ASTR 502
Data Mining and Machine Learning in Astronomy
(Spring 2022)

Lectures: 3:00 PM - 3:50 PM AZ time Monday, Wednesday

Location: Steward 208 or zoom https://arizona.zoom.us/j/6849448207

Instructor: Dr. Tim Eifler, Dr. Hung-Jin Huang
Email: timeifler@arizona.edu, hungjinh@arizona.edu
Office hours (Tim): Thu 12:00 1:00pm, Steward 312, please email to set an appointment

Office hours (Hung-Jin):

Course description: ASTR 502 is a grad level, elective course discussing machine learning applications in astrophysics. The first half of the course contains lectures about machine learning and artificial intelligence basics that are paired with exercises to deepen the understanding. The second part of the course is a discussion of papers at the interface of astrophysics and machine learning and has the goal to teach specific implementations of ML, their benefits and limits in the context of astrophysics. Participants are asked to reproduce some of the science results using ML techniques and explain the underlying concepts and gains to the other students. Ultimately the goal is to develop ideas how ML/AI can be integrated into the research projects of the participating graduate students.

Grading: Course grade will be based on the d2l chapter presentation and the term project paper and presentation.

Homework Assignments: Homework assignment is to read the relevant chapters for the next lecture. Details on the course structure can be found https://github.com/UA-ASTR502-2022 . There are no graded homework assignments.

Term Project: The term project is composed of a project paper (6 pages) and a 35+10min presentation that takes place during the last weeks of the semester. The general topic is "ML applications in astronomy and physics" and the specific topic is at the discretion of the student. The general concept is to read and understand of the paper and to explain the ML techniques used in the paper as well as the scientific application. Implementation of the code used in the paper and reproducing the results are the ultimate goal. The work needs to have a code component that can be run in google colab and the code needs to made available through github. Please start thinking about your project early and discuss the concept with the instructor multiple times. You have to prepare a 1-page concept paper on your proposed work that needs to be signed off by the instructor before you can start the project.

Texts: We will largely follow the excellent online book and material provided at d2l.ai. Additional material (astrophysics papers, links to educational material) will be provided

https://github.com/UA-ASTR502-2022.

Course Objectives and Expected Learning Outcomes: The overarching goal of this course is for you to understand 1) data mining and machine learning techniques in general and 2) their usefulness and limits in the context of astrophysical science questions. This course is designed to help you develop your communication skills, quantitative literacy, critical reasoning ability, and evidence-based problem solving skills.

At the end of this course, students will be familiar with the basics of topics in machine learning such as:

- Model Selection, Underfitting & Overfitting, Weight Decay, Dropout
- Forward & Backward Prop, Vanishing gradient and parameter initialization
- Deep Learning computation basics
- Convolutional Neural Nets basics (Padding & Stride, Channels, Pooling, LeNet)
- Optimization Basics, Convexity
- Gradient Descent
- Optimization algorithms (momentum, adagrad, RMSProp, Adadelta, Adam)
- Learning Rate decay, Batch Normalization
- astrophysical applications of ML techniques

Incomplete/Withdrawal: Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available at http://catalog.arizona.edu/policy/grades-and-grading-system#incomplete and http://catalog.arizona.edu/policy/grades-and-grading-system#Withdrawal respectively.

Attendance:

- If you feel sick, or may have been in contact with someone who is infectious, stay home. Except for seeking medical care, avoid contact with others and do not travel.
- Notify your instructor(s) if you will be missing a course meeting or an assignment deadline.
- Non-attendance for any reason does not guarantee an automatic extension of due date or rescheduling of examinations/assessments. Please communicate and coordinate any request directly with your instructor.
- If you must miss the equivalent of more than one week of class, you should contact the Dean of Students Office DOS-deanofstudents@email.arizona.edu to share documentation about the challenges you are facing.
- Voluntary, free, and convenient COVID-19 testing is available for students on Main Campus.

- If you test positive for COVID-19 and you are participating in on-campus activities, you must report your results to Campus Health. To learn more about the process for reporting a positive test, visit the Case Notification Protocol.
- COVID-19 vaccine is available for all students at Campus Health.
- Visit the UArizona COVID-19 page for regular updates.

Course Website: In this class we will make use of D2L. It is your responsibility to check D2L regularly for course announcements/updates and assignments.

Classroom Behavior Policy: To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming, and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (e.g., texting, chatting, reading a newspaper, making phone calls, web surfing, etc.).

Threatening Behavior Policy: The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students.

Code of Academic Integrity: Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See: http://deanofstudents.arizona.edu/academic-integrity/students/academic-integrity.

UA Nondiscrimination and Anti-harassment Policy: The University is committed to creating and maintaining an environment free of discrimination; see http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy.

Academic advising: If you have questions about your academic progress this semester, or your chosen degree program, please note that advisors at the Advising Resource Center can guide you toward university resources to help you succeed.

Life challenges: If you are experiencing unexpected barriers to your success in your courses, please note the Dean of Students Office is a central support resource for all students and may be helpful. The Dean of Students Office can be reached at 520-621-2057 or DOS-deanofstudents@email.arizona.edu.

Physical and mental-health challenges: If you are facing physical or mental health challenges this semester, please note that Campus Health provides quality medical and mental health care. For medical appointments, call (520-621-9202. For After Hours care, call (520) 570-7898. For the Counseling & Psych Services (CAPS) 24/7 hotline, call (520) 621-3334.

Accessibility and Accommodations: At the University of Arizona, we strive to make learning experiences as accessible as possible. If you anticipate or experience barriers based on disability or pregnancy, please contact the Disability Resource Center (520-621-3268,

https://drc.arizona.edu/) to establish reasonable accommodations.

Equipment and software requirements: For this class you might need access to the following hardware: laptop or web-enabled device with webcam, headphone, and microphone; regular access to reliable internet signal; ability to download and run software. Google CoLab, Jupyter lab, or jupyter notebook with some version of python 3 (please go for 3.7 if you are installing from scratch) are required for the term project and the exercises. The term project should be written in latex (overleaf). github username and access are also required.

Class Recordings: This class is not recorded. All recordings are subject to government and university regulations. Therefore, students accessing unauthorized recordings or using them in a manner inconsistent with UArizona values and educational policies are subject to suspension or civil action. You may record the class for your private notetaking purpose, but widely sharing/publication is disallowed.

Subject to Change Statement: Information contained in the course syllabus may be subject to change as deemed appropriate by the instructor. Updates will be announced.