Term	Class No.	Section	Units	Days & Times	Room	Mode
Spring 2019	CS499	007 (9235)	3	TuTh 9:35AM - 10:15M	069-224	Face-to-face

Enrollment Requirements

Pre-requisite or Corequisite: MAT 316 (Linear algebra), MAT 137 (Calculus), C programming experience. Optional but helpful: experience using git, github, software testing, and R .

Course Website

http://bblearn.nau.edu

Instructor(s)

Dr. Toby Dylan Hocking
Email: Toby.Hocking@nau.edu
Office Hours: by appointment.

Course Purpose

This course provides an introduction to machine learning, which is the domain of computer science concerned with algorithms that learn from experience, and adapt to patterns in large data sets. In contrast to other courses at NAU that emphasize theory and use of machine learning algorithms (e.g. INF504), this course teaches students how to code the machine learning algorithms themselves. The course requires prior knowledge of calculus and C programming. Students will learn how to write an R package with C code that implements machine learning algorithms. A primary purpose is to get students ready for machine learning research projects.

Course Student Learning Outcomes

Upon successful completion of this course, students will be able to demonstrate the following competencies:

- **LO1**: Remember and Understand the foundational concepts of machine learning, including optimization, regularization, and cross-validation.
- **LO2**: Create machine learning algorithms from statistical models and mathematical optimization problems.
- **LO3**: Create R packages with C/C++ code that implements machine learning algorithms.

- **LO4**: Analyze real-world data sets and apply machine learning algorithms to create predictive models.
- **LO5**: Evaluate and compare machine learning algorithms in terms of optimization objective and prediction error.

Assignments / Assessments of Course Student Learning Outcomes

Learning outcomes are assessed through a variety of means. Daily attendance quizzes and midterm and final exams assess student ability to describe and explain foundational concepts in machine learning (LO1), and to create algorithms from statistical models and optimization problems (LO2).

Group coding projects assess student ability to create R package with C/C++ code that implement machine learning algorithms (LO3), apply that code to analyze real-world data sets (LO4), and evaluate learning algorithms (LO5).

Assignments and course topics may change depending on the skill level of the class.

Grading System

A weighted sum of assessment components is used to determine your final grade in the course:

- Class participation quizzes: **20%**
- Group coding projects: **40%**
- Midterm Exam: **20%**
- Final Exam: **20%**

Grades will be assigned using the weighted sum described above using this scale:
A ≥ 90%, **B** ≥ 80%, **C** ≥ 70%, **D** ≥ 60%, **F** < 60%.

There is no “curve”. Each student’s grade is based on their own outcomes assessments and not affected by the grades of other students. Extra credit opportunities may present themselves throughout the semester and will be announced during class meetings. Mistakes in grading do happen, and students are encouraged to discuss such concerns with the instructor during office hours.

Readings and Materials

We will refer to two textbooks in this class:

Machine learning: a probabilistic perspective by Murphy. Free e-book available from NAU library. http://ebookcentral.proquest.com/lib/nau-ebooks/reader.action?docID=3339490

Elements of statistical learning by Hastie, Tibshirani, Friedman. Free PDF available on https://web.stanford.edu/~hastie/ElemStatLearn/

R packages by Wickham, http://r-pkgs.had.co.nz/

Students will also need access to a computer with RStudio and git. (installation instructions will be provided in class)

Group coding projects

There will be four group coding projects. In each coding project you are expected to work in a group of 2-3 in order to write an R package with C/C++ code that implements a machine learning algorithm, and write a report comparing your algorithm to other state-of-the-art R packages. Therefore it is best to form a group in which each student has different expertise he/she can contribute to the group: making figures, writing good English, R coding experience, C/C++ coding experience, etc. Topics (subject to change):

- Project 1: nearest neighbors for regression and binary classification.
- Project 2: smooth optimization, gradient descent algorithms, compare L2 regularization with early stopping.
- Project 3: neural networks, backpropagation algorithm with early stopping.
- Project 4: non-smooth convex optimization, L1 regularized regression and classification.

Grades will be based on the following rubric: 25% clarity of report (including figures), 25% reproducibility of report, 25% clarity of R package (including C/C++ code, documentation, tests), 25% group evaluations.

Class Outline and Tentative Schedule

The course topics and a tentative schedule (subject to change):
Reading: H=Hastie book, M=Murphy book.

		Tuesday		Thursday	Reading
Week 1	**Jan 15**	Applications of machine learning	**Jan 17**	Supervised learning	H Chapter 1 M Chapter 1
Week 2	**Jan 22**	Nearest Neighbors	**Jan 24**	Cross-validation	H Chapter 2 M Chapter 1
Week 3	**Jan 29**	Writing an R package with C/C++ code	**Jan 31**	continued…	R packages book
Week 4	**Feb 5**	Linear regression, gradient descent	**Feb 7**	continued…	H Chapter 3 M Chapter 7
Week 5	**Feb 12**	L2 regularization, logistic regression	**Feb 14**	continued… **Coding project 1 Due**	H Chapter 4 M Chapter 8
Week 6	**Feb 19**	Coding project 1 review	**Feb 21**	snow day	H Chapter 3 M Chapter 13
Week 7	**Feb 26**	Line search for gradient descent	**Feb 28**	continued…	M Chapter 13
Week 8	**Mar 5**	Coding workshop	**Mar 7**	continued… **Coding project 2 Due**	H Chapter 12
Week 9	**Mar 12**	Midterm exam review	**Mar 14**	**Midterm Exam**	
Week 10	**Mar 19**	Spring break	**Mar 21**	Spring break	
Week 11	**Mar 26**	Neural Networks for regression	**Mar 28**	continued…	H Chapter 4 M Chapter 8
Week 12	**Apr 2**	Neural networks for binary classification	**Apr 4**	continued…	H chapter 11 M Sec 16.5
Week 13	**Apr 9**	Coding workshop	**Apr 11**	continued… **Coding project 3 Due**	M Chapter 17
Week 14	**Apr 16**	L1-regularized linear regression (LASSO)	**Apr 18**	continued…	Papers
Week 15	**Apr 23**	L1-regularized logistic regression	**Apr 25**	continued…	Papers
Week 16	**Apr 30**	Coding workshop	**May 2**	continued… **Coding project 4 Due**	papers
Week 17	**May 7**	Final exam review	**May 9**	**Final Exam**	

There will be a written attendance/participation quiz at the end of every class, with one question based on the content of that class. Each will be worth 2 points (1 if you attend class, 1 for correct answer). There are a total of 30 quizzes and thus 60 quiz points possible.

Course Policies

The following policies will apply to this course:

- Attendance is required and will be recorded at the end of the class during the attendance quiz. Excessive absences will reduce your overall grade:
  - **3** unexcused absences will result in a 10% penalty in your final grade;
  - **4** unexcused absences will result in a 20% penalty in your final grade;
  - **5** unexcused absences will result in a 30% penalty in your final grade;
  - **6** unexcused absences will result in a 40% penalty in your final grade;
  - **7** or more unexcused absences will result in a failing grade for the class.
- Students who have not completed the prerequisite(s) for this course, or who are absent from the class during the first week may be administratively dropped from the course.
- The makeup and late work policies are as follows:
  - Quizzes: No make-ups or late submissions allowed.
  - Group coding projects: No make-ups or late submissions allowed.
  - Exams: Make-up exams will be given only in the case of a documented emergency supported by a class missed memo from Student Life (https://nau.edu/student-life/classes-missed-memos/) **and** with approval from the instructor. Make-up exams may be considerably different than the original exam. Make-up exams must be taken within 3 business days of the original exam.
- **Cheating and plagiarism are strictly prohibited**. All work you submit for grading must be your own -- for the coding projects this means that you are not allowed to copy code that you found on the web, and submit that code as your own. The point of the coding projects is for you to take the time to learn how to code the machine learning algorithms from scratch. It is OK to discuss intellectual aspects with other groups during the coding projects, but is it NOT OK to copy from other groups. During coding projects you will compare your code with other existing implementations, which is OK as long as you cite the source of the code that you used (which will typically be indicated in the assignment). All academic integrity violations are treated seriously. Academic integrity violations will result in penalties including, but not limited to, a zero on the assignment, a failing grade in the class, or expulsion from NAU.
- Electronic device usage must support learning in the class. All cell phones, PDAs, music players and other entertainment devices must be turned off (or in silent mode) during lecture, and may not be used at any time. Laptops or workstations (if

present) are allowed for note-taking and activities only during lectures; no web surfing or other use is allowed. I devote 100% of my attention to providing a high-quality lecture; please respect this by devoting 100% of your attention to listening and participating.

- Grades will be entered in BBLearn but your final grade will be calculated in Excel using the grading system described above and then entered in LOUIE. Your final course grade will **not** necessarily appear in BBLearn. Please check LOUIE for your final grade.
- Email to the instructor and teaching assistants must be respectful and professional. Specifically, all emails should:
    - Contain a salutation, (for example, "Dear Dr. Hocking" or "Dear Professor H")
    - Contain a closing, (for example, "Best, Jane Doe")
    - The body should contain complete sentences and correct grammar including correct usage of lowercase and uppercase letters. Composing emails on a mobile device is **not** an excuse for poor writing.
    - The body of your message should also be respectful and explain the full context of the query.
    - The subject should be prefixed with "CS499" so that the message can be easily identified or placed in an auto-folder. The subject should also use lower case and upper case correctly.
    - Although email will typically be answered quickly, you should allow up to three (3) business days for a response.
    - If you have a question that would require a long response or you have a lot of questions, please come to office hours or schedule an appointment with the instructor.
- Visiting the instructor(s) during office hours is encouraged! I am happy to talk about the class, careers, research, and topics related (even loosely) to this course.
- Anonymous feedback via the "parking lot." I will distribute post-it notes at the end of class. Please write (1) the concept you most clearly understood during the lecture, and (2) the concept that you had the most difficulty understanding. I will use the feedback to adapt future lectures.

Appendix A. UNIVERSITY POLICY STATEMENTS

ACADEMIC INTEGRITY

NAU expects every student to firmly adhere to a strong ethical code of academic integrity in all their scholarly pursuits. The primary attributes of academic integrity are honesty, trustworthiness, fairness, and responsibility. As a student, you are expected to submit original work while giving proper credit to other people's ideas or contributions. Acting with academic integrity means completing your assignments independently while truthfully acknowledging all sources of information, or collaboration with others when appropriate. When you submit your work, you are implicitly declaring that the work is your own. Academic integrity is expected not only during formal coursework, but in all your relationships or interactions that are connected to the educational enterprise. All forms of academic deceit such as plagiarism, cheating, collusion, falsification or fabrication of results or records, permitting your work to be submitted by another, or inappropriately recycling your own work from one class to another, constitute academic misconduct that may result in serious disciplinary consequences. All students and faculty members are responsible for reporting suspected instances of academic misconduct. All students are encouraged to complete NAU's online academic integrity workshop available in the E-Learning Center and should review the full academic integrity policy available at https://policy.nau.edu/policy/policy.aspx?num=100601.

COURSE TIME COMMITMENT

Pursuant to Arizona Board of Regents guidance (Academic Credit Policy 2-224), for every unit of credit, a student should expect, on average, to do a minimum of three hours of work per week, including but not limited to class time, preparation, homework, and studying.

DISRUPTIVE BEHAVIOR

Membership in NAU's academic community entails a special obligation to maintain class environments that are conductive to learning, whether instruction is taking place in the classroom, a laboratory or clinical setting, during course-related fieldwork, or online. Students have the obligation to engage in the educational process in a manner that does not breach the peace, interfere with normal class activities, or violate the rights of others. Instructors have the authority and responsibility to address disruptive behavior that interferes with student learning, which can include the involuntary withdrawal of a student from a course with a grade of "W". For additional information, see NAU's

disruptive behavior policy at https://nau.edu/university-policy-library/disruptive-behavior.

NONDISCRIMINATION AND ANTI-HARASSMENT

NAU prohibits discrimination and harassment based on sex, gender, gender identity, race, color, age, national origin, religion, sexual orientation, disability, or veteran status. Due to potentially unethical consequences, certain consensual amorous or sexual relationships between faculty and students are also prohibited. The Equity and Access Office (EAO) responds to complaints regarding discrimination and harassment that fall under NAU's Safe Working and Learning Environment (SWALE) policy. EAO also assists with religious accommodations. For additional information about SWALE or to file a complaint, contact EAO located in Old Main (building 10), Room 113, PO Box 4083, Flagstaff, AZ 86011, or by phone at 928-523-3312 (TTY: 928-523-1006), fax at 928-523-9977, email at equityandaccess@nau.edu, or via the EAO website at https://nau.edu/equity-and-access.

TITLE IX

Title IX is the primary federal law that prohibits discrimination on the basis of sex or gender in educational programs or activities. Sex discrimination for this purpose includes sexual harassment, sexual assault or relationship violence, and stalking (including cyber-stalking). Title IX requires that universities appoint a "Title IX Coordinator" to monitor the institution's compliance with this important civil rights law. NAU's Title IX Coordinator is Pamela Heinonen, Director of the Equity and Access Office located in Old Main (building 10), Room 113, PO Box 4083, Flagstaff, AZ 86011. The Title IX Coordinator is available to meet with any student to discuss any Title IX issue or concern. You may contact the Title IX Coordinator by phone at 928-523-3312 (TTY: 928-523-1006), by fax at 928-523-9977, or by email at pamela.heinonen@nau.edu. In furtherance of its Title IX obligations, NAU will promptly investigate and equitably resolve all reports of sex or gender-based discrimination, harassment, or sexual misconduct and will eliminate any hostile environment as defined by law. Additional important information about Title IX and related student resources, including how to request immediate help or confidential support following an act of sexual violence, is available at http://nau.edu/equity-and-access/title-ix.

ACCESSIBILITY

Professional disability specialists are available at Disability Resources to facilitate a range of academic support services and accommodations for students with disabilities. If you have a documented disability, you can request assistance by contacting Disability

Resources at 928-523-8773 (voice), 928-523-6906 (TTY), 928-523-8747 (fax), or dr@nau.edu (e-mail). Once eligibility has been determined, students register with Disability Resources every semester to activate their approved accommodations. Although a student may request an accommodation at any time, it is best to initiate the application process at least four weeks before a student wishes to receive an accommodation. Students may begin the accommodation process by submitting a self-identification form online at https://nau.edu/disability-resources/student-eligibility-process or by contacting Disability Resources. The Director of Disability Resources, Jamie Axelrod, serves as NAU's Americans with Disabilities Act Coordinator and Section 504 Compliance Officer. He can be reached at jamie.axelrod@nau.edu.

RESPONSIBLE CONDUCT OF RESEARCH

Students who engage in research at NAU must receive appropriate Responsible Conduct of Research (RCR) training. This instruction is designed to help ensure proper awareness and application of well-established professional norms and ethical principles related to the performance of all scientific research activities. More information regarding RCR training is available at https://nau.edu/research/compliance/research-integrity.

SENSITIVE COURSE MATERIALS

University education aims to expand student understanding and awareness. Thus, it necessarily involves engagement with a wide range of information, ideas, and creative representations. In their college studies, students can expect to encounter and to critically appraise materials that may differ from and perhaps challenge familiar understandings, ideas, and beliefs. Students are encouraged to discuss these matters with faculty.

Updated 8/20/2018