USC Viterbi

Ming Hsieh
Department of Electrical and Computer Engineering

EE 599 Machine Learning IIB: Learning Realms and Algorithms

2 units

Fall 2024

Times and Days

Lecture: Wednesday 12:00 – 1:50 PM

Discussion session: Friday 3:00 – 3:50 PM

Location: WPH B36

Course Contact Information

Instructor

Prof. B. Keith Jenkins
Office: EEB 404A
Email: bjenkins@usc.edu [please include "EE 599" in the subject line]
Phone: (213) 740-4149
Office hours: TBD. Office hours will be available in person and over zoom, unless announced otherwise. Zoom link will be provided on the Brightspace Course Calendar, and location will be announced.

Teaching Assistant(s)

Thanos Rompokos
Contact info TBA

Grader(s)

TBD

IT Help

For help with coding machine-learning algorithms, consult piazza, online forums, or the TA(s);

for help with other Python coding, working with datasets, or using library routines in Python, also try online help and documentation;

for help with USC-supplied software or on-campus networking, consult USC ITS at https://itservices.usc.edu/contact/ ;

for help with Brightspace, consult https://www.brightspacehelp.usc.edu/students/, email usc@d2l.com, or call 888-895-2812; for USC-specific Brightspace help, consult brightspace@usc.edu or 213-740-5555 (Students dial 1; Instructors dial 2).

Instructor reserves the right to make minor changes to the course timing, schedule and content to meet the needs and interests of students as appropriate. Also, minor changes to the grading breakdown might be made near the beginning of the semester.

Course Description

Sequel to EE 559: Statistical and tree-based models for supervised learning; models for partially supervised and unsupervised learning. Methods and degrees of human interpretability.

Students will develop an appreciation of different machine learning realms; value of, and techniques for, human interpretability; and an overall sense and understanding of the subtleties that can enable machine learning algorithms to generalize well and be trustworthy.

Intended for MS and PhD students in ECE and related Viterbi departments.

Learning Objectives

After successfully completed this course, the student will be able to:

(1) Analyze and apply machine learning (ML) models and algorithms in different learning realms (supervised, semi-supervised, unsupervised);

(2) Understand and apply techniques for human interpretability of ML models and algorithms;

(3) Evaluate other current and future ML models as they are created.

Relation to Other EE Machine Learning Classes

There are 2 EE classes that are set up as follow-ons to EE 559. EE 660 (Prof. Stephen Tu, 4 units) covers a general theoretical treatment of machine learning, providing a unified framework for most or all of machine learning, and its application to different models of machine learning. This new EE 599 class covers machine learning *algorithms* for different machine learning realms, and their practical use. This EE 599 may be taken independently of EE 660, and is a good complement to the EE 660 material.

Two other related classes are EE 541 and EE 641, both of which are focused on deep learning. These classes are complementary to the 3 classes mentioned above.

Note to MSECE Machine Learning and Data Science Program Students

This EE 599 class will qualify as a Learning and Data Analytics class.

Preparation

Prerequisite: EE 559.

Recommended preparation: Experience with Python 3 at the level of EE 541 or EE 559, including the use of modules, functions, classes, and OOP. Also material covered only in EE 559 Fall 2021 and later, including regression, radial basis function networks, K-means clustering, and computational complexity.

Course Notes and Software Requirements

Brightspace will be the main source for posting and receiving class materials:

https://brightspace.usc.edu/

The site includes:

- Course materials (handouts, homework assignments and solutions, lecture and discussion notes, instructor supplied reading materials), which will be posted as we progress through the semester;
- Link to our discussion forum (piazza);
- Course calendar, showing lectures, discussion sessions, and office hours;
- Grade book, showing your scores on assignments to date;
- Dropboxes for uploading your completed assignments, and links for viewing and retrieving your graded assignments.

Computer software requirements

Students are required to use Python 3 for the coding of all assignments. All students will be responsible for installing and maintaining their own Python distribution (e.g., from

https://www.anaconda.com/products/individual).

Python software packages will be used for some of the homework computer problems, including NumPy, pandas, SciPy, matplotlib, and scikit-learn.

Course Outline

[x] = approximate number of lectures

Introduction [1]

1. Learning realms

   Supervised, semi-supervised, unsupervised, interpretable

2. Course administrative info and syllabus.

Supervised learning [4]

3. Logistic regression [0.5]

   Cross-entropy error; maximum likelihood.

4. Graphical techniques for supervised learning [2.75]

   Classification and regression trees (CART);
   Bagging and boosting;
   Random forest;
   Adaboost.

5. Overfitting [0.75]

   Deep dive into overfitting

Midterm quiz [0.5]

Semi-supervised learning [3]

6. Introduction and models 1 [2]

   Overview, assumptions;
   Self-training algorithms;
   Mixture models and expectation maximization.

7. Models 2 [1]

   Co-training; graphical techniques; semi-supervised SVM.

Unsupervised learning [3]

8. Statistical techniques [1.5]

   Maximum likelihood, expectation maximization.

9. Nonstatistical techniques [1]

   Similarity measures; hierarchical and graphical techniques.

10. Evaluating cluster quality and choosing *K* [0.5]

Human interpretability [2.5]

11. Human interpretability overview [2.5]

    Using interpretable models; taxonomy of methods;
    Intrinsic interpretable models; model agnostic methods; example-based explanations.

Course conclusions [1]

12. Implications from learning theory and elsewhere [0.5]

    Occam's Razor, Axiom of Non-Falsifiability, Data snooping, Sampling bias

12. Course wrap-up and review [0.5]

Textbooks, Reading Materials, and Other Resources

Required textbooks and reading materials

Assigned readings (and some exercises) are selected from the reference sources listed below. They are all available for free download or viewing. [1]-[5] will be used in the order listed below.

1. Kevin P. Murphy, *Probabilistic Machine Learning: An Introduction* (MIT Press, Cambridge, 2022), ISBN 9780262046824; https://probml.github.io/pml-book/book1.html . Now available for purchase in hardcopy and e-book form; also the latest pre-print is available for free download at the above link. (This book has some of the topics and required readings for EE 599; it also covers many of the EE 559 topics so can provide a good review or reference.)

2. Xiaojin Zhu and Andrew B. Goldberg, *Introduction to Semi-Supervised Learning* (Synthesis Lectures on Artificial Intelligence and Machine Learning, Morgan and Claypool Publishers, 2009). Available for download through USC Library at:

   https://uosc.primo.exlibrisgroup.com/discovery/fulldisplay?context=L&vid=01USC_INST:01USC&search_scope=MyInstitution&tab=LibraryCatalog&docid=alma991044141158203731 (requires USC login).

3. Rui Xu and Donald Wunsch II, "Survey of Clustering Algorithms", IEEE Trans. Neural Networks, Vol. 16, No. 3 (May 2005). A link will be provided on the course web site.

4. Christoph Molnar, *Interpretable Machine Learning: A Guide for Making Black Box Models Explainable*, Second Ed., 2024. https://christophm.github.io/interpretable-ml-book/ .

5. Mengnan Du, Ninghao Liu, Xia Hu, "Techniques for Interpretable Machine Learning", arXiv:1808.00033v3 [cs.LG] 19 May 2019: https://arxiv.org/abs/1808.00033.

6. Instructor-provided notes and materials that will be posted on the course web site.

Supplementary books for your information

i. T. Hastie, R. Tibshirani, and J. Friedman, *The Elements of Statistical Learning: Data Mining, Inference, and Prediction*, Second Edition (Springer, 2009). 12th printing available for download at https://hastie.su.domains/ElemStatLearn/printings/ESLII_print12.pdf (Excellent book as a second resource, especially for graphical/tree based techniques in supervised learning.)

ii. Yaser S. Abu-Mostafa, Malik Magdon-Ismail, and Hsuan-Tien Lin, L*earning From Data* (AMLbook.com, 2012). (Very readable introduction to machine learning theory of generalization.) (Available from Amazon.)

iii. Kevin P. Murphy, *Probabilistic Machine Learning: Advanced Topics* (MIT Press, Cambridge, 2023); Preprint https://probml.github.io/pml-book/book2.html. Also available for purchase from Amazon and MIT Press. (Covers a plethora of ML topics for further exploration if you're interested. It does include a few of the topics of EE 599; however the required EE 599 readings are in other references.)

iv. Kevin P. Murphy, Machine Learning: A Probabilistic Perspective (MIT Press, Cambridge, 2012). (Forerunner of Murphy's second edition books; this first edition often has more detail of the topics, although tends to be less pedagogical.)

v. M Mohri, A. Rostamizadeh, and A. Talwalkar, *Foundations of Machine Learning*, second edition (MIT Press, Cambridge, 2018). (Good for a more theoretical viewpoint, and has extensions of treatments in [ii] above.)

vi. C. M. Bishop, "Pattern Recognition and Machine Learning" (Springer, 2006). (EE 559 textbook.)

vii. R. O. Duda, P. E. Hart, and D. G. Stork, , *Pattern Classification,* Second Edition (Wiley-Interscience, John Wiley and Sons, Inc., New York, 2001) (Classical book on pattern classification, with excellent treatment of many of its topics.)

viii. Ian Goodfellow, Yoshua Bengio, and Aaron Courville, *Deep Learning* (MIT Press, Cambridge, 2016). (Good introduction of deep learning, but missing some of the most recent techniques.)

Description and Assessment of Assignments

Homework assignments

There will be one homework assignment approximately every 2 weeks. Assignments will generally include some pencil-and-paper problems and some computer-coding problems.

Overall approximately 50% of your homework time will be devoted to computer-coding problems. Note that for some homework computer-coding problems, you will be required to code up the problem yourself, without the use of libraries or software packages. For other homework computer problems, you will be encouraged to use libraries or packages. Each homework problem will specify what packages are recommended and allowed. All coding for homework problems will be done in Python 3.

Quiz and exam

Midterm quiz will be on campus (in person) and will be 1 hour in length, short-answer questions.

Final exam will be on campus (in person), 2 hours in length: 1 hour on short-answer questions (covering primarily second half of semester), and 1 hour on long-answer questions (covering entire semester).

Final exam will take place on the date and time given by the university's official final examination schedule at https://classes.usc.edu/term-20243/final-examinations-schedule/ .

Grading Breakdown

This class will be graded on the curve.

Table 1. Grading breakdown.

Assignment	Weight (%)
Homework	30
Midterm quiz	30
Final exam	40
TOTAL	100

Assignment Submission Policy

The due date will be listed on each homework assignment. Each homework assignment is to be submitted by uploading 2 files to Brightspace: (1) a pdf file of your answers to all homework questions, in the same order as in the homework assignment; and (2) a computer-readable pdf file of all your code. Late submission policy will be posted at the beginning of the semester.

Grading Timeline

Assignments, quizzes, and exams will be graded as soon as possible, typically within 2 weeks of due date.

Policy on Collaboration and Individual Work in this Class

Collaboration on techniques for solving homework assignments and computer problems is allowed, and can be helpful; however, each student is expected to work out, code, and write up his or her own solution. Use of other solutions to homework assignments or computer problems, from any source including other students, before the assignment is turned in, is not permitted.

Of course, collaboration on quizzes and exams is not permitted.

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 is in contrast to the university's mission to educate students through a broad array of first-rank academic, professional, and extracurricular programs and includes any act of dishonesty in the submission of academic work (either in draft or final form).

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 original work and prepared specifically for the course/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.

Policy on use of AI tools in this class

Generally, AI Tools (including generative AI and large-language models) used to compose (in part or in whole) homework solutions or any other assignments, must be cited and referenced. Failure to clearly indicate and reference such material amounts to plagiarism and will be penalized.

AI Tools can be useful in the learning process, if used in an appropriate, fair, and ethical way. Part of the learning process is learning how to develop and test your own ideas, and using AI Tools in an inappropriate way can short-circuit this process and leave you unable to perform later in your studies and career.

A more detailed and complete description of appropriate and allowed use of AI Tools in this class will be posted separately at the beginning of the semester; it is also included below in the appendix.

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. This includes the following activities.

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 dishonestly and is strictly prohibited. (Living our Unifying Values: The USC Student Handbook, page 13).

Course Weekly Schedule

See next page. Actual schedule may be changed somewhat depending on student reception and interests, holidays, etc.

Timing (approximate)	Topic	Subtopic	No. of lectures	Readings/Preparation
Week 1	Introduction	Learning realms; course administrative info and syllabus.	1	
Week 2, Week 3 (first half)	Supervised learning	Logistic regression; graphical techniques 1 (CART)	1.5	[1] Sec. 10.1-10.3 [1] Sec. 18.1
Week 3 (2nd half), Week 4, Week 5 (first 4th)	Supervised learning	Graphical techniques 2 (bagging, boosting, random forest, Adaboost)	1.75	[1] Sec. 18.2 - 18.6
Week 5 (remaining ¾)	Supervised learning	Overfitting: deep dive	0.75	[6]
Week 6, Week 7	Semi-supervised learning	Overview, assumptions; models 1 (self-training, mixture models and EM)	2	[2] Ch. 2 - 3
Week 8 (1st half)	Midterm quiz		0.5	
Week 8 (2nd half), Week 9 (1st half)	Semi-supervised learning	Models 2 (co-training, graphical techniques, semi-supervised SVM)	1	[2] Ch. 4 - 6
Week 9 (2nd half), Week 10	Unsupervised learning	Statistical techniques (maximum likelihood, EM)	1.5	[3] Sec. IID
Week 11	Unsupervised learning	Nonstatistical techniques (similarity, hierarchical and graphical techniques)	1	[3] Sec. IIA,B,E
Week 12 (1st half)	Unsupervised learning	Evaluating cluster quality and choosing K	0.5	[3] Sec. IIM; [3] Sec. IIIA, B (optional)
Week 12 (2nd half)	Human interpretability	Using interpretable models	0.5	[4] Ch. 2
Week 13	Human interpretability	Taxonomy of methods; intrinsic interpretable models	1	[4] Ch. 3-5 [5] read lightly
Week 14	Human interpretability	Model-agnostic methods; example-based explanations	1	[4] Ch. 6-7, Sec. 8.0-8.3, 9.0-9.3
Week 15 (1st half)	Implications from learning theory and elsewhere	Occam's Razor, Axiom of Non-Falsifiability, Data snooping, Sampling bias	0.5	[6]
Week 15 (2nd half)	Course wrap-up and review		0.5	
FINAL EXAM				Refer to the final exam schedule in the *USC Schedule of Classes* at classes.usc.edu.

Statement on Academic Conduct 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.

Appendix: Policy on Use of AI Tools Including Generative AI

The ability to think creatively and originally, as well as analytically and critically, are important parts of learning in this class and in science and engineering generally. Learning from other resources can also help you acquire knowledge. In order to balance these approaches, in this class we will encourage and enforce the following policy on use of AI tools (such as generative AI tools like ChatGPT and other AI assistants).

Appropriate use of AI tools. In exploring concepts and approaches in machine learning (ML) in this class, you may find it useful to look online for information. This may include posing questions to a generative AI tool. In doing this, it is recommended to first consider the question yourself (or yourself and a few classmates in a learning group); the ability to explore new ideas or questions, and analyze them critically and creatively, are important skills to acquire, and these are best acquired by trying. After some of this analysis and thinking, you may find it useful to consult a generative AI tool to see it's response. Keep in mind that any generative AI response may sound convincing initially but may in fact be wrong, so analyzing its response will also need some critical thinking on your part.

Inappropriate use of AI tools. Use of these tools to solve homework problems, quiz, exam or exam-assignment problems, or some of the work of a course project (if applicable), are prohibited. These assignments are intended to help you learn the course material by having you think through how to solve a problem or analyze a result. In the case of quizzes and exams, they are designed to assess what you have learned and what you are capable of doing on your own. In both cases, use of AI tools will shot-circuit the intended purpose. This inappropriate use of AI tools amounts to plagiarism (using the AI tool's results as part of the work you are representing as your own work); when detected, this will result in penalties due to violations of academic integrity.

What about your future? Consider any of the following scenarios that are likely in your future: (i) you are interviewing for a job or for a PhD program; (ii) you are in your first job, presenting results of your work to your supervisor in person, and your supervisor is asking you questions about your work (e.g., how did you do this part; which method did you use for that part); (iii) you are presenting a proposal of future directions to take (to management at a company, or to funding agents for future research to pursue in academia or in a research lab), and they ask questions about your proposal during the presentation; (iv) you are giving a talk at a conference about work you have done, and people ask you probing questions about the work you did. In all these scenarios, you do not have the option of asking an AI tool before responding to the questions you are asked; you have to be able to develop an answer from your own knowledge and thinking ability.

Coding. While some generative AI tools are pretty good at coding, there is still the need for a person to check the code for accuracy and correctness, and especially to understand how the problem is being solved by the code provided (for example, to know in what cases the resulting outputs will be valid). So the person using the code must understand how to code well to be able to use the code reliably.

You may find AI tools useful in helping you with coding – for example, after you have written code to solve a task, you can see what code the AI tool comes up with, to see another approach. You can also have it help you with debugging. And, if you are coding and get stuck on how to code something or what function to use, you can ask the AI tool to get its opinion (notice the word "opinion"; don't assume its answer is always correct).

In our class, for solving assigned work you are expected to write your own code; using internet resources is OK to help you do so. The vast majority of the code you turn in should be written by you; if portions are taken from elsewhere, even if modified somewhat by you, you must cite the source in comments in the code, making it clear what portions were taken from elsewhere. Here also, violations amount to plagiarism and are subject to being penalized accordingly.

A short summary is given below.

In Summary

The above paragraphs give more detailed descriptions of what is allowed, prohibited, and why. Below is a brief summary for your convenience.

- AI tools including generative AI can help you learn if used in an appropriate way.
- AI tools can be a crutch that prevents you from learning if used excessively or in an inappropriate way.
- In this class you may find it beneficial to use AI tools to help you learn, and such use is fine.
- In this class using AI Tools in the following ways is prohibited:
    - to solve any assigned work;
    - to write any portion of your assigned solutions, even if you modify the AI tool's answers somewhat;
    - to write any portion of your code in assigned work, except for relatively small portions that are clearly cited in the comments as code that came from a source other than your own work (even if modified somewhat by you).