MISSISSIPPI STATE UNIVERSITY™
DEPARTMENT OF
BIOLOGICAL SCIENCES

BIO 4990/6990 Special Topics in Biological Sciences
Machine Learning in Biology, Spring 2024 Course Syllabus

Format: Lecture
Instructor: Dr. Megan Smith
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Phone: (662) 325-2572
Office Hours: Tuesdays 2PM-3PM in Harned 214, or by appointment
Class Meetings: MWF 12:00-12:50 PM
Prerequisites: BIO 1134 and BIO 1144
Required texts/other purchases:
Credits: 3
Section: 2
Method of delivery: Face-to-Face

Course Description:
(Prerequisites: BIO 1134 and BIO 1144). Three hours lecture. In this course, students will be introduced to the basics of machine learning and its applications in the biological sciences. Students will learn to apply machine learning approaches to biological datasets in python. Students will read and discuss current literature to explore uses of machine learning in biology.

Learning Outcomes:
After completing this course, all students will be able to:

- Demonstrate an understanding of unsupervised and supervised machine learning approaches.
- List and explain applications of machine learning approaches in biological research.
- Analyze biological data using machine learning approaches.
- Assess situations in which machine learning could enhance biological research.
- Discuss the limitations of machine learning approaches in biology.

Additionally, graduate students will be able to:

- Judge the effectiveness of previous applications of machine learning approaches in biology.
- Develop plans for applying machine learning in their own area of research.

Evaluation and Standards of Achievement:
A ten-point grading scale will be used (A:100-90; B: 89-80; C:79-70; D:69-60; F: less than 60). The final grade will be calculated as the percentage of total possible points. Final scores within 0.5 percentage points of the next letter grade will be rounded up, e.g., a score of 89.50 will be an A and 89.49 will be a B.

Final Grade Calculation (BIO 4990):

Regular Exams	2 x 15 percent each	30 percent
Final Exam		15 percent
Homework/In-Class Assignments		25 percent

[1] Students can expect a response from the instructor within 2 business days.

Discussion Board Posts	15 percent
Participation	15 percent
Total	100 percent

Final Grade Calculation (BIO 6990):

Regular Exams	2 x 15 percent each	30 percent
Final Exam		15 percent
Homework/In-Class Assignments		15 percent
Discussion Board Posts		15 percent
Participation		10 percent
Final Project and Presentation		15 percent
Total		100 percent

Exams: Questions will be taken from material covered in class, and from accompanying reading. Exams for students enrolled in 6990 will include additional questions emphasizing synthesis of the material and critical evaluation of applications of approaches in biological contexts.

Attendance Policy and Grading: This section is a face-to-face instruction class for which hands-on participation is required. Students are expected to attend all class meetings. Contact instructor in advance regarding any anticipated absences. Participation credit is worth 10 or 15% of the of the final grade (for 6990 and 4990, respectively), and students cannot participate if they are not present. See examples of excused absences in the Mississippi State University Syllabus included at the end of this course syllabus.

Participation: Participation in class discussion and activities is 10-15% of your final grade. You cannot participate if you do not attend class (See Attendance). Excused absences for missing class will be accommodated. Participation will be graded based on attendance, engagement during in-class discussions, and participation in in-class activities.

Course Materials: Students will need to bring a laptop to class on days in which there are computational activities. It may be possible to use a tablet, but please discuss this with the instructor as soon as possible. There are laptops available to check out from the library on a first-come first-serve basis for $20 per semester. Students should contact the library as soon as possible if interested in this option, as there are a limited number of laptops available. If none of these options work, the student should contact the instructor as soon as possible.

Make-up Exams & Assignments: Students who miss an exam or assignment due to an excused absence may schedule a time to make it up. Please contact the instructor by email as soon as you learn that you will need to schedule a make-up. In most instances, this will be before the exam is administered. Extenuating circumstances may exist that prevent prior notice; in such cases contact the instructor as soon as possible, ideally within 48 hours, to schedule a make-up.

Homework/In-Class Assignments: There will be seven computational activities throughout the semester. Students will begin these activities in class, and will be expected to complete these activities as homework. Completed activities will be due one week after the in-class activity. There will also be six

discussion board posts throughout the semester. Due dates are available on the detailed course schedule, and topics will be posted in Canvas no later than one week prior to the due date. Late assignments will be accepted for one week after the posted deadline. Ten percent of the initial total possible score will be deducted per day past the deadline. After one week, the assignment will receive a zero. Most computational assignments for students enrolled in 6990 will include an additional requirement to critically evaluate the focal machine learning application and its weaknesses in the applied context.

Final Projects (6990 only): Each student enrolled in 6990 will be responsible for completing a final project. Each student will develop a proposal for using machine learning in their own research. The proposal will include a review of relevant background literature, objectives, proposed methodologies, and anticipated results. The proposal will be two to three pages in length, and students will present their proposal to the class in a short (< fifteen minute) presentation.

Tentative Course Schedule:

Week 1 – Introduction
- Introduction to Machine Learning
- Computational Activity #0
- **Contact Hours:** 3

Week 2 – Supervised Learning: Linear and Logistic Regression
- Linear Regression
- Computational Activity #1
- Logistic Regression
- **Contact Hours:** 3

Weeks 3-4 – Other Classifiers
- Softmax Regression
- Support Vector Machines
- Paper Discussion #1
- Bias and Variance
- Computational Activity #2
- **Contact Hours:** 6

Weeks 4-5 — Synthesis of Unit 1
- Review Session
- Exam 1
- **Contact Hours:** 2

Weeks 5-6 — Decision Trees
- Decision Trees
- Ensemble Methods
- Computational Activity #3
- Paper Discussion #2
- **Contact Hours:** 4

Weeks 6-7 – Fully Connected Neural Networks
- Introduction to FCNNs
- Gradient Descent and Backpropagation
- Computational Activity #4
- **Contact Hours:** 3

Weeks 7-8 – Convolutional Neural Networks (CNNs)
- Introduction to CNNs
- Applications of CNNs
- Paper Discussion #3
- Computational Activity #5
- **Contact Hours:** 4

Week 9 – Synthesis of Unit 2
- Review Session
- Exam 2
- **Contact Hours:** 2

Weeks 9-10 – Other Neural Networks
- Recurrent and Graph Neural Networks
- Paper Discussion #4
- **Contact Hours:** 2

Weeks 10-11 – Generative Models
- Transformers and AlphaFold
- Paper Discussion #5
- **Contact Hours:** 2

Weeks 11-13 — Unsupervised Learning
- Overview
- PCAs
- Variational Autoencoders
- Clustering
- Computational Activity #6
- Paper Discussion #6
- **Contact Hours:** 6

Weeks 13-14 – Challenges in Machine Learning
- Hyperparameter optimization
- Overfitting
- Simulation Misspecification
- The Black Box
- Discussion #6
- **Contact Hours:** 3

Weeks 14-15—Graduate Student Presentations and Review
Contact Hours: 2

Final Exam (Thursday, May 2, 2024, 12:00-3:00 PM)
Contact Hours: 3

Total Contact Hours: 45 hours

University Syllabus: The Mississippi State University Syllabus contains all policies and procedures that are applicable to every course on campus and online. The policies in the University Syllabus describe the official policies of the University and will take precedence over those found elsewhere. It is the student's responsibility to read and be familiar with every policy. The University Syllabus may be accessed at any time on the Provost website under Faculty and
Student Resources and at https://www.provost.msstate.edu/faculty-student-resources/university-syllabus