DS-UA 301 Advanced Topics in Data Science

Machine Learning for Climate Change

Center for Data Science, New York University
Spring 2024

Instructor

Prof. Grace Lindsay
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Grader/TA

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Meeting schedule

Class time: 8 AM to 10:30 AM on Thursdays
Class Location: 70 Washington Sq S (Bobst) Room LL138
Labs:
Friday 2:45-3:35pm 7 E 12th St Rm 121
or
Friday 4:55-5:45pm 60 5th Ave Rm 125
Office hours with Kartik: 11am on Wed, CDS Rm 660
With Grace: By appointment, either in-person or on zoom.

Links to materials

Lecture slides:
https://lindsay-lab.github.io/teaching/#machine-learning-for-climate-change-spring-2024
Lecture Zoom: https://nyu.zoom.us/j/95440984119 , Meeting ID: 954 4098 4119
Class Slack:
https://join.slack.com/t/coursediscuss-tcx6125/shared_invite/zt-2auxlmtv7-TgCsZqb4PNzTromrN210Pg

Overview

Climate change is drastically altering the world around us and, left uncheck, will push natural and man-made systems past their operational points. While this is a grave threat to humanity's prosperity, it is also a great opportunity for innovation. In the coming years, the world will need to change with a speed and scale unseen before and machine learning will play an important role in making this transformation possible. In this course, students will learn the many ways in which machine learning can be applied to both the mitigation of and adaptation to climate change.

Because climate change touches nearly every aspect of daily life, no particular content expertise is required. The course will cover the basics of climate science and climate change before diving into the ways in which machine learning can be useful. The course will include examples that focus on applications for mitigation as well as applications for adaptation. Each week will provide domain area background as well as information on machine learning techniques. These will connect to a specific research paper on the topic.

Students should walk away from this course with an understanding of the complexities involved in tackling climate change and the landscape of applications for machine learning in this domain. Specifically, they will learn about how remote sensing can be used to monitor and interact with the natural and manmade world, how optimization methods can aid in the design of new materials, and how predictive models can help avoid worst-case outcomes. They should also gain the confidence to explore different datasets relevant to climate, energy, agriculture, etc. and brainstorm ways in which machine learning can be applied in new ways to these problems.

Course Structure

This course will introduce you to both modern machine learning techniques as well as their domain-specific application toward climate change problems. Lectures will be organized around published research papers. Unless otherwise noted, in the second half of each class, there will be a lecture that provides the necessary background needed to read the assigned paper. In the first half of the next class, we will have a group discussion on the assigned paper.

Course Schedule

Jan 25 - Intro and Background on Climate Change. Lecture on energy efficiency and regression techniques.
Paper 1 assigned.
Feb 1 - Discuss paper 1. Lecture on extreme weather/disaster response and computer vision/convolutional neural networks.
Paper 2 assigned. HW 1 assigned.
Feb 8 - Discuss paper 2. Lecture on global climate changes and remote sensing/segmentation.
Paper 3 assigned.
Feb 15 - Discuss paper 3. Lecture on climate science models and unsupervised and generative models.
Paper 4 assigned. HW 1 due. HW 2 assigned.
Feb 22 - Discuss paper 4. Lecture on food/agriculture and time series models.
Paper 5 assigned.
Feb 29 - Discuss paper 5. Lecture on communication/psychology and natural language processing.
Paper 6 assigned. HW 2 due. HW 3 assigned.
Mar 7 - Discuss paper 6. Career Day, Project Info and Exam Prep.
Mar 14 - Exam I. Lecture on climate finance and recommender systems and genetic algorithms.
Paper 7 assigned. HW 3 due (on Friday at midnight). Project HW assigned.
Spring Break
Mar 28 - Discuss paper 7. Lecture on transportation and reinforcement learning.
Paper 8 assigned.
Apr 4 - Discuss paper 8. Lecture on power grid/renewables and graph neural networks.

Paper 9 assigned. Project HW due.
Apr 11 - Discuss paper 9. Lecture on carbon dioxide removal and review of graph neural networks, RL, transformers etc.
Paper 10 assigned.
Apr 18 - Discuss paper 10. Project check-ins and exam prep.
Apr 25 - Exam II. Project time
May 2 - Project Presentations
Project reports due May 9th.

Papers:

1. Robinson, C., Dilkina, B., Hubbs, J., Zhang, W., Guhathakurta, S., Brown, M. A., & Pendyala, R. M. (2017). Machine learning approaches for estimating commercial building energy consumption. *Applied energy*, *208*, 889-904.
2. Chen, T. Y. (2022). Interpretability in convolutional neural networks for building damage classification in satellite imagery. *arXiv preprint arXiv:2201.10523*.
3. Diaconu, C. A., & Bamber, J. L. (2023). Detailed Glacier Area Change Analysis in the European Alps with Deep Learning. In NeurIPS 2023 Workshop on Tackling Climate Change with Machine Learning (pp. 1-5).
4. Hoffmann, S., & Lessig, C. (2021). Towards Representation Learning for Atmospheric Dynamics. arXiv preprint arXiv:2109.09076.
5. Jo, H. W., Koukos, A., Sitokonstantinou, V., Lee, W. K., & Kontoes, C. (2022). Towards global crop maps with transfer learning. arXiv preprint arXiv:2211.04755.
6. Suresh, A., Milikic, L., Murray, F., Zhu, Y., & Grossglauser, M. (2023, May). Mining Effective Strategies for Climate Change Communication. In *ICLR 2023 Workshop on Tackling Climate Change with Machine Learning*.
7. Asikis, T. (2023). Towards Recommendations for Value Sensitive Sustainable Consumption.
8. Yeh, C., Li, V., Datta, R., Yue, Y., & Wierman, A. SustainGym: A Benchmark Suite of Reinforcement Learning for Sustainability Applications.
9. Nauck, C., Lindner, M., Schürholt, K., & Hellmann, F. (2022). Towards dynamic stability analysis of sustainable power grids using graph neural networks. arXiv preprint arXiv:2212.11130.
10. Shivashankar, S. (2023). AI assisted Search for Atmospheric CO2 Capture

Course Materials

The application of machine learning to climate change is a relatively new and quickly-evolving field. As such there are no established textbooks for the field as a whole, however there are many online resources, as well as textbooks for the more established sub-components of the field. The course will primarily focus on research papers but also draw from resources such as:

https://www.climatechange.ai, specifically its landmark white paper outlining the many ways in which machine learning can be applied to climate change:
https://dl.acm.org/doi/10.1145/3485128

https://regeneration.org/nexus

Introduction to Remote Sensing by Cambell, Wynne, & Thomas

Artificial Intelligence for Humanitarian Assistance and Disaster Response Workshop and Applications of artificial intelligence for disaster management

Machine Learning and Artificial Intelligence to Advance Earth System Science

Prerequisites

Students should be comfortable programming in Python and have familiarity with basic data science and visualization toolboxes (scikit-learn, matplotlib). No domain expertise in climate change topics is required.

Evaluation

Your grade will be calculated according to following proportions:

Exams - 20% (10% each exam)
Project - 35%
Homeworks - 25%
Participation - 20%

Exams: Two in-class exams will be administered that evaluate understanding of climate change concepts and the papers read in class. Make-up exams will only be offered in the case of medical emergencies and must be arranged before the start of the exam. They must be completed before the next class.
Project: Students will work in groups on an advanced research project of their design. Grades will be the same for all members of the group and will be based on both the project and its presentation.
Homework: Three out of four homework assignments will be coding assignments related to the themes of the class. The fourth will be a project plan. Assignments must be turned in before the start of class on the due date unless otherwise noted. Students will have 3 “grace days” they can use toward the first three assignments that will allow them to turn in assignments late. They can be used altogether (allowing a single assignment to be 3 days late) or separately. *Once the grace days are used, late assignments will not be accepted and will be treated as a 0.* Grace days cannot be applied to the project plan or final project.
Participation: Students will be required to submit a PMIRO+Q before and after in-class discussions of assigned papers. Participation grades will also be based on attendance, which will be taken by discussion groups (if you need to participate virtually you must set this up with your discussion group). You can miss one discussion without penalty.
Extra Credit - Students who demonstrate a sincere desire to correct poor performance before the end of the course can request an additional assignment. This assignment will involve executing a task relevant to Lindsay Lab research on climate change. Requests for extra credit ***cannot*** be made after May 2.

Academic integrity

Academic Integrity, Plagiarism, and Cheating (adapted from the website of the College of Arts & Science): Academic integrity means that the work you submit is original. Obviously, bringing answers into an examination or copying all or part of a paper/code straight from a book, the Internet, or a fellow student is a violation of this principle. But there are other forms of cheating or plagiarizing which are just as serious — for example, presenting an oral report drawn without attribution from other sources (oral or written); writing a sentence or paragraph which, despite being in different words, expresses someone else's idea(s) without a reference to the source of the idea(s); or submitting essentially the same paper in two different courses (unless both instructors have given their permission in advance). Receiving or giving help on a take-home paper, examination, or quiz is also cheating, unless expressly permitted by the instructor (as in collaborative projects).

Disability Disclosure Statement

Academic accommodations are available for students with disabilities. The Moses Center website is www.nyu.edu/csd. Please contact the Moses Center for Student Accessibility (212-998-4980 or mosescsd@nyu.edu) for further information. Students who are requesting academic accommodations are advised to reach out to the Moses Center as early as possible in the semester for assistance.