EE 375/475: Machine Learning: Foundations, Applications, and Algorithms

Fall 2023: M 5-8p; Tech L211
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Office Hours: Tu 5-6p
TAs: Deanna Dimonte and Wei Wei

Prerequisites

A basic understanding of Linear Algebra and Vector Calculus (e.g., students should be able to easily compute gradients/Hessians of a multivariate function), as well as basic understanding of Python programming environments.

- **Course is cross listed with Data_Sci 423**

REQUIRED TEXT: J. Watt, R. Borhani, and A. K. Katsaggelos, *Machine Learning Refined: Foundations, Algorithms, and Applications*, Cambridge University Press, 2nd edition, 2020.

COURSE OUTLINE:

1. Introduction
    1. What kinds of things can you build with machine learning tools?
    2. How does machine learning work?
    3. Predictive models – our basic building blocks
    4. Feature design and learning – what makes things distinct?
    5. Numerical optimization – the workhorse of machine learning
2. Fundamentals of numerical optimization
    1. Calculus defined optimality
    2. Using calculus to build useful algorithms
    3. Gradient descent
    4. Newton's method
3. Regression
    1. Linear regression - applications in climate science, feature selection, compression, neuroscience, and marketing
    2. Knowledge-driven feature design for regression
    3. Nonlinear regression
    4. The L-2 regularizer
4. Classification
    1. The perceptron
    2. Logistic regression/Support Vector Machines
    3. Multiclass classification
    4. Knowledge driven feature design for classification– examples from computer vision (object/face detection and recognition), text mining, and speech recognition

5. Feature learning
    1. Function approximation and bases of features
    2. Feed-forward neural network bases, deep learning, and kernels
    3. Cross-validation
6. Tree-based Learners
7. Dimensionality reduction: K-means clustering and Principal Component Analysis

PROBLEM SETS:

Weekly pencil-and-paper and computer problems will be assigned and graded. A few small computer projects will also be assigned. Homework will be typically assigned on Monday and will be due on Monday a week later at midnight. **No late homework will be accepted.**

PROJECT:

A literature survey or computer project is required. Please submit a short description (a few paragraphs, less than a page) of the course project you would like to work on by **Monday October 23, 2023**, midnight. You are encouraged to work with other students in the class. The maximum size of a group is 4 people.

Project Scope:

Your choice of project is up to you (and your team). All we ask is that it be **related to the course material**, and that you pick something that interests you. If you are having trouble deciding on a project idea talk with one of us (TAs and me).

For example, you could pursue:

• a machine learning curiosity (e.g., how do I put together a robust face detection pipeline?), and prototyping a simple version of the curiosity (e.g., putting together a simple face detection pipeline)

• pet projects / apps with a substantial machine learning component

• reading a selection of papers to better familiarize yourself with a specific topic in machine learning and presenting a comprehensive summary of the findings, with description of open problems and possible solution directions

Deliverables:

Your final deliverables for the course project will be

1) A short Python Jupyter notebook (less than 5 pages long) explaining and illustrating your project topic, including any fundamental Python code.

2) A short Youtube video (3 - 5 minutes in length maximum) summarizing what you / your team pursued, any trials and setbacks along the way, and conclusions. All team members should take part in this video presentation.

Both of these items (a URL to the Youtube video) are to be uploaded to canvas.

Due date: **Tue 12/5/22 at midnight.**

COURSE GRADE:

Final grades for the course will be based on the homework assignment grades (65%) and the project (35%).