Fall 2024

AME 505:
Machine Learning for Engineering Applications

Department of Aerospace & Mechanical Engineering
University of Southern California

COURSE SYLLABUS

Instructor: Prof. Yan Jin
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Course Section:	28976R (campus) 28980D (den)
Course Unit:	4 Units
Prerequisite:	None
Class Hours:	Mon, Wed 12:00 – 1:50 pm
Class Location:	OHE-100B & DEN@viterbi
Office Hours:	Wed 3:00 -5:00 pm or by appointment. @ OHE-412C & Zoom
Teaching Assistant:	TBD

AME505:
Machine Learning for Engineering Applications

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Course Description

This graduate-level course is designed for students seeking to advance their expertise in Machine Learning with a focus on its applications in engineering domains. Geared towards individuals with a foundational understanding of machine learning principles, this course delves into advanced topics, enabling students to model intricate engineering challenges, employ a spectrum of cutting-edge algorithms including supervised, unsupervised, and reinforcement learning, apply statistical analysis techniques, harness the potential of evolutionary algorithms, grasp support vector machines and Bayesian learning, and explore the transformative potential of GPT (generative pretrained transformer) and large language models. Aspirationally, students will develop a profound appreciation for the role of Machine Learning in reshaping the future of engineering, equipping them with valuable skills that extend beyond the classroom, enriching their professional journeys, and fostering a lasting passion for the field.

Learning Objectives

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

- Identify and formulate real-world engineering problems where machine learning can provide innovative solutions and evaluate the impact of machine learning solutions on engineering processes.
- Analyze and interpret engineering data using advanced statistical methods, make informed decisions, and test hypotheses in practical applications.
- Implement supervised and unsupervised machine learning algorithms to model and solve complex engineering problems proficiently.
- Apply reinforcement learning techniques to optimize engineering processes and systems that can autonomously adapt and improve performance.
- Design and execute experiments utilizing evolutionary algorithms to optimize engineering designs and manufacturing processes.
- Develop practical applications of support vector machines, Bayesian learning, and large language models like GPT by leveraging these techniques for real-world engineering challenges and innovative solutions.

- Demonstrate effective communication and collaboration skills in interdisciplinary engineering teams and effectively convey machine learning concepts and solutions to both technical and non-technical stakeholders.
- Exhibit proficiency in staying current with the rapidly evolving field of machine learning by independently researching and exploring emerging trends and technologies.

Prerequisite(s): None

Co-Requisite(s): None

Concurrent Enrollment: None

Recommended Preparation: None

Course Notes

This course employs letter grading. Following each lecture, the lecture notes will be promptly accessible on the class online platform Brightspace. To foster active learning, our lectures will include classroom exercises where students collaboratively work in groups to solve small problems. The course is project-based, requiring students to form project teams and propose engineering topics of their interest. Upon approval by the instructor, teams will work together and apply machine learning techniques to create demonstrable solutions for their chosen project topics.

Technological Proficiency and Hardware/Software Required

Prerequisite hardware/software skills for this course include a fundamental proficiency in computer usage, including tasks such as downloading and installing software applications, along with familiarity in utilizing spreadsheet tools like Excel. Throughout the course, various software tools will be utilized, including the open-source machine learning and data mining toolkit Orange3,, the Python programming environment PyCharm, and the cloud-based Google Colab platform, all of which are readily accessible at no cost.

To enhance the learning experience, it is advisable for students to bring their laptops to class. This facilitates active participation in classroom exercises and enables quick access to specific websites during discussions. USC students in need of laptops can explore the USC Computing Center Laptop Loaner Program, while relevant software applications are available for download through the Software available to USC Campus.

Required Readings and Supplementary Materials

Mandatory for students in this course is the timely completion of assigned reading materials before the commencement of each week's lecture. To ensure accessibility, the course reader chapters for a specific week will be available online via Brightspace no less than one week prior to the scheduled lectures.

Optional Readings and Supplementary Materials

There are no optional reading and supplementary materials.

Grading Breakdown

The coursework for students includes the following: homework, quizzes, a midterm exam, and a course project. The following table shows the grading breakdown.

Assessment Tool (assignments)	% of Grade
Homework	30%
Quizzes	15%
Midterm exam	25%
Course project	30%
TOTAL	**100%**

Homework assignments:

Homework assignments are designed to encourage students to engage with the course material by probing designated chapters of the course reader in advance of class lectures. Typically, each homework assignment comprises 2-3 concise questions centered around key concepts, definitions, or methods covered in the reading material slated for the lectures in the week. These assignments serve a dual purpose: to facilitate a deeper understanding of the reading materials and to help students structure their thoughts for forthcoming class discussions and future practical applications. The overviews of the eleven (11) homework assignments are listed below.

Homework grading is structured as follows: Each homework assignment consists of 6 main topics, each worth 1 point. For each topic, the answer is assessed as "missing" (-1.0), "little effort and incorrect" (-0.75), "good argument, but incorrect"(-0.5), and "good argument, controversial" (-0.25).

Quiz assignments:

Weekly online quizzes will become available immediately after the second lecture on the class website (D2L or Blackboard). Each quiz must be completed before the commencement of the first lecture session of the subsequent week. These quizzes are designed to assess students' comprehension of the materials covered and discussed during the corresponding week's lectures. Below is a list of overviews of the ten (10) quizzes integral to the course.

Each quiz consists of four (4) questions, which may be in the form of multiple-choice or multiple-selection questions, each carrying a value of 1 point. The grading process is automated, and the online system promptly provides students with immediate feedback on their completed quiz questions.

Mid-term Exam:

The midterm exam is a comprehensive assessment designed to evaluate students' understanding of key course materials, encompassing topics such as statistical data analysis, data-mining, supervised and unsupervised learning, and reinforcement learning. This open-book exam permits students to access reading materials, lecture notes, and their personal class notes. However, it strictly prohibits internet access and the use of generative tools to ensure a fair and accurate assessment of student's knowledge and application of the subject matter.

Course Project:

In the course project, students will form teams of 3-5 members. Members of each team will work together to propose a project topic by choosing a specific engineering application problem. Throughout the project's lifecycle, student teams will engage in activities including problem identification and modeling, dataset collection or generation, and the development of robust machine learning and data analysis solutions. These project deliverables are expected to culminate in demonstrable software systems, encompassing essential components like GUI (graphical user interface), datasets, computing algorithm modules, and multiple test scenarios. This immersive course project offers students the unique opportunity to apply the theories, methods, and techniques of machine learning and data analysis acquired during the course to tackle authentic engineering application problems, bridging the gap between theory and real-world practice. The course project aligns with all learning objectives and makes a significant contribution to LO7, emphasizing collaboration and communication skills. Following is a form of course project description.

Assignment Submission Policy

Late submissions are not allowed. However, in exceptional circumstances, such as health or travel-related issues, late submissions may be considered if prior notification via email is provided.

Course-Specific Policies

There are no course-specific policies.

Attendance

Attendance will not impact course grades; however, as classes involve interactive exercises and Q&A sessions, in-person attendance is highly encouraged to maximize the learning experience**.**

Academic Integrity

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 in the subsequent "Statement on Academic Conduct and Support Systems" section.

For this class, you are expected to submit work that demonstrates your individual mastery of the course concepts. Unless specifically designated as a "group/team project," all assignments are expected to be completed individually.

If found responsible for an academic violation, students may be assigned university outcomes, such as suspension or expulsion from the university, and grade penalties, such as an "F" grade on the assignment, exam, and/or in the course.

Please ask the instructor and/or TA(s) if you are unsure about what constitutes unauthorized assistance on an exam or assignment, or what information requires citation and/or attribution.

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.

Use of Generative AI in this Course

In this course, you are permitted to use artificial intelligence (AI)--powered programs to help you by strictly following the instructions below:

- AI tools are permitted to help you brainstorm topics or **revise** (grammar check or language improvement) work you have already written.
- The use of AI tools to directly **generate** verbatim text for assignment submissions is strictly prohibited.
- In case a partial text of your submission is **generated** by AI tools, you must clearly **cite** such text in your work and provide the tool & 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.

Course Evaluations

At the end of the semester, a university-wide course evaluation allows students to provide valuable feedback on their experience in this class. Our course evaluation will be organized by a student coordinator elected by the class. A dedicated 15-minute session will be allocated for this purpose, and we strongly encourage all students to actively participate in the evaluation process.

Course Schedule

Week of	Monday Lecture	Wednesday Lecture	Readings Due	Quiz Due	HW Due
8/26	**Course Introduction** Engineering application challenges CE#0: Teaming	**Introduction to artificial intelligence and machine learning** CE#1: Discuss engineering apps & AI	Course Syllabus Ch1: Intro to AI/ML		
9/2	**Intro to statistics** Descriptive statistical analysis CE#3: Data generation & collection	**Intro to statistical analysis** Inferential statistical analysis CE#4: Data analysis	Ch2: Intro to statistical analysis	Quiz #1	HW #1
9/9	**Supervised learning & classification** Nearest neighbor method CE#5: Data analysis tool intro & kNN	**Decision tree approach** Classification result evaluation CE#6: Data analysis with decision tree	Ch3: Intro to Data Mining Ch4: Classification	Quiz #2	HW #2
9/16	Biological & computational neurons **Perceptron & neural network** CE#7: Data analysis w/ neural net	**Deep neural network**: Concepts Deep neural network: Methods CE#8: Data analysis w/ deep neural net	Ch5: Introduction to neural network	Quiz #3	HW #3
9/23	**Clustering concepts & methods** K-means approach to clustering CE#9: Data analysis w/ K-means	**Hierarchical clustering**: Concepts H-clustering algorithms & examples CE#10: Data analysis w/ H-clustering	Ch6: Cluster Analysis	Quiz #4	HW #4
9/30	**Collaborative filtering methodology** SVD & matrix factorization method CE#11: Recommender applications	**Rule-based machine learning** Association rule learning CE#12: Discuss team project topic	Ch7: Collab filtering Ch8: Assoc. analysis	Quiz #5	HW #5
10/7	**Intro to MDP and POMDP** Reinforcement learning introduction CE#13: MDPs in the real world	**RL Algorithm**: Policies & value functions Q-learning & applications CE#14: Applying Q-learning	Ch9: Intro to RL	Quiz #6	HW #6
10/14	**Midterm Exam**	• **Deep reinforcement learning** • RL application examples • CE#15: Solving problems with RL	Ch10: Deep RL	**Project proposal**	
10/21	**Python concepts,** structure, and frameworks	CE#16: Install and use PyCharm & Colab	Python, PyCharm docs	Quiz #7	HW #7
10/28	**Python common packages** & machine learning packages	CE#17: Programming ML in Python	Python, PyCharm docs		
11/4	**Python: GUI** & QtDesigner for apps	CE#18: Programming for your project	Python, PyCharm docs		
11/11	**Intro to evolutionary computing** Genetic algorithm & modeling CE#19: Solving optimization problems	**CE#20: Project Briefing**	Ch11: Genetic algorithm	**Progr-Rep** HW#8	
11/18	**Max margins & Linear support vector machines (SVM).** CE#21: Compare SVM with others	**Non-linear SVM and SVM applications** Project Q & A	Ch12: Support vector machines	Quiz #8	HW #9
11/23	**Bayesian Learning:** Probability & inferential statistics CE#22: Problems with small datasets	**Naïve Bayesian classifier & applications**. Project Q & A	Ch13: Bayesian learning	Quiz #9	HW #10
12/2	**Introduction to Generative Pretrained Transformer** (GPT) CE#23: Make Chatbots work for you.	**Large language models (LLMs)** Project Q & A	Ch14: GPT	Quiz #10	HW #11
Final	**Final Project Presentation**			**Final project Report**	

NOTE: CE = Classroom Exercise

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.

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 relationship to the class, whether obtained in class, via email, on the internet, or via any other media. (Living our Unifying Values: The USC Student Handbook, page 13).

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.