Syllabus

1. Title: BIOS 7747 - Machine Learning for Biomedical Applications

2. Credits: 2

3. Intended Audience: MS or PHD students in Biostatistics, Bioengineering, Computational Bioscience

4. Meeting Time and Location

- Time: 9:00 -9:50 am, Tuesday and Thursday, Fall semester
- Location: CU Anschutz Medical Campus – Education 1: P26-MPC-1100 (the classes of 11/22-29, 12/1-6 and 12/13 will be in P26-1400).

5. Instructor

- Instructor: Antonio R. Porras
- Office: Building 500, W4132
- E-mail: antonio.porras@cuanschutz.edu
- Office hours: 12:00-1:30pm – Tuesday

6. Course Website

- All course materials will be available through Canvas.

7. Course Description

- This course presents the theoretical background of unsupervised and supervised machine learning methods and their application to biomedical problem solving. In addition to understanding methodological details, students will learn how to use and apply machine learning methods in Python, will improve their coding skills, will present methods and state-of-the-art research articles and will participate in scientific discussions around them.

8. Prerequisites or Co-requisites

- Biostatistical methods (e.g., BIOS 6611, BIOS 6612), linear algebra (e.g., MATH 3191) and Python programming (e.g., BIOS 6642), or permission from the instructor.

9. Course Objectives/Expected Outcomes

- Understand the theoretical background of traditional supervised and unsupervised machine learning methods
- Learn the theoretical background and design details of deep neural networks
- Become familiar with state-of-the-art machine learning methods used in the biomedical domain
- Learn how to implement machine learning solutions in Python

10. Competencies

Identifier	MS / PhD Biostatistics Competencies

MS-BIOS-3	Carry out exploratory and descriptive analyses of complex data using standard statistical software and methods of data summary and visualization
MS-BIOS-4	Carry out valid and efficient modeling, estimation, model checking and inference using standard statistical methods and software.
PhD-BIOS-3	Carry out exploratory and descriptive analyses of complex data using standard statistical software and methods of data summary and visualization.
PhD-BIOS-4	Carry out valid and efficient modeling, estimation, model checking and inference using standard statistical methods and software.

11. Textbook and Software Required

- No textbook required. Class notes, slides and readings are provided by the instructor.
- Python 3 programming environment.

12. Recommended Reading (not mandatory)

- Introduction to Machine Learning. Ethem Alpaydin. Third Edition. 2014. ISBN 0262028182.
- Deep Learning. Ian Goodfellow and Yoshua Bengio and Aaron Courville. MIT Press. 2016. https://www.deeplearningbook.org/.

13. Additional resources (not mandatory)

- Introduction to Statistical Learning by Gareth James, Daniela Witten, Trevor Hastie and Robert Tibshirani. Springer, 2013. Corrected 8th printing, 2017. ISBN 1461471370.
- Deep Learning with PyTorch: Build, train, and tune neural networks using Python tools 1st Edition. Eli Stevens, Luca Antiga, and Thomas Viehmann. Manning. 1617295264.

14. Evaluation

- Assignments: 20%
- Paper presentation: 15%
- Classroom 15%
- Final exam: 50%

Assignments: Ten weekly practical assignments will be submitted through canvas. Late homework will be penalized 20% per day.

Paper presentation: Student will be responsible for presenting one state-of-the-art machine learning paper and leading a discussion. All other students are expected to read the paper and be prepared for the discussion.

Classroom: Students will be expected to attend all classes and participate in the discussions on the paper presentation days. Students will also be asked to prepare and

present the theory behind some of the most common machine learning methods to the rest of the class.

Final exam: Students will take a final in-person exam at the end of the course to evaluate the concepts learned. The exam will take less than two hours.

Letter grades: A final grade will be assigned according to the following scale.

A: 94-100
A-: 90-93.99
B+: 87-89.99
B: 83-86.99
B-: 80-82.99
C+: 77-79.99
C: 73-76.99
C-: 70-72.99
D+: 67-69.99
D: 63-66.99
D-: 60-62.99
F: < 60

15. Course outline

Date	Format	Topic
8/30	Lecture	Course introduction
9/1	Practical	Practical warm-up class: Python setup and use of common libraries
9/6	Lecture	Supervised machine learning: regression, regular gradient descent optimization, linear and non-linear regression.
9/8	Practical	Regression and optimization with Python: Statsmodels, Scikit-learn and Scipy.
9/13	Lecture	Feature exploration, visualization, pre-processing and normalization.
9/15	Practical	Feature exploration and pre-processing for a non-linear regression problem.
9/20	Seminar	Invited seminar: “Ethics and Bias in Machine Learning: More than the Data”. Dr. Matthew DeCamp, MD, PhD
9/22		Canceled
9/27	Lecture	Supervised machine learning: classification and logistic regression. Performance evaluation and cross-validation.
9/29	Practical	Cross-validation of logistic regression-based classification methods.
10/4	**Flipped classroom**	Supervised machine learning: Naïve Bayes, K-nearest neighbors, decision trees and random forests. Strong vs. weak learners (boosting, bootstrap and bagging)
10/6	Practical	K-nearest neighbors, decision trees and random forests in Python.
10/11	**Flipped classroom**	Supervised machine learning: Lagrange multipliers and support vector machines. The kernel trick. Platt’s algorithm. Support vector regression.
10/13	Practical	Support vector machines, class imbalance, Platt’s algorithm, understanding and visualizing overfitting in Python.
10/18	**Flipped classroom**	Unsupervised learning: clustering, mixture models and other alternatives. Selecting the appropriate data for clustering. Performance evaluation.

10/20	Practical	Clustering and visualization in Python.
10/25	Lecture	The curse of dimensionality and dimensionality reduction. Unsupervised dimensionality reduction using principal component analysis. Generalized principal component analysis and principal component analysis-based modeling. Supervised dimensionality reduction using linear discriminant analysis.
10/27	Practical	Implementation and visualization of principal component analysis and linear discriminant analysis in Python.
11/1	**Student presentations**	Presentations of feature-based machine learning research papers.
11/3	**Student presentations**	Presentations of feature-based machine learning research papers.
11/8	Lecture	Introduction to neural networks. Feed-forward networks, activation and backpropagation. Examples of biomedical applications.
11/10	Practical	Introduction to Neural Networks with Pytorch and Tensorboard in Python.
11/15	Lecture	Working with time series and images: convolutional neural networks. Examples and application to biomedical data.
11/17	Practical	Convolutional Neural Networks with Pytorch.
11/22	Lecture	Design alternatives in neural networks, examples in biomedical applications. Incorporating diverse data.
11/24		Break
11/29	Practical	Practical considerations when training a neural network. Understanding the effect of design modifications
12/1	Practical	Practical considerations when training a neural network. Understanding the effect of design modifications
12/6	**Student presentations**	Presentations of deep learning research papers.
12/8	**Student presentations**	Presentations of deep learning research papers.
12/13		Exams week
12/15		Exams week

16. Inclusive Learning Environments

In this class, we will work together to develop a learning community that is inclusive and respectful. Our diversity may be reflected by differences in race, age, sexual orientation, gender identity and expression, religion/spirituality, ability, socioeconomic background, and myriad other social identities and life experiences. In a diverse community, the goal of inclusiveness encourages and appreciates expressions of different ideas, opinions, and beliefs so that conversations and interactions are opportunities for intellectual and personal enrichment.

A dedication to inclusiveness requires respecting what others say, their right to say it, and the thoughtful consideration of others' communication. Both speaking up and listening are valuable tools for furthering thoughtful and enlightening dialogue. Respecting one another's individual differences is critical in transforming a collection of diverse individuals into an inclusive and collaborative learning community. We will hold ourselves and one another accountable, which includes bringing attention to times when microaggressions or macroaggressions happen in a classroom. Our core commitment shapes our core expectations for behavior inside and outside

of the classroom. We encourage students to review the ColoradoSPH Equity, Diversity, and Inclusion Common Language and Commitment Statement https://www1.ucdenver.edu/docs/librariesprovider151/default-document-library/edi-commitment-and-terms-5-11-21.pdf?sfvrsn=804479ba_0

Title IX: Non-Discrimination and Sexual Misconduct, Intimate Partner Violence, and Stalking

Non-Discrimination
The ColoradoSPH and University of Colorado Non-Discrimination Policy prohibits discrimination on the basis of race, color, national origin, sex, age, disability, pregnancy, creed, religion, sexual orientation, veteran status, gender identity, gender expression, political philosophy or political affiliation in admission and access to, and treatment and employment in, its educational programs and activities.

Sexual Misconduct, Intimate Partner Violence, and Stalking
The ColoradoSPH and University of Colorado Sexual Misconduct, Intimate Partner Violence, and Stalking Policy prohibits conduct including sexual assault, dating violence, domestic violence, Title IX stalking, stalking, sexual exploitation, Title IX harassment, hostile environment, Title IX quid pro quo sexual harassment, and quid pro quo sexual harassment.

ColoradoSPH Partner Campus Title IX Offices and Contact Information:
Incidents of discrimination, sexual misconduct, intimate partner violence, and stalking should be reported to the **Title IX office of the university where the incident occurred**. Incidents involving microaggressions or incidents that may not otherwise rise to the level of a policy violation, may also be reported to the appropriate university Title IX office listed below. Please refer to the CU Anschutz campus Office of Equity website for a self-learning guide about microaggressions.

If you have any questions on clarity related to the reporting of incidents, please contact the **ColoradoSPH Title IX Liaison**, Dr. Danielle (Dani) Brittain, PhD. You can reach Dr. Brittain at Danielle.Brittain@cuanschutz.edu.

CU Anschutz Campus: On the CU Anschutz campus, please contact the Office of Equity. The Office of Equity staff, including the University's Title IX Coordinator, may be reached at (303) 315-2567 or equity@ucdenver.edu.

Colorado State University Campus: On the Colorado State University campus, please contact the Office of Title IX Programs and Gender Equity. The Office of Title IX Programs and Gender Equity staff may be reached at (970) 491-1715 or through email by reaching out to one of the listed Title IX coordinators.

University of Northern Colorado Campus: On the University of Northern Colorado campus, please contact the Office Institutional Equity and Compliance. The Office Institutional Equity and Compliance staff may be reached at (970) 351-4899 or titleix@unco.edu.

17. Academic Conduct Policy

All students are expected to abide the Honor Code of the Colorado School of Public Health. Unless otherwise instructed, all of your work in this course should represent completely independent work. Students are expected to familiarize themselves with the Student Academic Honor and Conduct Code. Any student found to have committed acts of misconduct (including, but not limited to cheating, plagiarism, misconduct of research, breach of confidentiality, or illegal or unlawful acts) will be subject to the procedures outlined in the ColoradoSPH Honor Code.

18. Accommodations for Disabilities: Virtual and In-Class

The University of Colorado Anschutz Medical Campus is committed to providing equitable access to our programs for students with disabilities (e.g., psychological, attentional, learning, chronic health, sensory, and physical).

To engage in a confidential conversation about the process for requesting reasonable accommodations in the classroom and clinical settings please contact The Office of Disability, Access, and Inclusion at: disabilityaccess@cuanschutz.edu or begin the process via the website Accommodations are not provided retroactively, therefore, students are encouraged to begin this process early.

19. Mental Health Services

Please visit the Office of Student Affairs – Student Health Promotion website OR the Department of Psychiatry website for information on mental health services.

20. Religious Observances

The University of Colorado Denver, Anschutz Medical Campus has a legal obligation to accommodate students who must be absent from an educational activity in order to observe religious holidays or other observances. Students should speak to the faculty member to request accommodations for religious observances in advance during the first week of class. Requests received by faculty must be kept confidential and should be considered unless they create an undue hardship. If the student and faculty member cannot agree on an accommodation, the matter should be referred to the Assistant Dean for Graduate Programs for resolution.