



CSCI 624: Automata Theory, Logic, and Formal Verification

Units: 4.0

Spring 2026 — 230mins once weekly

Location: TBD

Instructor: Jyotirmoy V. Deshmukh

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Office Hours: 11:00am-1pm TuTh

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Catalogue Description

Omega-Regular Languages, Automata over infinite words and trees, Logic and Automata for timed languages, First-order Logic and Monadic Second Order Logic, Mu Calculus, Probabilistic Logics and Model Checking.

Course Description

Complex software systems are everywhere. How do we reason about the correctness of software programs, from distributed message-passing programs to shared-memory concurrent programs to autonomous cyber-physical systems? The area of formal verification provides you with tools that allow you to express the correctness of software programs in a mathematically precise fashion and algorithms that can check for correctness, often with minimal human intervention or input.

This course will provide you with the necessary background to reason about topics such as correctness of sequential and concurrent programs and requirement formalisms based on mathematical logic and automata theory. We will examine the theory and algorithms for formal verification in discrete software programs, hybrid dynamical systems, multi-agent systems, and AI-based systems. This course is meant to be a depth course that focuses on the theoretical considerations surrounding decision procedures in automata theory and logical formalisms.

Learning Objectives

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

- Construct and analyze automata over infinite words and trees to model system behaviors and reason about acceptance, expressiveness, and decidability.
- Apply automata-based methods to formally specify, verify, and analyze complex software and real-time systems.
- Translate between logical and automata-based formalisms and use these translations to design algorithms for specifying, verifying, and synthesizing systems.
- Evaluate the theoretical limitations and practical challenges of formal verification techniques and select appropriate methods for given classes of systems and properties.
- Apply theoretical concepts from algebraic foundations of automata and logic to problems in single-agent and multi-agent autonomous systems.

Prerequisite(s)

CSCI 570: Analysis of Algorithms

Recommended Preparation

Big-O notation, algorithm analysis, propositional and first-order logic (CSCI 170), software development (CSCI 270), and complexity theory (CSCI 475). Software verification and program analysis/synthesis (CSCI 610 or CSCI 625) is preferred, but not required.

Course Notes

Grading type: Letter grade

Course Structure. Teaching will be accomplished through lectures. The course will have 4 written homework assignments through the semester, and a final paper/project. Lecture notes will be made available on the course website.

Technological Proficiency and Hardware/Software Required

Students will be expected to type answers to homework assignments using some word processing software and submit a PDF. While any word processing software is permitted, proficiency in LaTeX is highly encouraged. Students are encouraged to use websites such as <https://www.overleaf.com/> to compose their documents in LaTeX.

Required Readings and Supplementary Materials

The course will cover material from the following textbooks/handbook chapters:

- 1) **BK:** Principles of Model Checking by Christel Baier and Joost Pieter Katoen, MIT Press, ISBN: 9780262267564
- 2) **EAE:** E. Allen Emerson. Temporal and Modal Logic. *Handbook of Theoretical Computer Science, Volume B: Formal Models and Semantics* 1990, J. van Leeuwen, ed., North-Holland Pub. Co./MIT Press, Pages 995-1072. ISBN: 9780262220392
- 3) **MP:** Manna,Z., Pnueli, A.:Temporal Logic of Reactive Systems, Springer Verlag. ISBN: 9781461242222
- 4) **WT:** Thomas, Wolfgang. "Languages, automata, and logic." In *Handbook of Formal Languages: Volume 3 Beyond Words*, pp. 389-455. Springer Berlin Heidelberg, 1997. ISBN:3540606491
- 5) **AI:** Principles of Cyber-Physical Systems. MIT Press. ISBN 9780262328449

Some lectures will cover material from handouts that will be made available on the course website.

Description of Assignments and How They Will Be Assessed

Written Assignments: There will be 4 written assignments that will test the theoretical understanding of the techniques and algorithms introduced. Each assignment will consist of four questions of increasing level of difficulty.

Structure:

- 1) Level A: These questions will test basic understanding of a theoretical concept and will be based on examples covered in the lecture.
- 2) Level B: These questions will require students to formulate a novel algorithm, logic, or automata type to specify some system type not covered in the lectures.
- 3) Level C: These questions will require students to give a mathematical proof of some theorem based on principles taught in the class.
- 4) Level D: These questions will require students to exercise considerable amount of critical thinking and utilizing concepts introduced across several lectures. These questions will often be optional and provided as extra credit opportunities.

Rubric: Homework assignments will be graded for correctness of answers and provided explanation/proofs. Partial credit will be given wherever applicable.

Final Paper/Project: The students are expected to propose one of the following: (1) an original problem in the field of automata, logic, or formal verification, (2) an original approach to solve an existing problem, (3) a software tool containing a novel implementation of an existing approach or an existing tool applied to novel case studies with appropriate comparisons to the state-of-the-art. Final papers and projects will be evaluated on the following metrics: (1) Technical Novelty, (2) Presentation Quality, (3) Technical Impact, (4) Depth/Breadth of Results, (5) Survey of related work in the literature.

Participation

The class will use Piazza for online discussions related to the concepts covered in the class. Students will be expected to: (1) ask questions during in-class lectures, (2) participate in discussions during class, and (3) participate in discussions on Piazza. There is no credit for participation.

Grading Breakdown

Category		Points	% of Grade	
Written Assignments	HW1	100	15	70
	HW2	100	20	
	HW3	100	15	
	HW4	100	20	
Final Project	Presentation	100	5	30
	Report	100	25	
TOTAL				100

Grading Scale

Grading will be based on the distribution of final weighted scores. Roughly, the students within 80% of the top score will receive an A, within 70% of the top score will receive an A-, within 65% will receive a B+, within 60% will get a B, within 55% will get a B-, and within 50% will get a C, within 40% will get a D, and below that will receive an F.

Assignment Submission Policy

Assignments are expected to be turned in to the instructor/TA by 11:59.59pm Pacific Time on the deadline. There will be a 10% penalty for assignments late up to 7 days. Assignments submitted 7 days after the deadline will be returned with a zero grade.

Course-Specific Policies

Students are expected to demonstrate understanding for missed classes in the subsequent classes.

Attendance

Students are expected to attend lectures unless excused for approved health reasons, excused travel to conferences or for any other university-related events.

Academic Integrity for this Class

Unless otherwise noted, this course will follow the expectations for academic integrity as stated in the [USC Student Handbook](#). The general USC guidelines on Academic Integrity and Course Content Distribution are provided later in this syllabus.

The policies for this class are as follows:

- Collaboration: Student collaboration is permitted for assignment questions of type C or D. Students should clearly mark the names of the collaborators on submitted assignments. Collaboration is limited to groups of 3 students, and the grade will be shared equally among the collaborators. Limited collaboration is also permitted for final papers/projects subject to instructor approval. Students may seek to work in a team (of at most 3 students) for the final project/paper if the scope of the project/paper is sufficiently ambitious. Students should clearly identify individual contributions in a team project/paper. Collaborative projects will be expected to be longer in scope or technically more challenging than single-person projects.
- Student found responsible for an academic violation will receive grade penalties.

Class Recordings and Course Content Distribution: You may not record this class without the express permission of the instructor and all other students in the class. Distribution of any notes, recordings, exams, or other materials from a university class or lectures — other than for individual or class group study — is prohibited without the express permission of the instructor; violations will be considered an intentional act to facilitate or enable academic dishonesty and reported to the university.

Use of Generative AI in this Course

Generative AI is permitted but limited as follows: In this course, you are permitted to use artificial intelligence (AI)-powered programs to help you. All the homework assignments in this course will require providing proofs of mathematical theorems, logical arguments, or algorithms. Arguments that are logically invalid will not receive points irrespective of whether they are generated by humans or generative AI tools. The students are permitted to try generative AI models to answer homework questions (with the acknowledgment that they have used it). However, we warn that generative AI does not do well at logical reasoning and is likely to give incorrect answers. If you do use generative AI, please explain in detail why you think the output of the generative AI models is correct/incorrect, and if incorrect, suggest a correction. Directly copying the answers of a generative AI tool without an accompanying argument about why the output is correct/incorrect will result in the question receiving **zero** credit.

- You should also be aware that AI text generation tools may present incorrect information, biased responses, and incomplete analyses; thus, their answers may not meet the standards of this course.

- To adhere to our university values, *you must cite any AI-generated material (e.g., text, images, and other content) included or referenced in your work and provide the prompts used to generate the content.* Using an AI tool to generate content without proper attribution will be treated as plagiarism and reported to the Office of Academic Integrity. Please use the guidance from: [USC Libraries AI Generators Citation Guidance](#) to cite the use of Generative AI tools.
- Students will be held accountable for AI's tendency toward *hallucination* if the text generated has illogical/unsound mathematical arguments, and if the student answers do not point these instances out to the instructor/TA.
- AI is a tool, but one that you need to acknowledge using. Please *include a paragraph at the end of any assignment explaining if, how, and why you used AI and indicate/specify the prompts you used to obtain the results.* Failure to do so is a violation of academic integrity policies.

Course Evaluations

Students will be encouraged to perform end-of-semester course evaluations when the evaluation window is open. The evaluations will help the instructor tune the content and difficulty of the course and should be used to suggest topics to be added/dropped from the syllabus.

Course Schedule

	Topics/Daily Activities	Due Dates	Readings ¹
Week 1	Modeling Concurrent/Distributed Systems as Labelled Transition Systems		BK 1,2; MP 0
Week 2	Deductive Verification, and Formalizing Safety, Liveness, and Fairness		BK 2, 3 MP 1, 2
Week 3	Linear Temporal Logic, ω -regular languages, Automata on Inifinite Words, Automata-theoretic Verification	HW1 posted	BK 5, MP 2, 3, Al 5
Week 4	Computation Tree Logic, Automata on Infinite Trees, and Symbolic Model Checking		EAE, BK 6
Week 5	Abstraction-Refinement, Trace Equivalences	HW1 due	BK 7, 8
Week 6	Alternating Automata and the Mu Calculus	HW2 posted	EAE, WT
Week 7	Project Proposal Presentations		
Week 8	First Order Logic, Monadic Second Order Logic, Modal and Dynamic Logics	HW2 due	Course Notes
Week 9	Timed and Hybrid Automata, Reachability for timed/hybrid automata	HW3 posted	BK 9, Al 9
Week 10	Timed Logics (MTL, TPTL, STL): Decision Problems and Complexity		BK 9, Handout
Week 11	PCTL, Markov chains and Probabilistic Model Checking	HW3 due	BK 10
Week 12	Statistical Model Checking	HW4 posted	Handout
Week 13	Runtime Verification and Spatio-temporal logics		Handout

¹ Numbers indicate chapter numbers in the respective textbooks.

Week 14	Runtime Shielding and Safe Reinforcement Learning	HW4 due	Handout
Week 15	Final Project Presentations		
FINAL	Final Paper	Final Papers due on university-scheduled date of the final exam. Refer to the final exam schedule in the USC Schedule of Classes at www.usc.edu/soc	

Academic Integrity

The University of Southern California is foremost a learning community committed to fostering successful scholars and researchers dedicated to the pursuit of knowledge and the transmission of ideas. Academic misconduct — which includes any act of dishonesty in the production or submission of academic work (either in draft or final form) — is in contrast to the university's mission to educate students through a broad array of academic, professional, and extracurricular programs.

This course will follow the expectations for academic integrity as stated in the [USC Student Handbook](#). All students are expected to submit assignments that are their own original work and prepared specifically for this course and section in this academic term. You may not submit work written by others or “recycle” work prepared for other courses without obtaining written permission from the instructor(s). Students suspected of engaging in academic misconduct will be reported to the Office of Academic Integrity.

Other violations of academic misconduct include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

Academic dishonesty has a far-reaching impact and is considered a serious offense against the university. Violations will result in a grade penalty, such as a failing grade on the assignment or in the course, and disciplinary action from the university itself, such as suspension or even expulsion.

For more information about academic integrity see the [student handbook](#) or the [Office of Academic Integrity's website](#), and university policies on [Research and Scholarship Misconduct](#).

Please ask your instructor if you are unsure what constitutes unauthorized assistance on an exam or assignment or what information requires citation and/or attribution.

Course Content Distribution and Synchronous Session Recordings Policies

USC has policies that prohibit recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Recording a university class without the express permission of the instructor and announcement to the class, or unless conducted pursuant to an Office of Student Accessibility Services (OSAS) accommodation. Recording can inhibit free discussion in the future, and thus infringe on the academic freedom of other students as well as the instructor. ([Living our Unifying Values: The USC Student Handbook](#), page 13).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which had been distributed to students or in any way had been displayed for use in relation to the class, whether obtained in class, via email, on the internet, or via any other media. Distributing course material without the instructor's permission will be presumed to be an intentional act to facilitate or enable academic dishonesty and is strictly prohibited. ([Living our Unifying Values: The USC Student Handbook](#), page 13).

Statement on University Academic and Support Systems

Students and Disability Accommodations:

USC welcomes students with disabilities into all of the University's educational programs. [The Office of Student Accessibility Services](#) (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at osas.usc.edu. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Student Financial Aid and Satisfactory Academic Progress:

To be eligible for certain kinds of financial aid, students are required to maintain Satisfactory Academic Progress (SAP) toward their degree objectives. Visit the [Financial Aid Office webpage](#) for [undergraduate](#)- and [graduate-level](#) SAP eligibility requirements and the appeals process.

Support Systems:

[Counseling and Mental Health](#) - (213) 740-9355 – 24/7 on call

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

[988 Suicide and Crisis Lifeline](#) - 988 for both calls and text messages – 24/7 on call

The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline consists of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

[Relationship and Sexual Violence Prevention Services \(RSVP\)](#) - (213) 740-9355(WELL) – 24/7 on call

Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

[Office for Equity, Equal Opportunity, and Title IX \(EEO-TIX\)](#) - (213) 740-5086

Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

[Reporting Incidents of Bias or Harassment](#) - (213) 740-2500

Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

[The Office of Student Accessibility Services \(OSAS\)](#) - (213) 740-0776

OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

[USC Campus Support and Intervention](#) - (213) 740-0411

Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

[Diversity, Equity and Inclusion](#) - (213) 740-2101

Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

[USC Emergency](#) - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call

Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

[USC Department of Public Safety](#) - UPC: (213) 740-6000, HSC: (323) 442-1200 – 24/7 on call

Non-emergency assistance or information.

[Office of the Ombuds](#) - (213) 821-9556 (UPC) / (323)-442-0382 (HSC)

A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

[Occupational Therapy Faculty Practice](#) - (323) 442-2850 or otfp@med.usc.edu

Confidential Lifestyle Redesign services for USC students to support health-promoting habits and routines that enhance quality of life and academic performance.