Spring 2020

AME 505: ENGINEERING INFORMATION MODELING

Department of Aerospace & Mechanical Engineering

University of Southern California

COURSE SYLLABUS

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Course Section:	28864R (campus) 29035D (den)
Course Unit:	3 Units
Prerequisite:	Graduate Standing
Class Hours:	Tuesdays 6:40pm – 9:20pm
Class Location:	OHE-122
Office Hours:	Tuesdays, 11am-12pm
Teaching Assistant:	TBD

AME505:

ENGINEERING INFORMATION MODELING

- Machine Learning & Data Analysis for Engineering -

Spring 2020

Course Description and Objectives

Computer and information technologies have been applied to almost every corner of industries and engineering practice. The recent progress in *machine learning* (ML) and *data analysis* (DA) theories and technologies has opened ways to solving many difficult engineering problems that involve human intelligence. To compete in today's relentless market and contribute to the engineering advancement, an engineer must have a good grasp of contemporary information technologies (IT), identify and model engineering problems in IT relevant terms, and develop quality IT solutions to these engineering problems. Engineering information modeling and machine learning & data analysis technologies are fundamental for such IT solution developments. In this course, information modeling theories and techniques are introduced and applied, including object-oriented modeling, machine learning, and data analysis, in the context of solving engineering problems that usually require human involvement. Developing computational thinking and fostering creativity are two general goals of this class. The specific objectives for this course are for students to:

- *Understand information modeling principles and methodologies*: We will study basic approaches of information modeling including symbolic logic, object-oriented techniques, machine learning, and data analysis. We will investigate and develop specific logical and machine learning representations for *entities* such as system components and activities, *relationships* such as functional & spatial constraints, and *intelligent operations* that enable system behaviors.

- *Develop basic skills through building an object-oriented and machine learning based engineering support system*: Students will learn basic information modeling skills by using *Python* and other modeling and machine learning tools for their classroom exercises and term projects. The hands-on experience will be useful for students to digest the principles and methods and develop system solutions. Note that this class will teach Python and does NOT require students having Python background.

- *Understand the state of the art of information modeling technologies*: We will review the state-of-the-art modeling approaches and machine learning and data analysis methods and their application case studies. We will examine specific representations and algorithms used to improve engineering design and manufacturing. In addition, we will hold discussion sessions to criticize these models.

- *Apply the learned knowledge and skills to solve engineering problems*: Students will form term project teams. Each team will prepare a project proposal and develop a proof-of-concept computer system for solving their selected engineering problem. Along with the development of their application system, project teams will present to the class their modeling approach, algorithms, and completed application system.

Course Structure

The scope of this course covers four major components, namely, basic concepts and theories of information modeling, modeling techniques, programming techniques, and advanced topics. To make the learning process more effective and efficient, the course structure is designed to include the following modules.

Part 1: Basic concepts and theories of information modeling

The goal of this module is to introduce basic concepts and theories of information modeling.

- What is engineering information modeling?
- What is symbolic modeling?
- What are the basic concepts for modeling going beyond numbers and equations?
- How can we capture both know-what and know-how knowledge in computers?
- What object-oriented modeling and why it is so important?

Part 2: Machine learning and data analysis – Theories and methods

The goal of this module is to introduce engineering relevant machine learning and data analysis theories and methods.

- What is machine learning, data analysis; what are different types of them?
- What some of the techniques for supervised learning and unsupervised learning?
- What is deep learning and when to use it?
- What is big-data? What to do with Big-data and Small-data?

- What is reinforcement learning and how to apply it?

Part 3: Python programming techniques

In order for students to be able to apply their learned knowledge and techniques to develop IT system solutions, this module offers basic Python programming techniques.

- What is Python, and PyCharm programming environment?
- What are the basic programming techniques using Python?
- How can one build an application system in Python programming environment?
- How can one build graphical user interfaces (GUIs) easily?
- What programming packages (e.g., machine learning) are available?

Part 4: Advanced topics: Evolutionary computing and application examples

In this module, genetic algorithm will be introduced as a way to optimize the performance of application systems/algorithms. In addition, some machine learning applications and further algorithms will be discussed.

- What is evolutionary computing?
- How can one apply genetic algorithm to make an application system more efficient?
- What are some interesting system applications out there?
- What are the techniques that are not covered in this class?

Prerequisite

Graduate standing. No restrictions on graduate students. Senior students may also take this class after receiving approval from the instructor.

Course Work

Classroom Lectures:

Weekly lectures will be offered on Tuesdays. Students are required to complete reading assignments, indicated in the schedule page, before each lecture. Usually the weekly 3-hour classroom lecture is divided into two parts. During the first 80 minutes, the instructor will present and discuss the contents outlined in the schedule page. In the second 70 minutes, students will work *in groups* to discuss the topics introduced by the instructor and complete the "classroom exercises" by applying learned methods to small engineering problems (in the first several weeks) and their team project problems (as the course progresses). Active participation in classroom exercise is strongly required for all students.

Quizzes:

Online quizzes will appear after each lecture on the Desire2Learn class website and are due before the next class session. Quizzes usually cover the materials presented and discussed in the last class.

Homework:

Each homework assignment usually has 2-3 short questions. The questions are usually about (1) the content of the previous lecture and (2) the reading assignment for the next lecture. The homework is intended to help students digest key concepts learned from the lectures and assimilate the reading materials and organize their thoughts about them for the class discussion and future practice.

Mid-term Exam:

Mid-term exam will be open-book. Problems of the exam will be similar to, and more comprehensive than, the homework questions.

Term Project:

For the term project, students will need to form teams of 4-5 people. Each team will work together to propose a project topic by choosing a specific engineering application problem. Teams will need to develop specific information models as well as machine learning and data analysis algorithms, build system components including GUI (graphical user interface), and compose a demonstrate-able system as a solution to their selected project problem. The term project will give students the opportunity to review and apply the theories, methods and techniques of modeling, machine learning, and data analysis that they learned from the class.

Course Materials

- Required: AME505 Course Reader: Will be available on the course website.
- Others (will be added).

Grading Requirements

Students will be graded according to the following grading scheme:

Quizzes: 10%

A total of twelve (12) quizzes will constitute 10% of the overall grade. Online quizzes will appear after each lecture on the Desire2Learn class website, and are due before the next class session at 6:30pm.

Homework: 30%

Total eight (8) homework assignments will constitute 30% of the overall grade, with each amounting to 3.75%. Each homework assignment has 2-3 short questions and/or one small modeling or analysis problem. Questions can be open-ended. Thoughtfulness, clarity, conciseness and incisiveness are required.

Midterm exam: 25%

Midterm exam is open-book and open-note, limited to the materials that have been discussed in classroom lectures, quizzes, homework assignments, and team projects. Questions will be similar to, but more comprehensive than, the homework questions and system development problems. There will be query questions and small modeling and analysis problems involved.

Term project: 35%

Note that 35% of your semester grade is based on the result of your term project, which is a team effort. All project work done by a team is first given a team grade. This team grade is then weighted for each student, based on confidential peer-evaluations by all team members at the end of the semester according to the following scheme.

Each student will be asked to fill out a questionnaire, which rate every team member (including him/herself) for the percentage participation to the team project, from 1 (10% or less participation) to 10 (100% participation). The evaluations are averaged to find each student's participation. The project grade of each student of a team will be weighted based on his or her percentage of participation.

Academic Conduct

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Section 11, Behavior Violating University Standards https://scampus.usc.edu/1100-behavior-violating-university-standards-and-appropriatesanctions/. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct/.

Discrimination, sexual assault, and harassment are not tolerated by the university. You are encouraged to report any incidents to the Office of Equity and Diversity http://equity.usc.edu/ or to the Department of Public Safety http://capsnet.usc.edu/department/department-publicsafety/online-forms/contact-us. This is important for the safety of the whole USC community. Another member of the university community – such as a friend, classmate, advisor, or faculty member – can help initiate the report or can initiate the report on behalf of another person. *The Relationship and Sexual Violence Prevention & Services* https://studenthealth.usc.edu/rsvp/ provides 24/7 confidential support, and the sexual assault resource center webpage https://sarc.usc.edu/reporting-options/ describes reporting options and other resources.

Students with Disabilities

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to the instructor as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. Website and contact information for DSP: http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html, (213) 740-0776 (Phone), (213) 740-6948 (TDD only), (213) 740-8216 (FAX), ability@usc.edu.

Emergency Preparedness/Course Continuity in a Crisis

In case of a declared emergency if travel to campus is not feasible, *USC Emergency Information* http://emergency.usc.edu/ will provide safety and other updates, including ways in which instruction will be continued by means of blackboard, teleconferencing, and other technology..

Course Schedule

Date	Lecture	Class Exercise	Readings	Quiz Due	Work Due
1/14	Course Intro & Intro to AI and engineering applications	CE#0: Teaming CE#1: Discuss engineering apps	Course Syllabus	Quiz#1	
1/21	Entity relationship model and Object-Oriented Modeling	CE#2: Vending machine modeling CE#3: Entity-relationship modeling CE#4: Programming in CLIPS	Chap1: ER model & Chap2: RBS	Quiz#2	HW#1
1/28	Supervised learning: Nearest neighbor, decision tree	CE#5: Data analysis tool intro CE#6: Data analysis with kNN & DT	Chap3: Supervised learning	Quiz#3	HW#2
2/4	Neural network and Deep learning	CE#7: Data analysis with neural net	Chap4: Neural network	Quiz#4	HW#3
2/11	Unsupervised learning: K-mean, hierarchical clustering	CE#8: Clustering data and finding insights	Chap5: Unsupervised learning (1)	Quiz#5	HW#4
2/18	Unsupervised learning: collaborative filtering,	CE#9: Discuss team project topic	Chap6: Unsupervised learning (2)	Quiz#6	HW#5
2/25	Reinforcement learning: Q-learning, deep RL	CE#10: Applying reinforcement learning	Chap7: RL	Quiz#7	HW#6 Project proposal
3/3	Midterm Exam				
3/10	Python A: Concepts, structure	CE#11: Install and use PyCharm	Python, PyCharm doc		HW#7
3/17	Spring Break. No class.				
3/24	Python B: GUI/Tkinter and build small apps	CE#12: Programming in Python	Python, PyCharm doc		
3/31	Python C: More on packages	CE#13: Program your project	Python, PyCharm doc		Progress Report
4/7	Genetic algorithm	CE#14: Program your project	Chap8: GA	Quiz#8	HW#8
4/14	Support vector machine	CE#15: Project Q&A (1)	Chap9: SVM	Quiz#9	HW#9
4/21	Bayesian Learning	CE#16: Project Q&A (2)	Chap10: BL	Quiz#10	HW#10
4/28	Recap & Adv modeling topics	Project Presentation			
5/8	Final Project Report PDF file due 11:59pm				FinalProj Report

CE: Class Exercise.