GEORGIA INSTITUTE OF TECHNOLOGY
School of Mechanical Engineering

ME 8813
Machine Learning Fundamentals for Mechanical Engineering

Course Objective

To introduce the fundamentals of machine learning and artificial intelligence including methods and algorithms, with emphasis on familiarizing students with computational methods to solve complex, data-driven mechanical engineering problems.

Course Outline

1. Introduction to AI, Historical Context (Search Algorithms), and Linear Algebra
2. Dimensionality Reduction (PCA) and Unsupervised Clustering
3. Deterministic Learning: Regression, Regularization (LASSO), and SVMs
4. Probability Foundations and Bayesian Belief Networks
5. Markov Models: Markov Chains and Hidden Markov Models (HMMs)
6. Gaussian Processes and Covariance Functions
7. Active Learning and Bayesian Optimization
8. Artificial Neural Networks (ANNs), Backpropagation, and Stochastic Gradient
9. Convolutional Neural Networks (CNNs) and Spatial Data
10. Generative AI Fundamentals, Autoencoders, and Unsupervised Learning
11. Generative Adversarial Networks (GANs) and Topology Optimization
12. Reinforcement Learning Framework and Markov Decision Making
13. Q-Learning, Active Learning, and Applied Control Theory
14. Autonomous Agents in Engineering Applications
15. Final Project Presentations

Lectures

The lectures are 75 minutes long, meeting twice a week. The schedule is uniquely structured to bridge mathematical theory with practical software application:

- **Weeks 1–3:** Both weekly sessions are dedicated to mathematical foundations and theory lectures.
- **Weeks 4–15:** The schedule shifts to a Theory/Lab split:

- *Session 1:* 75-minute Theoretical Lecture (introducing new algorithms and their mathematical proofs).
- *Session 2:* 75-minute Hands-On Python Lab (deploying the algorithm taught in the previous session using Python libraries).

Instructor

Dr. Luis Barrales

Office Hours

By appointment / Fixed hours will be announced at semester's start

Course Prerequisite

Graduate standing, or permission of Instructors

Books, Handouts & Library Resources

The course utilizes the following primary references:

- Brunton, S. L., & Kutz, J. N. (2022). *Data-Driven Science and Engineering* (2nd ed.).
- Bishop, C. M. (2006). *Pattern Recognition and Machine Learning.*
- Rasmussen, C. E., & Williams, C. K. I. (2006). *Gaussian Processes for Machine Learning.*
- Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep Learning.*
- Zhang, A., et al. (2023). *Dive into Deep Learning.*
- Sutton, R. S., & Barto, A. G. (2018). *Reinforcement Learning: An Introduction.*
- Géron, A. (2022). *Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow.*

Recommended ME Journals for ML Papers:

- ASME Journal of Computer and Information Science in Engineering
- ASME Journal of Mechanical Design
- Mechanical Systems & Signal Processing

Canvas, Communications, and File Naming

Canvas is the mandatory communication tool in this class. The Discussions area provides a venue to give questions and answers. For any question that is general, you should post it in the Discussions area first, instead of sending emails to instructors or TAs.

- **Emails:** All course-related e-mails must have a descriptive subject field starting with: `ME8813 LastName, FirstName` and a brief description.
- **Computer Files:** All computer files (code, reports) must be named as follows: `ME8813_LastName_FirstName_BriefDescription.filetype`.

Honor Code and Academic Honesty

GT Academic Honor Code will be strictly enforced. Adherence to Georgia Tech's Honor Code is expected. You will find detailed information at: `http://osi.gatech.edu/content/honor-code`.

Specific to Programming: Unless stated in writing, all assignments are individual work. Students are not allowed to "share" flow-charts, drawings, programs/codes, listings, or results, even though you are encouraged to collaborate during the initial problem solving process. Note that for an experienced reviewer it is not difficult to detect "shared" logic.

Grading & Grade Scale

Your grade will be determined using the following weighting:

- Homework & Lab Assignments: 20%
- Interim Project: 35%
- Final Project: 45%

Grade Scale: A: 90-100, B: 80-89, C: 70-79, D: 60-69, F: 0-59. The final grade will be curved based on your attendance, performance and participation in class. Over two unexcused absences, no curving will be applied.

Project Deliverables

Each student chooses a problem to solve; own research is strongly encouraged.

- **Interim Project Report:** Defines the problem, proposes the methodology to solve, and summarizes the preliminary result.
- **Final Project Report:** Comprehensive description of the problem, relevant background, finalized methodology, obtained results, and discussions. The main evaluation criterion of the project is whether the result and final report are publishable.

Policies: Attendance, Exams, and Due Dates

- **Attendance:** Taken at the beginning of each class (`http://www.catalog.gatech.edu/rules/4/`).
- **Assignments:** Solutions will periodically be posted; no late assignments will be accepted.
- **Presentations/Exams:** If you will miss a presentation, please send an email as written notice at least 12 hours in advance. Proof/document of emergency is required to make an appointment for a make-up. Failure in providing the certificate will result in a zero.
- **Incomplete Grades:** Only given to students who have had a written agreement with the instructors at least three weeks before the final presentation date.

Disabilities

Georgia Institute of Technology is committed to providing reasonable accommodations for all persons with disabilities. Students with disabilities must submit an ADAPTS accommodation letter to the professor within the first 4 weeks of the semester. Contact the ADAPTS Office in 221 Smithgall Student Services Building.

Miscellaneous

In the classroom, cellphones are to be turned off or in silent mode. Computer use is intensive; Python-based libraries will be used for assignments and projects. Make sure that you have access to a Python programing environment (Jupyter Notebooks, VScode, PyCharm) on your personal computer.