CE 5319 Machine Learning for Civil Engineers
Spring 2020

Time and Location: TBD

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Office Hours: 2:30 - 4:30 TTH, or by appointment (preferred)

Textbook: Understanding Machine Learning – From Theory to Practice; S. Shalev-Schwarts and S. Ben-David, Oxford University Press; ISBN: 9781107057135 (available free online for personal use: https://www.cse.huji.ac.il/~shais/UnderstandingMachineLearning/understanding-machine-learning-theory-algorithms.pdf)

Additional Readings: Additional journal articles and computer software and data manuals will be required. Students are required to find this material online or in the library as necessary.

Pre-requisites:

CE 5315 – Probabilistic Methods for Engineers, or permission of the instructor (**required**)
CE 5310 – Numerical Methods in Engineering (**recommended**)

The course is mathematically oriented and will require developing scripts (short computer programs) using R statistical and programming environment and Python and associated libraries. No prior experience with Python is necessary, but familiarity with programming concepts covered in CE 1315 – Introduction to Engineering and in CE 5315 Probabilistic Methods for Engineers is expected. Students are strongly encouraged to take CE 5310 Numerical Methods in Engineering prior to this course.

Technical Background: I expect you to have working knowledge of linear algebra and calculus (through ordinary differential equations), basic understanding and knowledge of the fundamental principles covered in university physics and undergraduate civil engineering classes is assumed to follow the illustrative applications presented in the class.

Course Purpose

The purpose of this early graduate level class is to provide students with broad introduction to the theory and practice of machine learning (ML) and illustrate how ML concepts and algorithms can be applied to solve civil engineering problems. Students will be exposed to many civil engineering datasets and the versatile R and Python programming languages.

Course Objectives

The availability of big data is transforming Civil Engineering profession. Data-driven tools and algorithms have the potential to model highly nonlinear civil engineering phenomena and extract information that is not possible through traditional modeling methods. Machine learning is a fast-growing field and its use in civil engineering will become standard in the next few years. The primary objective of this course is to provide necessary theoretical basis and exposure to ML applications in Civil Engineering.

Tentative Course Outline

Week	Course Material
Week 1	Introduction to machine learning, classification and regression, supervised, unsupervised and reinforcement learning paradigms; A basic introduction to Python – Numpy and Pandas libraries
Week 2	Formal Statistical Machine Learning Framework for Continuous variables (regression) Empirical Risk Minimization (ERM), over-fitting and inductive bias
Week 3	Discrete Choice models (classification), Probably Approximately Correct (PAC) learning and Uniform Convergence learning
Week 4	Bias-Variance Tradeoff; Vapnik-Chervonekis (VC) dimension; Sample Size; Structural Risk Minimization (SRM) and nonuniform learnability; Consistency and Efficiency
Week 5	Linear Predictors – Linear, Logistic (and Multinomial) Regression
Week 6	Weak learnability – Boosting; Convex learners – Lipschitznes; Smoothness and Regularization
Week 7	Gradient Descent and Stochastic Gradient Descent algorithms
Week 8	Support Vector Machines and Higher dimensional mapping
Week 9	Decision Trees and Decision Tree Algorithms – CART, MARS
Week 10	Decision Trees and Decision Tree Algorithms – Random Forests
Week 11	Artificial Neural Networks - Multilayer Perceptron and variants
Week 12	Artificial Neural Networks – Time Delay Algorithms – Jordan, Elman, GRU, LSTM architectures
Week 13	Artificial Neural Networks – Introduction to deep learners; Stacked Autoencoders
Week 14	An overview of other learning methods
Week 15	Final Reports and Wrap up

The instructor reserves the right to change the above outline depending upon his assessment of the class performance and due to changes in the subject material and other extenuating factors. The changes are not limited to the content and coverage but also include deadlines for homeworks, assignments, project reports and in-term exams. The date and time of the final examination (if any) will not be changed. Project report submissions may occur after the final exam for the course but on or before the last date of final examinations for the semester according to the university schedule.

The emphasis of the class, to the extent possible, is on developing the relevant material from first-principles. As such, the class emphasizes derivations of mass balance equations and appropriate theory behind analytical and numerical solutions. The class is not memorization intensive and emphasizes learning via thinking. Students uncomfortable with first-principles based pedagogy are forewarned.

Methods of Assessment

Assessment Method	Weight (%)
Assignments	60
Term Project	30
Journal Paper - Critique	10

The overall letter grades for the class will be assigned as follows: A ≥ 90%, 80 – 89% B, 70 – 79% C, 60 – 69% D and < 60% F. I will assign + and – grades to qualitatively indicate student's performance

in the class. According to current TTU policies, + and – grades do not change the overall GPA of the student which is based on the letter grade alone. The instructor reserves the right to change the scaling of the letter grades upon his discretion. Any changes in scale will be applied uniformly to all students in the class.

Assignments:
Periodic assignments will be given to help students understand and apply the concepts presented and discussed in the class. Students can work together on assignments (collaborate) but not copy from each other. **Students must present their work individually as Hard-Copies**. Any collaboration must be explicitly acknowledged in the submission (for e.g., X,Y and Z worked collaborated on projects a, b, and c; or I discussed problem c with Y and Z). Students will receive a grade of zero, if collaborations are not explicitly acknowledged and may be reported as plagiarism which could lead to a failure grade and other punitive action.

Term Project:
The students will also be required to carry out a semester-long term project **Each student will work on the project individually.** – 1) The term project must address a practical civil engineering problem; 2) analyze a 'real-world' dataset and 3) Evaluate the suitability of of every concept that is presented in the class to the problem at hand and use them as appropriate; 4) Use a concept that builds on the material presented in the class – Examples include – Markov Chains, Risk, Resilience and Vulnerability Assessments; Queuing Theory, Survival Analysis; Entropy and information theoretic methods; Decision-theoretic approaches. Feel free to discuss with the instructor, if you have any questions.

Students progressively work with the dataset throughout the semester and apply the concepts learned in the class to the problem of their choosing, using the dataset.

A template for final report submission will be provided and must be adhered to. Students have the option to submit a draft report to obtain feedback – This draft submission is optional but strongly recommended. The draft report will not count towards the grade but can help students get critical feedback that can help improve the final report and therefore the final grade. Important deadlines for the project are:

Electronic sources
Supplmentary materials, online quizzes and assignments are posted on the course home on Texas Tech University ***Blackboard*** *Content Management System* (http://www.blackboard.ttu.edu/); therefore, students should the site periodically.

Modeling software
The course will use R statistical and programming environment which can be downloaded for free from the comprehensive R archive network (https://cran.r-project.org/). We will also use the Anaconda distribution of Python (https://www.anaconda.com/). I will post code snippets and tutorials on using R and Python over the course of the semester.

Academic misconduct
Please refer to the Texas Tech University Catalog and operating policies (OP 34.12) regarding academic integrity, cheating, and plagiarism. Academic dishonesty will not be tolerated.

Religious holidays

A student who intends to observe a religious holy day (as defined by OP 34.19) should make that intention known to the instructor prior to the absence in order to receive accommodations prescribed by OP 34.19.

Disability policy

Any student who, because of a disability, may require special arrangements in order to meet the course requirements should contact the instructor as soon as possible to make any necessary arrangements. Students should present appropriate verification from Student Disability Services during the instructor's office hours. Please note instructors are not allowed to provide classroom accommodations to a student until appropriate verification from Student Disability Services has been provided. For additional information, you may contact the Student Disability Services office at 335 West Hall or 806-742-2405.

CECE departmental calculator policy for exams

Only NCEES approved calculators will be permitted during tests and your test will be collected and your grade will be a zero if you are caught using a non-approved calculator. The approved calculators include the following:

- Hewlett Packard – HP 33s, HP 35s, and no other
- Casio – All FX-115 models. Any Casio calculator must contain FX-115 in its model name.
- Texas Instruments – All TI-30X and TI 36X models. Any TI calculator most contain either TI-30X or TI-36X in its model name.
- If you are unsure about your calculator, it is your responsibility to check with the instructor for approval.

Laptops/PDAs/MP3 Players/Cell Phones/etc.

As a matter of common courtesy to fellow students as well as your instructor, you shall not use any unauthorized electronic device during lectures, quizzes, or examinations. Unapproved electronic devices could include but are not limited to: cell phones, PDAs, MP3 players, laptops, and non-approved calculators. You will be asked to place your electronic devices in your bag during tests. If I find a student using an unapproved electronic device during a test, quiz, or the final examination, I will award that student a grade of zero on that test, quiz, or the final examination and the student will be referred to appropriate academic disciplinary committee.

The course is modeling intensive and I encourage students to bring their laptops to class with properly loaded software to work on models and analysis. Engineering practice requires professional demeanor, Examples of unprofessional behavior include but not limited to: talking on the cell phone, texting during class, being on websites not related to the class, working on homework or assignments not related to the class or talking and other disruptive behavior during the class lecture. Please keep your cell phones muted during the class hours. Please do not come to the class if you want to simply work on assignments from other classes or want to engage in other social behavior (including but not limited to surfing the web for non-class related activities).