ISTA 421 (undergraduate) and INFO 521 (graduate)
Introduction to Machine Learning
Fall 2021

Course Description:
Machine learning is the discipline that develops and studies algorithms that can adjust their parameters (i.e., *learn*) based on data (experience). This course will introduce the fundamentals of modern machine learning. We will describe how to implement several practical methods for pattern recognition (regression and classification), clustering, and dimensionality reduction, as well as methods for training and evaluating learned models.

Prerequisites:
Calculus I (derivatives) and II (integrals), Linear Algebra;
Programing experience (at least 3 courses; the language used in the course is Python 3);
Introductory statistics and probability (ISTA 311 recommended).

Units: 3

Course Location and Times:
Modern Languages, Room 311
Monday and Wednesday, 12:30 PM to 1:45 PM

Instructors:

Clayton T. Morrison, PhD, Associate Professor
School of Information
Office Phone: 520-621-6609
Email: claytonm@arizona.edu
Office Hours: Wednesday 2-3pm. (Initially by zoom)

Cristian Roman-Palacios, PhD, Assistant Professor
School of Information
Email: cromanpa94@arizona.edu
Office Hours: Thursday 3-4pm. (Initially by zoom)

Course home page:
https://ml4ai-2021-fall-ml.github.io/

Course Objectives:
The objective of this course is to introduce the core methods used in modern machine learning, gain experience implementing these methods as algorithms in a programming language (Python), and use and evaluate them on data.

By the end of this course, all students will be able to:
• Identify standard machine learning methods appropriate for different applications (regression, classification, clustering).
• Write programs that can identify parameters of a model based on training data.
• Compare and contrast the performance of different learning algorithms applied to different types of problems.

By the end of this course, graduate students will also be able to:
• Design, write, and evaluate machine learning programs that solve real-world problems.

School of Information Competencies addressed by this course:
• Undergraduates (ISTA)
https://ischool.arizona.edu/undergraduate-student-competencies
F1.2 – Students will demonstrate facility using basic research methods, for example: research design; statistics and analysis; organization, identification, and location of data and information including open- and closed-access sources; and/or presentation of findings in oral, written and multi-media form, including proper use of and citation of sources.
DAISBS2.2 – Students will establish the ability to exercise the four key techniques of computational thinking (decomposition, pattern recognition, abstraction, and algorithms) in solving information and data challenges.
• Graduates (INFO)
https://ischool.arizona.edu/ms-student-competencies
Students will establish the ability to exercise the four key techniques of computational thinking: decomposition (C1.A), pattern recognition (C1.B), abstraction (C1.C), and algorithms (C1.D) in solving information and data challenges, in addition to analytically. Students will also demonstrate fluency in at least one programming language (C1.E).
C2.A: Students will be able to identify specific types of data for different analytical methods.
C2.C: Students will be able to apply appropriate statistical, machine learning, visual analytics, and other techniques to identify patterns and make sound predictions with given data.

Courses Meeting Information for Fall 2021 during the Pandemic

Instruction Mode: In Person

Statement on compliance with COVID-19 mitigation guidelines: As we enter the Fall semester, your and my health and safety remain the university's highest priority. To protect the health of everyone in this class, students are required to follow the university guidelines on COVID-19 mitigation. Please visit www.covid19.arizona.edu.

Classroom 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 instructors 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 (https://covid19.arizona.edu/test-trace-treat) 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 (https://covid19.arizona.edu/test-trace-treat/positive-case-protocol).
- COVID-19 vaccine is available for all students at Campus Health (https://health.arizona.edu/covidvaccine).
- Visit the UArizona COVID-19 (https://covid19.arizona.edu/) page for regular updates.

Office Hours:

Our goal is to be able to hold office hours in person. However, with the uncertain pandemic conditions, especially at the beginning of the semester, we will start by holding office hours by zoom. The zoom link will be provided in class. Once we feel that it is safe to hold in-person office hours, we will announce in class and on D2L our change in office hours mode.

Obtaining Help

- **Academic advising:** If you have questions about your academic progress this semester, please reach out to your academic advisor (https://advising.arizona.edu/advisors/major). Contact the Advising Resource Center (https://advising.arizona.edu/) for all general advising questions and referral assistance. Call 520-626-8667 or email to advising@.arizona.edu

- **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.

Grade policies:

Grade categories and proportions:
Grading will be based on programming exercises and written assignments (Assignments), one in-class midterm (Midterm) and a final assignment (Final Assignment). **Points** will be assigned to each according to the estimated amount of effort based on the exercise difficulty. Graduate students will receive additional and alternate problems, and therefore need to earn more points total for many of the assignments; this reflects the expected higher level of competency and preparation of graduate students.

The total points in each category are scaled to contribute to the final **cumulative grade percentage** value according to the following distribution (the same distribution scaling is used for both undergraduates and graduates):

Assignments: 70%
(Written Homework & Programming Exercises, assigned approximately every other week.)
Midterm: 10%
Final Assignment: 20%

Letter grades are then assigned according to the final cumulative grade percentage:

A: 90% ≤ cumulative grade
B: 80% ≤ cumulative grade < 90%
C: 70% ≤ cumulative grade < 80%
D: 60% ≤ cumulative grade < 70%

Late Work Policy:
Assignments are due by the date/time specified.
No examinations may be taken after the examination date.
Assignments will generally be submitted as PDF documents and code files that are committed and pushed to the course GitHub Classroom repository. We *may* also use the course D2L assignment turn-in for some assignments.
In case of emergencies affecting turning work in on time, you ***must*** contact the instructor *immediately*.

Classroom Behavior:
Please be considerate: Please disable your mobile device ringer or sound notifications. If you get an urgent call, please quietly leave the lecture hall to conduct it. Screens are distracting! If you want to use a laptop or tablet for taking notes, please sit toward the side and back of the class in order to not disrupt other students.
Asking Questions: During class, feel free to ask questions whenever they occur to you. Raise your hand if you have a question; politely interrupt if the instructor does not appear to have noticed your hand. The instructor may ask you to hold off on your question for a few moments.

Answering Questions: The instructors frequently ask questions of the class during lectures to judge the level of understanding. Some students really like answering questions, sometimes to the point of discouraging anyone else from answering. If you are an eager answerer, pace yourself; let someone else answer an easy one once in a while, and save the hard ones for yourself.

Textbooks and Resources:

- Simon Rogers and Mark Girolami (2016). *A First Course in Machine Learning, Second Edition*. Chapman & Hall / CRC Press.
  This is available for free through the UA Library; see course website for direct link. Be sure to use the *Second Edition*.
- Marc Peter Deisenroth, A. Aldo Faisal, and Cheng Soon Ong (2020). *Mathematics for Machine learning*. MIT Press.
  Available online for free: https://mml-book.github.io/
- Gareth James, Daniela Witten, Trevor Hastie and Robert Tibshirani (2013). *Introduction to Statistical Learning, with Applications in R*. Springer.
  Available online for free: http://www-bcf.usc.edu/~gareth/ISL/

Other resources, recommended for additional, complementary, and more in-depth coverage; many of these are also available for free online. If I assign any readings from these, they will be provided through D2L:

- Hal Daumé III (2019). *A Course in Machine Learning*. Online: http://ciml.info
- Trevor Hastie, Robert Tibshirani and Jerome Friedman (2009). *The Elements of Statistical Learning: Data Mining, Inference, and Prediction* (Second Edition).
  Online: http://www-stat.stanford.edu/~tibs/ElemStatLearn/download.html
- David Barber (2012). *Bayesian Reasoning and Machine Learning*.
  [Available for free online: http://www.cs.ucl.ac.uk/staff/d.barber/brml/]
- A. Blum, J. Hopcroft and R. Kannan (2018). *Foundations of Data Science*.
  Online: https://www.cs.cornell.edu/jeh/book%20no%20so;utions%20March%202019.pdf
- I. Goodfellow, Y. Bengio and A. Courville (2016). *Deep Learning*. [On the foundations of modern neural networks. Available for free online: http://www.deeplearningbook.org/]
- C. Rasmussen and C. Williams (2006). Gaussian Processes for Machine Learning.
  [Available for free online: http://www.gaussianprocess.org/gpml/]
- Y. S. Abu-Mostafa, M. Magdon-Ismail and H.-T. Lin (2012). *Learning from Data*. AMLBook. [Very good introductory book with more of a focus on learning theory.]
- Kevin P. Murphy (2012). *Machine Learning: A Probabilistic Perspective*. The MIT Press. [Very comprehensive, a good reference; but beware of numerous errors in the first four printings – read with the errata handy (errata available from Kevin's book site: http://www.cs.ubc.ca/~murphyk/MLbook/).]
- Christopher Bishop (2006). *Pattern Recognition and Machine Learning.* Springer. [More advanced, Bayesian perspective.]

Course Topics

- Introduction
- The Linear Model
  - Linear Regression and Linear Least Mean Squares
  - Linear classification and the Perceptron
  - Extending the Linear Model
- Learning Theory and Model Evaluation
  - Bias-Variance Tradeoff
  - Cross Validation
- Probabilistic methods
  - Review of Probability
  - Maximum Likelihood
  - The Bayesian approach
    - Priors, Marginal Likelihood, Hyperparameters
- Optimization and Approximation Methods
  - Gradient methods (gradient descent, Newton's method)
  - Laplace estimation
  - Sampling, MCMC, Metropolis-Hastings
- Classification
  - Logistic Regression
  - Bayesian Classification, Naive Bayes
  - Nearest Neighbors
  - Support Vector Machines
- Neural Networks
  - Perceptron, Backpropagation
  - Autoencoders and "Deep" architectures
- Clustering
  - K-means
  - Mixture Models
  - Expectation Maximization
- Projection Methods
  - Principal Components Analysis
  - Latent Variable Models
- Additional Topics (depending on time)
  - Nonparametric Bayesian methods
    - Gaussian Processes
    - Topic Modeling
  - Ensembles, Boosting and Random Forests

UNIVERSITY POLICIES

Honors Credit:
Students wishing to contract this course for Honors Credit should email me to set up an appointment to discuss the terms of the contract and to sign the Honors Course Contract Request Form.
The Honors College website: https://www.honors.arizona.edu/

Missed Classes (Absence):
The UA's policy concerning Class Attendance and Administrative Drops is available at: http://catalog.arizona.edu/policy/class-attendance-participation-and-administrative-drop

All holidays or special events observed by organized religions will be honored for those students who show affiliation with such religions. Absences pre-approved by the UA Dean of Students office will be honored. See:
http://policy.arizona.edu/human-resources/religious-accommodation-policy

No matter the reason for missing class, the student is <u>always</u> responsible for any missed material.

Final Exams:
Final Exam Regulations and Information:
https://www.registrar.arizona.edu/courses/final-examination-regulations-and-information Final Exam Schedule:
http://www.registrar.arizona.edu/students/courses/final-exams

Audit Policy:
http://catalog.arizona.edu/policy/audit-policy

Accessibility and Accommodations:
It is the University's goal that learning experiences be as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, please let me know immediately so that we can discuss options. You are also welcome to contact Disability Resources (520-621-3268) to establish reasonable accommodations. DRC online: http://drc.arizona.edu/
Please be aware that the accessible table and chairs in this room should remain available for students for whom standard classroom seating is not usable.
Disability Resource Center. 1221 E. Lowell St. Tucson, Az 85721 Tel: 520-621-3268 (TTY). Fax: 520-621-9423. uadrc@email.arizona.edu

UA SALT Center: http://www.salt.arizona.edu

Student Code of Academic Integrity (a.k.a., Cheating):
Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See:
http://deanofstudents.arizona.edu/policies-and-codes/code-academic-integrity

The University Libraries have some excellent tips for avoiding plagiarism available at: http://new.library.arizona.edu/research/citing/plagiarism

*Selling class notes and/or other course materials to other students or to a third party for resale is **not permitted** without the instructor's express written consent*. Violations to this and other course rules are subject to the Code of Academic Integrity and may result in course sanctions. Additionally, students who use D2L or UA email to sell or buy these copyrighted materials are subject to Code of Conduct Violations for misuse of student email addresses. This conduct may also constitute copyright infringement.

Additional Information on conduct:

The Arizona Board of Regents list of Prohibited Conduct (pdf):
https://public.azregents.edu/Policy%20Manual/5-303-Prohibited%20Conduct.pdf

The Arizona Board of Regents Student Code of Conduct (pdf):
https://public.azregents.edu/Policy%20Manual/5-308-Student%20Code%20of%20Conduct.pdf

Policies Against Threatening Behavior:
The Student Code of Conduct (5-308.F.11) dictates that no person or organization may interfere with or threaten University-sponsored classroom activities. The following links provides details about the policy:
http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students
http://policy.arizona.edu/education-and-student-affairs/disruptive-behavior-instructional-setting

Non-Discrimination and Anti-Harassment Policy:
http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

Statements of Inclusion:
Elective name and pronoun usage: This course supports elective gender pronoun use and self-identification; rosters indicating such choices will be updated throughout the semester, upon student request. As the course includes in-class discussion, it is vitally important for us to create an educational environment of inclusion and mutual respect.

More information on updating your preferred name and pronouns is available on the Office of the Registrar site at https://www.registrar.arizona.edu/.

Inclusive Excellence is a fundamental part of the University of Arizona's strategic plan and culture. As part of this initiative, the institution embraces and practices diversity and inclusiveness. These values are expected, respected and welcomed in this course.

Office of Diversity: http://diversity.arizona.edu/
Health: https://www.health.arizona.edu/
Counseling: http://www.health.arizona.edu/counseling-and-psych-services

Confidentiality of Student Records:
http://registrar.arizona.edu/personal-information/family-educational-rights-and-privacy-act-1974-ferpa

Required or Special Materials: None.

Notice of Potentially Offensive Material: None.

Miscellaneous University Policies:

(1) On Dropping Classes:

See the official University of Arizona Registrar fall 2021 Dates and Deadlines:
https://registrar.arizona.edu/dates-and-deadlines

If you find yourself thinking about dropping this (or any other) class, first make sure that that's what you really want to do. Chatting with the instructor or your academic advisor may help.

University of Arizona Class Attendance and Administrative Drop Policy:
http://catalog.arizona.edu/policy/class-attendance-participation-and-administrative-drop

(2) Grades of 'Incomplete':

Office of Curriculum and Registration Grading Policy Manual:
https://www.registrar.arizona.edu/grades/incomplete-i-grade

UA General Catalog's Grades and the Grading System:
http://catalog.arizona.edu/policy/grades-and-grading-system

The university's course catalog contains all of the details about incompletes, but here's the key sentence: "The grade of I may be awarded only at the end of a term, when all but a minor portion of the course work has been satisfactorily completed."

To qualify for an incomplete, a student must have maintained a passing grade for the class until the term is nearly complete, and then, due to an unusual and substantiated cause beyond the student's control, the student is unable to complete the class work. In short, you *cannot* get an "I" just because you aren't happy with your grade.

Additional Resources for Students:

- UA Acadmic policies and procedures are available at http://catalog.arizona.edu/policies.

- **Campus Health:** http://www.health.arizona.edu/ . Campus Health provides quality medical and mental health care services through virtual and in-person care. Voluntary, free and convenient COVID-19 testing is available for students on Main Campus. COVID-19 vaccine is available for all students at Camps Health. Phone: 520-621-9202.

- **Counseling and Psychological Services (CAPS):**
  https://health.arizona.edu/counseling-psych-services . CAPS provides mental health care, including short-term counseling services. Phone: 520-621-3334

- **The Dean of Students Office's Student Assistance Program**
  http://deanofstudents.arizona.edu/student-assistance/students/student-assistance
  Student Assistance helps students manage crises, life traumas, and other barriers that impede success. The staff addresses the needs of students who experience issues related to social adjustment, academic challenges, psychological health, physical health, victimization, and relationship issues, through a variety of interventions, referrals, and follow up services. Email: DOS-deanofstudents@email.arizona.edu
  Phone: 520-621-7057

- **Survivor Advocacy Program**
  https://survivoradvocacy.arizona.edu/

The Survivor Advocacy Program provides confidential support and advocacy services to student survivors of sexual and gender-based violence. The Program can also advise students about relevant non-UA resources available within the local community for support.
Email: survivoradvocacy@email.arizona.edu
Phone: 520-621-5767

- **Campus Pantry**
  Any student who has difficulty affording groceries or accessing sufficient food to eat every day, or who lacks a safe and stable place to live and believes this may affect their performance in the course, is urged to contact the Dean of Students for support. In addition, the University of Arizona Campus Pantry is open for students to receive supplemental groceries at no cost. Please see their website at: https://campuspantry.arizona.edu/ for open times.

"Subject to Change" Statement:
The instructor reserves the right to change with advance notice where appropriate the content of the course. This right does not apply to the grade, absence or University policies.

Land Acknowledgement Statement
We respectfully acknowledge the University of Arizona is on the land and territories of Indigenous peoples. Today, Arizona is home to 22 federally recognized tribes, with Tucson being home to the O'odham and the Yaqui. Committed to diversity and inclusion, the University strives to build sustainable relationships with sovereign Native Nations and Indigenous communities through education offerings, partnerships, and community service.