Spring 2022

CE 485-004: ST - Machine Learning and Data Analytics for Civil Engineering Systems

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John A. Reif, Jr. Department of Civil & Environmental Engineering

Machine Learning and Data Analytics for Civil Engineering Systems

CE 485 (Thursday from 2:30 PM to 5:20 PM)

Course Description:

This course provides students with hands-on and fundamental knowledge of machine learning, data science, and data mining methodologies for scraping, manipulating, transforming, cleaning, visualizing, summarizing, and modeling large-scale data using analytical tools. This course includes data management and analysis, data wrangling and exploration, unsupervised learning, pattern recognition, supervised learning for classification and regression purposes, data preprocessing, and model training and evaluation. Students will explore the capabilities of these concepts in addressing the challenging and interesting problems in the field of civil engineering, and they will develop skills to apply these techniques to solve multiple real-world civil engineering problems. Python programming language will be introduced and used throughout this course to illustrate practical examples and to show students how to apply the learned techniques into practice. Students can bring their own dataset for their final project presentations and reports.

Course Pre-requisites:

CS 101, MATH 211, and MATH 279: Basic knowledge of Programming, Calculus, Statistics and Probability.

Course Lecture Hours and Credits:

This is a three-lecture hours and three-credits course.

Course Learning Outcomes:

This course provides students with hands-on experience and state-of-the-art knowledge to model and analyze big datasets and to solve challenges, issues, and practical cases faced in civil engineering, infrastructure systems, and construction. The student learning outcomes include:

1. Develop an understanding of the recent developments and applications in the field of machine learning
2. Learn Python programming language and the associated libraries/packages for data management and data analysis
3. Build and evaluate regression and classification models for prediction purposes
4. Apply various supervised and unsupervised machine learning methods to model data

Course Instructor:

Rayan H. Assaad, PhD, A.M.ASCE
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Office Hours: Thursday 5:30 PM to 7:30 PM or by e-mail or appointment. Feel free to stop by my office at any time of your convenience. I will try to meet you immediately unless I have a very pressing deadline or a conflicting scheduled meeting.

Course Textbooks:

There is no required textbook for this course. However, the following books are recommended:

- Jake VanderPlas. "Python Data Science Handbook", 1st Edition, O'Reilly Media, 2016, ISBN-13: 978-1491912058.
- Aurélien Géron. "Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems", 2nd Edition, O'Reilly Media, 2019, ISBN-13: 978-1492032649.
- Sebastian Raschka and Vahid Mirjalili, "Python Machine Learning: Machine Learning and Deep Learning with Python, scikit-learn, and TensorFlow 2", 3rd Edition, Packt, 2019, ISBN-13: 978-1789955750.

Other References and Reading Material:

Additional references and reading material might be provided to students to enhance their understanding of the course's material, the covered topics, and the discussed concepts.

Canvas and Technology Requirement:

All course materials will be available on Canvas. It is the student's responsibility to check the course page on Canvas regularly. Students are expected to have a working computer to participate in this course. It is highly recommended that students bring their personal computer (i.e., laptop) to the class to have hands-on and fundamental knowledge of the covered machine learning concepts and applications. If you do not have a computer, please contact the Dean of Students.

Course Requirements:

- Assignments: Each student will be requested to submit 4 assignments. All due dates are already noted in the below course schedule.
- Midterm: Each student is expected to take 1 in-class midterm scheduled during class time as noted in the below course schedule.
- Project: A group project needs to be submitted by the end of the semester. To gauge the progress of students throughout the semester in relation to their project, students will be requested to submit project updates. All due dates are already noted in the below course schedule. A separate document will detail the requirements and expectations of such final project.

Course Grade Breakdown:

4 Assignments	30%
1 Mid-Term (in-class)	30%
Final Project Presentation	10%
Project Updates/Report	30%
Potential Extra-Credit Work	5%

Course Grading:
Cumulative points in all course requirements will be rounded to the next highest whole number (for example 84.1 will be rounded to 85 and 95.7 will be rounded to 96). Afterwards, your final grade will be determined according to the following scale:

≥90	A
≥85 and ≤89	B^+
≥80 and ≤84	B
≥75 and ≤79	C^+
≥70 and ≤74	C
≥60 and ≤69	D
<60	F

Withdrawals:
To ensure consistency and fairness in application of the NJIT policy on withdrawals, student requests for withdrawals after the deadline will not be permitted unless extenuating circumstances (e.g., major family emergency or substantial medical difficulty) are documented. The course Professors and the Dean of Students are the principal points of contact for students considering withdrawals.

Course Specific Policies:
- Eating and use of cell phones are strictly prohibited during class time.
- Professional conduct in all matters related to class activities (i.e., sitting, talking, and discussing matters) is required at all times.
- The specific nature of this class demands active participation during class discussions. The objective of these discussion is to enrich the course environment, enhance student learning experience, foster critical thinking, and strengthen your communication skills. Thus, please get engaged and know that you are NOT being evaluated at all on the answers you provide in class. Also, please realize that there is no reason to take a back seat and be shy as there is no embarrassment whatsoever from any reasonable attempt to provide an answer.
- Students are required to attend all lectures to maximize their benefit and are required to arrive on time to minimize disturbance to the learning environment. Unexcused absence will result in a zero being assigned for any required in-class course task (including exams and midterms), and no make-up will be given. Bearing the aforementioned in mind, some absences can be excused due to reasons beyond a student control (i.e., a surgery or accident for example). In such unlikely event, immediate communication with the Instructor may help generate some timely solutions that cannot work out afterwards.
- You need to complete ALL course requirements in order to earn a passing grade.
- All assignment, final project, and extra credit work should be computer typed in a neat and organized manner. Any submission should have a cover page including university name, department name, course number, instructor name, nature of submission (i.e., assignment, final project, or extra credit), your name, due date, and date of submission.
- Assignments are due at 11:59 PM according to the below course schedule. Late submissions will be penalized 10% of the points for each day late, up to 48 hours; after which the assignment will be recorded as a zero with no exceptions. Having a prior excused absence from attending

a specific class does not warrant missing a submission date. Post excused absence – if any – will be handed on case by case basis.

- Poor performance in the class (for example, not submitting two assignments or recording less than 50% in two assignments or obtaining a grade less than the average grade of the class minus twice the standard deviation, etc.) automatically warrants an academic alert. If your performance deems you under two academic alerts, you should automatically provide an improvement plan that is accepted by the Instructor.
- The most reasonable human attention is provided in grading all course requirements but in the unlikely event that something is overlooked one way or the other, there will be no problem whatsoever to revise your grade on such submission.

Students with Disabilities:

NJIT is fully committed to providing students with documented disabilities equal access to programs and activities. If you have - or believe that you may have - a physical, medical, psychological, or learning disability that may require accommodations, please contact the Office of Accessibility Resources and Services (https://www.njit.edu/studentsuccess/node/5).

Copyright:

All course content (including this syllabus, lecture materials, homework assignments, and exams) is protected content. Students should not make copies of any course materials or distribute these materials in the public domain.

Academic Integrity:

Academic Integrity is the cornerstone of higher education and is central to the ideals of this course and the university. Cheating is strictly prohibited and devalues the degree that you are working on. As a member of the NJIT community, it is your responsibility to protect your educational investment by knowing and following the academic code of integrity policy that is found at: http://www5.njit.edu/policies/sites/policies/files/academic-integrity-code.pdf.

Please note that it is my professional obligation and responsibility to report any academic misconduct to the Dean of Students Office. ***Any student found in violation of the code by cheating, plagiarizing or using any online software inappropriately will result in disciplinary action. This may include a failing grade of F, and/or suspension or dismissal from the university.*** *If you have any questions about the code of Academic Integrity, please contact the Dean of Students Office at dos@njit.edu*

Tentative Course Outline/Schedule:**

**The Instructor reserves the full right to amend or change this tentative schedule, according to class progress, with consultation with the students.

Week	Date	Topic	Notes
1	Thursday, January 20th, 2022	Course Information + Introduction to Machine Learning	-
2	Thursday, January 27th, 2022	Introduction to Python	-
3	Thursday, February 3rd, 2022	Data Management and Analysis	-
4	Thursday, February 10th, 2022	Data Exploration and Visualization	Submission of Group Names for Final Project
5	Thursday, February 17th, 2022	Dimension Reduction and Unsupervised Learning	Project Update #1 due by 11:59 PM
6	Thursday, February 24th, 2022	Dimension Reduction and Unsupervised Learning	Assignment 1 due by 11:59 PM
7	Thursday, March 3rd, 2022	Supervised Learning: Regression Algorithms	-
8	Thursday, March 10th, 2022	Supervised Learning: Regression Algorithms	Assignment 2 due by 11:59 PM
9	Thursday, March 17th, 2022	Spring Recess – No Class	-
10	Thursday, March 24th, 2022	In-Class Midterm (90 mins) + Supervised Learning: Classification Algorithms (80 mins)	-
11	Thursday, March 31th, 2022	Supervised Learning: Classification Algorithms	Assignment 3 due by 11:59 PM
12	Thursday, April 7th, 2022	Data Preprocessing, Training, and Prediction	Project Update #2 due by 11:59 PM
13	Thursday, April 14th, 2022	Data Preprocessing, Training, and Prediction	Assignment 4 due by 11:59 PM
14	Thursday, April 21th, 2022	Working with Text Data and Web Scraping	-
15	Thursday, April 28th, 2022	Project Presentations	Due before class time
16	Thursday, May 5th, 2022	-	Project Report due by 11:59 PM

Outcomes Course Matrix

Strategies, Actions, and Assignments	ABET Student Outcomes (1-7)	Program Educational Objectives	Assessment Measures
Student Learning Outcome 1: Develop an understanding of the recent developments and applications in the field of machine learning			
Students will disseminate the range of modern concepts related to data science, data mining, and data analytics to solve multiple civil engineering problems	1, 2	1, 2	Homework, Midterm, in-class discussions, final project
Students will gain fundamental knowledge of machine learning, data science, and data mining methodologies for scraping, manipulating, transforming, cleaning, visualizing, summarizing, and modeling large-scale civil engineering-related data using analytical tools	1, 2	1, 2	Homework, Midterm, in-class discussions, final project
Student Learning Outcome 2: Learn Python programming language and the associated libraries/packages for data management and data analysis			
Students will acquire the needed skills to collect and manipulate data	2, 7	1, 2	Homework, in-class discussions, final project
Students will develop a set of tools and skills to visualize data and reduce data dimension	2, 7	1, 2	Homework, in-class discussions, final project
Student Learning Outcome 3: Build and evaluate regression and classification models for prediction purposes			
Students will have a working knowledge and experience of how to design and apply machine learning techniques to real-world datasets	1, 2, 4, 7	1, 2	Homework, in-class discussions, final project
Students will acquire hands-on experience and state-of-the-art knowledge to model and analyze big datasets	1, 2, 4, 7	1, 2	Homework, in-class discussions, final project
Student Learning Outcome 4: Apply various supervised and unsupervised machine learning methods to model data			
Students will solve multiple challenges, issues, and practical cases faced in civil engineering, infrastructure systems, and construction	1, 2, 3, 4, 5, 6, 7	1, 2, 3	Homework, in-class discussions, final project
Students will advocate their proposed machine learning project in a mock presentation and report format	3, 4, 5, 6	1, 2, 3	Final project presentation and report

CEE Mission, Program Educational Objectives, and Student Outcomes

The mission of the Department of Civil and Environmental Engineering (CEE) is:

- to educate a diverse student body to be employed in the engineering profession
- to encourage research and scholarship among our faculty and students
- to promote service to the engineering profession and society

Our Program Educational Objectives are reflected in the achievements of our recent alumni:

1. Engineering Practice: Alumni will successfully engage in the practice of civil engineering within industry, government, and private practice, working toward safe, practical, sustainable solutions in a wide array of technical specialties including construction, environmental, geotechnical, structural, transportation, and water resources.
2. Professional Growth: Alumni will advance their technical and interpersonal skills through professional growth and development activities such a graduate study in engineering, research and development, professional registration and continuing education; some graduates will transition into other professional fields such as business and law through further education.
3. Service: Alumni will perform service to society and the engineering profession through membership and participation in professional societies, government, educational institutions, civic organizations, charitable giving and other humanitarian endeavors.

Our Student Outcomes are what students are expected to know and be able to do by the time of their graduation:

1. an ability to identify, formulate and solve complex engineering problems by applying principles of engineering, science and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety and welfare, as well as global, cultural, social, environmental and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Revised: 2/13/18