and-practices

Makeup Policy for Students Who Register Late

Students who register after the first class meeting must make up all missed assignments/quizzes before the end of the second week of class (September 5th).

Course Communications

Announcements will be made in person during our regularly scheduled class times and will be presented in writing on the class D2L site. Important information may occasionally be sent to your university email address. Students are responsible for checking for announcements in these locations if they miss a class session.

Required Texts or Readings

There is no required textbook for this course. ***This makes your attendance and participation in class sessions even more important!*** Optional readings, if any, will be made available in electronic form through the class D2L site.

Assignments and Examinations: Schedule/Due Dates

There will be three kinds of assignments that make up your course grade: daily quizzes, written homework assignments, and take-home tests.

Quizzes: There will be a short quiz in D2L for each class session, with the exception of review days or in-class tests. These quizzes must be completed within 7 days of that class session, but I recommend completing them as soon after a class session as possible. The purpose of these daily quizzes is to help you see how well you've understood the concepts introduced in a class session and highlight for yourself any topics that you need to review. If you attended class, actively participated, and asked questions when things were not clear, the quiz for that day should not be difficult. Quizzes can be attempted multiple times, so if you don't receive a perfect score on your first attempt, I recommend that you review your notes and re-attempt it. If you don't understand what the correct answers should be on a quiz, please talk to the instructor or TA for guidance. If you must miss a class session, you are responsible for understanding that day's content and passing the daily quiz. Your cumulative quiz grade will comprise 30% of your course grade.

Homework: There will be six major written assignments, roughly one every two weeks. These assignments will give you opportunities to take the concepts, models, and tools that we practice in class and apply them in a new, realistic context. Altogether these will comprise 40% of your course grade.

Tests: There will be a **mid-term test** and a **final exam**. Both tests will be administered in person, and will have questions that are similar to those on the homework assignments. No outside resources will be permitted during the test; no notes, no course materials, and no online tools (including writing tools and generative AI tools). The mid-term test will cover content from the first quarter of the course, and the final exam will primarily cover content from the second quarter of the course, though you may need to apply some content from the first half of the course to the questions on the final, as well. Altogether the tests will comprise 30% of your course grade.

New course material will be posted on D2L every Monday, which may include optional readings, other online resources or activities, and assignments (due in two weeks). The due date and time for each assignment will be marked in D2L; times are always given in local Tucson time. ***Unless otherwise permitted by UA policy, late work will not be accepted.*** It's best to plan ahead, give yourself plenty of time to work, and submit what you have (even if it's incomplete) on time.

Final Examination Schedule

The final exam for the course, described above, will be completed in person at our scheduled final exam time (Monday, 12/15, 10:30am to 12:30pm).

Grading Scale and Policies

Grade component	Description	Category weight
Unit assignments	Written assignments applying content from each unit; roughly one every two weeks.	40%
Midterm and final	Midterm will be due in week 8 and cover content from weeks 1-7; final will be due during finals week and will cover content from weeks 9-16, but may incorporate content from weeks 1-7 as well.	30%
Quizzes	Roughly weekly; can be attempted multiple times.	30%

Grade improvement option for unit assignments: If a student's overall grade on a unit assignment is less than 90%, the student has until the following assignment is due to try to improve their score for one or more questions on the assignment, using the following process:

- Arrange an in-person time with the instructor; this can be during normal office hours or at another time.
- Present your own analysis of your original answer to the question. What was incorrect, unclear, or missing from this answer?
- Present an improved answer to the question; this improved answer must represent your own work. The instructor or TA will evaluate the improved answer using the grading rubric.

Students will receive a final course grade of A, B, C, D, or E. The instructor reserves the right to curve grades *up*. The following minimum percentages will guarantee the corresponding letter grades.

A: 90% – 100%
B: 80% – 89.9%
C: 70% – 79.9%
D: 60% – 69.9%
E: 0% – 59.9%

Incomplete (I) or Withdrawal (W)

Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policy, which is available at https://catalog.arizona.edu/policy/courses-credit/grading/grading-system.

Dispute of Grade Policy

Students have two days to appeal the grade they receive on an assignment, starting from the time grades are posted in D2L for that assignment.

Honors Credit

If you would like to receive honors credit for this course, you will need to complete an honors contract, and create an independent project. My recommendation is to apply one of the mathematical tools we'll learn about to describe a language (besides English) that you speak; I'm willing to accept alternative proposals if you have another idea that you're interested in. Honors contract information is available at https://www.honors.arizona.edu/honors-contracts.

Scheduled Topics/Activities

Our course schedule will follow this plan (though precise details and dates are subject to modification):

Module	Dates	Description
Unit 1 Thinking formally about language	class sessions 1-5 8/25, 8/27, 9/3, 9/8, 9/10	What is language and meaning like? What benefit do we gain by formalizing it?
Unit 2 Language **forms**: formal tools for modeling syntax	class sessions 6-8 9/15, 9/17, 9/22	Formally characterizing a language with a rule-based grammar or a finite-state automaton
Unit 3 Language **forms**: apply the tools to model English	class sessions 9-12 9/24, 9/29, 10/1, 10/6	Why a finite state automaton is insufficient for human languages; using a rule-based grammar to characterize English
Quarter 1 Review and midterm	class sessions 13-15 10/8, 10/13, 10/15	Review Unit 1-3 for the midterm Midterm in class on 10/15
Unit 4 Language **meaning**: foundations of semantics	class sessions 16-19 10/20, 10/22, 10/27, 10/29	Basic concepts in sentence meaning: Entailment, presupposition, and implicature
Unit 5 Language **meaning**: Propositional logic	class sessions 20-23 11/3, 11/5, 11/10, 11/12	The syntax and semantics of propositions; Modeling the meaning of complex propositions using propositional logic
Unit 6 Language **meaning**: Set theory	class sessions 24-28 11/17, 11/19, 11/24, (11/26 optional), 12/1	Naive set theory Modeling the meaning of atomic propositions using set theory
Quarter 2 Review and final	class sessions 29-31 12/3, 12/8, 12/10	Review Unit 4-6 for the final Final 12/15 at our scheduled final exam time

Course materials will be updated in the D2L course site shortly before or after each class session.

Classroom Behavior Policy

To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming, and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (e.g., texting, chatting, reading online, making phone calls, playing games, etc.).

We'll be working in groups on in-class activities in every class session, and I want you to talk to your classmates to complete these activities. However, I ask that you refrain from disruptive conversations with people sitting around you during our class sessions. Students observed engaging in disruptive activity will be asked to cease this behavior. Those who continue to disrupt the class will be asked to leave the room and may be reported to the Dean of Students.

Threatening Behavior Policy

The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students.

Accessibility and Accommodations

At the University of Arizona, we strive to make learning experiences as accessible as possible. If you anticipate or experience barriers based on disability or pregnancy, please contact the Disability Resource Center (520-621-3268, https://drc.arizona.edu/) to establish reasonable accommodations.

Code of Academic Integrity

Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See: https://deanofstudents.arizona.edu/student-rights-responsibilities/academic-integrity.

The University Libraries have some excellent tips for avoiding plagiarism, available at https://lib.arizona.edu/research/citing/plagiarism.

Course policy on the use of AI: Course assignments and tests must be the product of your own thought, without the use of AI tools. The instructor and TA will be watching for evidence that answers have been provided by AI, and will treat any such cases as an academic integrity violation. Assignment submissions that were completed by AI will receive a score of zero. All evidence, including students' assignment submissions, will be provided to the Dean of Students office, following the policy linked above. Consequences may include loss of credit or other sanctions.

I do not recommend using AI tools for studying the content of this course. Sources that you find online that are different from the ones provided through the course website may also be more confusing than helpful. There are different approaches on the Internet to the concepts we'll see in this course, and someone else's ideas—whether you find them from an online search or from chatting with an AI tool—may br inconsistent with the ways we'll use these formalisms in this course. ***We will actually test and evaluate as a class how well Generative AI tools handle the tasks that are part of this course.***

Why this policy exists: Generative AI is a useful tool, like a calculator is a useful tool for doing math, but generative AI is like a calculator that is sometimes completely untrustworthy. In some contexts, being able to use a calculator is an important skill, while in other contexts—like when you're taking a math test to see

whether you know basic math facts—using a calculator short-circuits your own learning. As another example, a bicycle is a tool that allows us to get from one place to another faster and more efficiently than running, but if you're going to be tested in your time for a 5k run, it won't help you to train for running solely by riding a bicycle; you need to train for running by actually running, yourself. Likewise, you don't get better at running by paying someone else to run for you. You may need to know how to use generative AI at some point, but having one write your homework for this class is not appropriate. Put in the thinking yourself, so that you can reap the mental benefit for yourself. You need to know how to apply course concepts on your own well enough that you can see where some AI-generated output is partially or completely off the mark.

Selling class notes and/or other course materials to other students or to a third party for resale is not permitted. Violations to this and other course rules are subject to the Code of Academic Integrity and may result in course sanctions. Additionally, students who use D2L or UA e-mail to sell or buy these copyrighted materials are subject to Code of Conduct Violations for misuse of student e-mail addresses. This conduct may also constitute copyright infringement.

Nondiscrimination and Anti-harassment Policy

The University of Arizona is committed to creating and maintaining an environment free of discrimination. In support of this commitment, the University prohibits discrimination, including harassment and retaliation, based on a protected classification, including race, color, religion, sex, national origin, age, disability, veteran status, sexual orientation, gender identity, or genetic information. For more information, including how to report a concern, please see
http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

Our classroom is a place where everyone is encouraged to express well-formed opinions and their reasons for those opinions. We also want to create a tolerant and open environment where such opinions can be expressed without resorting to bullying or discrimination of others.

Additional Resources for Students

UA Academic policies and procedures are available at http://catalog.arizona.edu/policies

Campus Health
http://www.health.arizona.edu/
Campus Health provides quality medical and mental health care services through virtual and in-person care.
Phone: 520-621-9202

Counseling and Psych Services (CAPS)
https://health.arizona.edu/counseling-psych-services
CAPS provides mental health care, including short-term counseling services.
Phone: 520-621-3334

The Dean of Students Office's Student Assistance Program
https://deanofstudents.arizona.edu/support/student-assistance
Student Assistance helps students manage crises, life traumas, and other barriers that impede success. The staff addresses the needs of students who experience issues related to social adjustment, academic challenges, psychological health, physical health, victimization, and relationship issues, through a variety of interventions, referrals, and follow up services.
Email: DOS-deanofstudents@arizona.edu
Phone: 520-621-7057

Survivor Advocacy Program
https://survivoradvocacy.arizona.edu/
The Survivor Advocacy Program provides confidential support and advocacy services to student survivors of sexual and gender-based violence. The Program can also advise students about relevant non-UA resources available within the local community for support.
Email: survivoradvocacy@arizona.edu
Phone: 520-621-5767

Campus Pantry
Any student who has difficulty affording groceries or accessing sufficient food to eat every day, or who lacks a safe and stable place to live and believes this may affect their performance in the course, is urged to contact the Dean of Students for support. In addition, the University of Arizona Campus Pantry is open for students to receive supplemental groceries at no cost. Please see their website at: *campuspantry.arizona.edu* for open times.

Preferred Name & Pronoun

This course affirms people of all gender expressions and gender identities. If you prefer to be called a different name than what is on the class roster, please let me know. Feel free to correct instructors on your preferred gender pronoun. If you have any questions or concerns, please do not hesitate to contact me directly in class or via email (instructor email). If you wish to change your preferred name or pronoun in the UAccess system, please use the following guidelines:

Preferred name: University of Arizona students may choose to identify themselves within the University community using a preferred first name that differs from their official/legal name. A student's preferred name will appear instead of the person's official/legal first name in select University-related systems and documents, provided that the name is not being used for the purpose of misrepresentation. Students are able to update their preferred names in UAccess.

Pronouns: Students may designate pronouns they use to identify themselves. Instructors and staff are encouraged to use pronouns for people that they use for themselves as a sign of respect and inclusion. Students are able to update and edit their pronouns in UAccess.

Information on updating your preferred name and pronouns is available from the Office of the Registrar: https://registrar.arizona.edu/records-enrollment/personal-information/updating-personal-information.

Safety on Campus and in the Classroom

For a list of emergency procedures for all types of incidents, please visit the website of the Critical Incident Response Team (CIRT): https://cirt.arizona.edu/case-emergency/overview
You may also watch the video that is part of the *Active Shooter Preparedness Training*, available at https://arizona.sabacloud.com/Saba/Web_spf/NA7P1PRD161/common/learningeventdetail/crtfy0000000000003560

Confidentiality of Student Records

You have a right to privacy concerning your academic records, which includes your activities, assignments, and performance in this class. You can find more information at http://www.registrar.arizona.edu/ferpa

Subject to Change Statement

Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.