Phys 494/594: Special Topics in Physics: Introduction to Machine Learning
Spring 2022

THE UNIVERSITY OF TENNESSEE KNOXVILLE
DEPARTMENT OF PHYSICS & ASTRONOMY

Course Description & Syllabus

Faculty Contact Information

Prof.	Adrian Del Maestro
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Office:	306 South College Hall

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 formally **asynchronous**, but lectures will be recorded *live* with the opportunity for optional participation in group programming exercises on

`Tuesday/Thursday 11:30 AM - 12:45 PM`

Online on Zoom (link on Canvas). Lecture videos will be ready to download shortly after 1:00 PM on Tuesdays and Thursdays.

Office Hours

`Friday 3:00 - 4:30 PM`

1-on-1 meetings to discuss any course related item can also be made by scheduling via email.

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. As mentioned above, the videos will be recorded *live* twice per week and anyone interested in attending the meeting time is strongly encouraged. Those students will have the opportunity to interact with the instructor live and participate in group programming exercises which will assist with learning the material. These exercises can also be completed *off-line* and live participation is purely voluntary/optional.

We will use ISAAC, 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/. **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

Participation	10%
Short Quizzes Performed on Canvas	10%
4-5 Assignments	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. The lowest quiz grade will be dropped at the end of the semester.

Important Dates

The final project will be due on our scheduled final exam date: Monday May 16, 2021.

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

COVID-19

The best source of information for information related to the University of Tennessee's response to the COVID-19 pandemic can be found online at: https://www.utk.edu/coronavirus/.

1 Campus Syllabus

1.1 University Civility Statement

"Civility is genuine respect and regard for others: politeness, consideration, tact, good manners, gracious-ness, cordiality, affability, amiability and courteous-ness. Civility enhances academic freedom and integrity and is a prerequisite to the free exchange of ideas and knowledge in the learning community. Our community consists of students, faculty, staff, alumni, and campus visitors. Community members affect each other's well-being and have a shared interest in creating and sustaining an environment where all community members and their points of view are valued and respected. Affirming the value of each member of the university community, the campus asks that all its members adhere to the principles of civility and community adopted by the campus."
https://civility.utk.edu/

1.2 Emergency Alert System

The University of Tennessee is committed to providing a safe environment to learn and work. When you are alerted to an emergency, please take appropriate action. Learn more about what to do in an emergency and sign up for UT Alerts. Check the emergency posters near exits and elevators for building specific information. In the event of an emergency, the course schedule and assignments may be subject to change. If changes to graded activities are required, reasonable adjustments will be made, and you will be responsible for meeting revised deadlines.
https://safety.utk.edu/

1.3 Academic Integrity

Each student is responsible for his/her personal integrity in academic life and for adhering to UT's Honor Statement. The Honor Statement reads: "An essential feature of the University of Tennessee, Knoxville is a commitment to maintaining an atmosphere of intellectual integrity and academic honesty. As a student of the university, I pledge that I will neither knowingly give nor receive any inappropriate assistance in academic work, thus affirming my own personal commitment to honor and integrity."

1.4 Your Role in Improving This Course Through Assessment

At UT, it is our collective responsibility to improve the state of teaching and learning. During the semester you may be requested to assess aspects of this course either during class or at the completion of the class. You are encouraged to respond to these various forms of assessment as a means of continuing to improve the quality of the UT learning experience.

1.5 Students with Disabilities

Any student who feels they may need an accommodation based on the impact of a disability should contact Student Disabilities Services in Dunford Hall, at 865-974-6087, or by video relay at, 865-622-6566, to coordinate reasonable academic accommodations.
https://sds.utk.edu

1.6 Accessibility Policy & Training

https://accessibility.utk.edu

1.7 Wellness

The Student Counseling Center is the university's primary facility for personal counseling, psychotherapy, and psychological outreach and consultation services. The Center for Health Education and Wellness manages 974-HELP, the distressed student protocol, case management, the Sexual Assault Response Team, and the Threat Assessment Task Force.
https://counselingcenter.utk.edu/ and https://wellness.utk.edu/