CAS PY 580: Machine Learning for Physicists

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Time: TTh 9:30-11:00, SCI B58

Office Hours: Tuesday: 2:30-3:30 (before colloquium)

Course Credits: 4 credits

Prerequisites: PY 410/PY 541 or permission of instructor

Description: Machine Learning (ML) is one of the most exciting and dynamic areas of modern research and application. The purpose of this class is to provide an introduction to the core concepts and tools of machine learning in a manner easily understood and intuitive to physicists. The class begins by covering fundamental concepts in ML and modern statistics such as the bias-variance tradeoff, overfitting, regularization, and generalization before moving on to more advanced topics in both supervised and unsupervised learning. Possible topics covered in the class include ensemble models, deep learning and neural networks, clustering and data visualization, energy-based models (including MaxEnt models and Restricted Boltzmann Machines), and variational methods. Throughout, we emphasize the many natural connections between ML and statistical physics. A notable aspect of the class is the use of Jupyter notebooks to introduce modern ML/statistical packages to readers using physics-inspired datasets (the Ising Model and Monte-Carlo simulations of supersymmetric decays of proton-proton collisions). We will conclude with an extended outlook discussing possible uses of machine learning for furthering our understanding of the physical world as well as open problems in ML where physicists maybe able to contribute.

Books and Other Course Materials

The course follows are recent review available here:
https://www.sciencedirect.com/science/article/pii/S0370157319300766
as well as the corresponding notebooks available here:
https://physics.bu.edu/~pankajm/MLnotebooks.html

Grading: There will also be a final group project in teams of 3. The grade will be based 40% on HWs, 10% on Final Project, 50% on class participation/readings.

HW: The class will have a mix-of more theoretical problems and practical programming assignments in the 20 Notebooks (https://physics.bu.edu/~pankajm/MLnotebooks.html).

Final Project: The final project must be chosen in consultation with the instructor by the beginning of November. The final project will be a group project (teams of 2-3 members) and must have a significant practical programming/data analysis component.

Community of Learning: Class and University Policies

1) Course members are responsibility for ensuring a positive learning environment by being respectful of their fellow students.
2) **Attendance & Absences.** Class discussion and participation are a major part of the course. Class participation is 40% of the grade and absences will lower this score as appropriate except when students receive permission from the instructor or for religious observances.

3) Assignment Completion & Late Work. Due dates for notebooks are 1 week after assignment. **You will be expected to turn in HWs on time. There will be 50% credit for HWs turned in within one week of due dates. Late HWs will not be accepted after 1 week.**

4)Academic Conduct Statement. All students are expected to follow GRS Academic Conduct Code: http://www.bu.edu/cas/students/graduate/grs-forms-policies-procedures/academic-discipline-procedures/

Weekly assignments: We will work through 1-2 chapter in the review each week. Students are expected to read the corresponding text in the review before class to facilitate discussion. The exact pace of readings depends on discussions/confusions and interest of the students.

A typical course will read Chapters 1-7 in **Weeks 1-7**, Chapters 9-13 in **Weeks 8-10**, and then depending on students interests a selection of topics from Chapter 5, 14-17 in **Weeks 11-14**. There are notebooks associated with each chapter that students must complete 1 week after discussion in class.

We will probably skip following chapters to discuss stable diffusion models and large language models.