Phys 494/594: Special Topics in Physics: Introduction to Machine Learning Spring 2023

THE UNIVERSITY OF TENNESSEE KNOXVILLE

DEPARTMENT OF PHYSICS & ASTRONOMY

Course Description & Syllabus

Faculty Contact Information

Prof.	Adrian Del Maestro
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Office:	Nielsen 401

Instructor Availability: Please don't hesitate to email me with updates, questions, or concerns. I will typically respond within 24 hours during the week and 48 hours on the weekend. I will notify you if I will be out of town and if connection issues may delay a response. I monitor the class Mattermost server and will often provide more frequent responses there when possible.

Meeting Time

The course is **asynchronous** with videos, lecture notes, programming exercises and reference material posted on the course canvas site:

https://utk.instructure.com/courses/169958

New course modules and associated content will be posted before Monday of each week.

Office Hours

Tuesday 1:30 - 3:00 PM

1-on-1 meetings to discuss any course related item can also be made by choosing an available time via:

https://fantastical.app/adrian-oXwI/ml4s-course-meeting.

Course Description

Machine Learning is rapidly becoming one of the most exciting and useful areas of modern research with important applications across the sciences. This class will provide an introduction to the fundamental concepts and applied tools of machine learning while being aligned with the needs and experience of physicists. We will focus on deep neural networks that can trained to perform a wide variety of tasks including image recognition, pattern identification, and natural language processing and discuss how these basic techniques can be applied to problems in physics, ranging from the prediction of material properties, super-resolution imaging, the analysis of high-dimensional data sets, and to the discovery of phase transitions.

An outline of topics that will be discussed include:

1. Basics of neural networks and deep learning
2. Linear and Logisitic Regression
3. Supervised learning: feed forward and convolutional neural networks.
4. Unsupervised learning: clustering and data visualization in high-dimensional spaces
5. Generative models such as auto encoders and restricted Boltzmann machines
6. If time permits: advanced topics including the use of neural networks to encode quantum states and learn physical Hamiltonians from experimental data.

Prerequisites

To be successful in this course you will need an understanding of linear algebra and calculus, including matrix multiplication and the chain rule. Python or similar programming experience, while not essential, will be extremely useful. **Students without any prior programming experience should expect to spend extra time outside of class learning basic skills.** Statistical physics at an undergraduate level would also be useful in developing a deeper appreciation of the intended applications, but is not required.

Student Learning Outcomes

This course aims to provide students with the skills needed to move from data to decisions. This includes (1) understanding data; (2) make predictions, including regression, classification, and neural networks; (3) make decisions under uncertainty; (4) determine causal inference; and (5) understand how to apply the tools of machine learning to classical and quantum physics.

Value Proposition

Understanding large complex data sets and being able to rapidly identify fundamental patterns and make inferences is an essential skill of modern science.

Learning Environment

The class will be delivered in an asynchronous fashion with lecture notes, Jupyter notebooks, code libraries, and videos provided. Weekly programming exercises will be assigned and those students wishing to interact with the instructor in person should attend office hours.

We will use ISAAC-NG, UTK's supercomputer via web-based Jupyter notebooks to write and run all code. This will give us access to the latest machine learning frameworks (TensorFlow and PyTorch) as well as acceleration via GPUs.

Canvas

All course details, assignments, lecture notes and announcements will be available on Canvas at `https://utk.instructure.com/courses/169958`. **You are required to be aware of anything posted to the course website.** Please update your canvas notification settings.

Reference Materials

I will provide copies of my lecture notes and videos on Canvas. There is no specific textbook for the course and we will take material from a variety of sources including:

- P. Mehta, M. Bukov, C.-H. Wang, A. G. R. Day, C. Richardson, C. K. Fisher, and D. J. Schwab, A High-Bias, Low-Variance Introduction to Machine Learning for Physicists, Physics Reports **810**, 1 (2019).
  https://arxiv.org/abs/1803.08823.
- Michael Neilsen, *Neural Networks and Deep Learning* (2019).
  http://neuralnetworksanddeeplearning.com/.
- David J.C. MacKay, *Information Theory, Inference, and Learning Algorithms*, (2005).
  http://www.inference.org.uk/mackay/itila/book.html
- Giuseppe Carleo, Ignacio Cirac, Kyle Cranmer, Laurent Daudet, Maria Schuld, Naftali Tishby, Leslie Vogt-Maranto, and Lenka Zdeborová, Machine learning and the physical sciences, Rev. Mod. Phys. **91**, 045002, (2019).
  https://arxiv.org/abs/1903.10563

Grading & Policies

Programming Exercises	15%
Engagement	5%
Assignments (5)	50%
Final Project & Presentation	30%

Participation

While the course is asynchronous, I would like everyone to participate via the course message board, a mattermost channel, via email, office hours etc. Investing in this component will build course community and ensure your success.

Assignments

Late assignments will be accepted with a penalty of 15% per day.

Important Dates

The final project will be due on our scheduled final exam date: Monday May 15, 2022.

Religious Holidays

Students have the right to practice the religion of their choice. If you need to miss class to observe a religious holiday, please submit the dates of your absence to me in writing via email by the end of the second full week of classes. You will be permitted to make up work within a mutually agreed-upon time.

Statement on Civility & Community

The Department of Physics & Astronomy at the University of Tennessee is committed to creating an environment that welcomes all people, regardless of their identities. We value the diversity that enriches our department. We understand the importance of free and open dialogue that includes the free exchange of ideas. We do not tolerate uncivil speech or any form of discourse that infringes on others' rights to express themselves, or has a negative impact on their education, or work environment. We actively promote an environment of collegiality and an atmosphere of mutual respect and civility. We understand that respect includes being considerate of others' feelings, circumstances, and their individuality. We recognize the necessity of a civil community in realizing the potential of individuals in teaching, learning, research, and service. We believe these values extend beyond the department into our work within physics regionally, nationally, and internationally, as well as work and studies in the university, and the broader community. We encourage all members of the department to intervene and report any incidents involving bigotry, or that violate the university code of conduct.

`http://www.phys.utk.edu/about/civility-community.html`

Campus Syllabus

The campus syllabus provides important information that is common to all courses at UT Knoxville, such as academic integrity and addressing disability needs.

`https://teaching.utk.edu/the-syllabus/`