CSCI 699 : Theory of Machine Learning
Units: 4
Fall 2023 Mondays 2-5:20pm

Instructor: Vatsal Sharan
Office Hours: TBD
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Course Description

This course focuses on the theoretical foundation of machine learning. The focus will be on understanding fundamental questions regarding both computational and statistical aspects of learning, with an overarching goal to answer the core question: what is the complexity of learning, in terms of its computational and statisitical requirements? The course will also cover several modern aspects of the theory of maching learning---including memory complexity of learning, robustness, and fairness.

Learning Objectives

The goal of this course is to understand when and why machine learning works from a mathematical aspect. The hope is that through the training of this course you will think about machine learning in a more rigorous and principled way and have the skills to design provable and practical machine learning algorithms, which also work in the face of various computational and statistical constraints. The course will also equip you with the tools required to undertake research in theoretical machine learning, and will shed light on various interesting research frontiers.

Prerequisite(s): familiarity with probability, linear algebra, calculus, and analysis of algorithms. Some basic understandings of machine learning would be very helpful.

Required Readings and Supplementary Materials

There are no required textbooks. Relevant (optional) reading material for all lectures will be posted in advance. Some relevant books:

- Michael Kearns and Umesh Vazirani. An Introduction to Computational Learning Theory. MIT Press
- Percy Liang's course notes for CS229T (Stanford)

Description and Assessment of Assignments

There will be weekly assignments. Collaboration is allowed but must be stated. Grades are based on correctness. Must be written in Latex.

There will also be final project on a short survey of a particular topic in learning theory. The project includes two parts: one 20-30 minutes presentation near the end of the semester, and a final report written in Latex.

Grading Breakdown

Assessment Tool (assignments)	% of Grade
Weekly assignments (10 weeks)	50
Final project presentation	25
Final project report	25
TOTAL	100

Assignment Submission Policy

Via email.

Grading Timeline

All assignments will be graded and feedback provided within one week of submission.

Course Schedule: A Weekly Breakdown

Assignments will be posted every Wednesday starting the first week of class and will be due by next Friday. There is no mandatory reading for the lectures, optional reading material will be posted in advance of the lecture.

	Topics/Daily Activities
Week 1	Introduction; statistical learning; PAC learning; Proper vs improper learning; online learning
Week 2	Uniform convergence; finite hypothesis class; concentration inequalities; Sub Gaussian random variables
Week 3	Rademacher complexity; neural networks
Week 4	VC dimension; covering techniques; Sauer's lemma; Regression: covering number; chaining technique
Week 5	Kernel methods; Reproducing Kernel Hilbert Spaces (RKHS); Learning using kernels; Efficient computation
Week 6	Online learning; online convex optimization; Follow the Leader (FTL) algorithm and Follow the Regularized Leader (FTRL) algorithm
Week 7	Computational learning theory; Computational Complexity (Background);
Week 8	Learning in the presense of noise; SQ Learning; Agnostic Learning
Week 9	Fourier analysis and learning; Learning Parities with noise; Learning Juntas
Week 10	Complexity-theoretic and cryptographic hardness of learning
Week 11	Memory complexity of learning; Memory-sample tradeoffs for learning
Week 12	Robustness in ML algorithms; Adversarial robustness; Robustness to distributional shifts
Week 13	Fairness and calibration for prediction algorithms
Week 14	Student presentations
Week 15	Student presentations
FINAL	Final Project Report due on university-scheduled date of the final exam

Statement on Academic Conduct and Support Systems

Academic Integrity:
The University of Southern California is a learning community committed to developing successful scholars and researchers dedicated to the pursuit of knowledge and the dissemination of ideas. Academic misconduct, which includes any act of dishonesty in the production or submission of academic work, comprises the integrity of the person who commits the act and can impugn the perceived integrity of the entire university community. It stands in opposition to the university's mission to research, educate, and contribute productively to our community and the world.

All students are expected to submit assignments that represent their own original work, and that have been prepared specifically for the course or section for which they have been submitted. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s).

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

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university. All incidences of academic misconduct will be reported to the Office of Academic Integrity and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

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.

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.

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 is comprised 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) 740-5086 or (213) 821-8298*
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.