CPEN 355 : Machine Learning with Engineering Applications 2024-25 Term 2

Lecture Syllabus

Instructor: Prof. Xiaoxiao Li *Scribe: Xiaoxiao Li*

1 Course Description

- Credits: 4
- Pre-reqs: One of MATH 152, MATH 221 and one of MATH 318, MATH 302, STAT 302, STAT 321, ELEC 321 and one of CPEN 221, CPEN 223, CPSC 259.
- This course is restricted to students in year: ≥ 3 with one of these specializations: IN CPEN
  -OR-
  in year: ≥ 3 with one of these specializations: IN ELEC -OR-
  in year: ≥ 4 with one of these specializations: ****ENPH,****IGEN.

2 Contact Information

- Instructor: Xiaoxiao Li
- Email: xiaoxiao.li@ece.ubc.ca

3 Time and Location

- Class Meets:
  Mon & Weds & Fri || 13:00 – 14:00 || ORCH-Floor 3-Room 3018
- Tutorials: Mon || 14:00 – 15:00 || CHBE-Floor 1-Room 103
  - Beidi Zhao beidi.zhao16@gmail.com
  - Chun-Yin Huang chunyinhuang17@gmail.com
- Instructor Office Hours: Weds 14:00 - 15:00 pm (by appointment only)

4 Prerequisites

- Proficiency in Python
  All class assignments will be in Python.

- College Calculus, Linear Algebra
  You should be comfortable taking derivatives and understanding matrix vector operations and notation.
- Basic Probability and Statistics
  You should know basics of probabilities, Gaussian distributions, mean, standard deviation, etc.

5 Course Goals

The course aims to provide an introductory level exposure to machine learning concepts with a balance between practical and theoretical aspects and hands-on experience suitable for engineering students. At the end of the course, students will be able to: apply the concept of learning and machine learning to real-world problems; identify the machine learning tasks and select suitable machine learning models; execute training and validation of models; apply techniques to control overfitting and assess the success of learning; use and modify available software for machine learning models and apply to new problems; realize the ongoing challenges and problems in machine learning; continue with specialized and advance machine learning courses.

6 Computational Resources

GPU computing is required for this class. I strongly recommend to Google Colab or use your own/lab's GPU since that is the most convenient way of writing and testing code with GUI. Click here to try out the Colab tutorial.

7 Course Content

This course will cover the following topics:

1. Course Policy (Jan 6)
2. Introduction to Machine Learning (Jan 8)
3. Machine Learning Basics (Jan 10 - 31)
   - Concepts and Basic Math
   - Linear Regression
   - Penalized Regression: Lasso and Bridge
   - Logistic Regression
   - Newton's Method
   - Intro to Machine Learning Practice (Python, Pytorch, Co-lab, etc.)
   - Model Training and Evaluation
   - Assignment 1 Announcement (Jan 10)

- Assignment 1 Submission (Jan 24)
- Assignment 2 Announcement (Jan 24)
- Assignment 2 Submission (Feb 7)

4. Supervised Learning (Feb 3 – Mar 3)
    - Introduction to Supervised Learning and K-Nearest Neighbors
    - KNN and Computational Complexity
    - Support Vector Machines
    - Decision Tree and Random Forest
    - In-class Quiz (Feb 12, tentative)
    - Practice: Housing Price Prediction
    - Assignment 3 Announcement (Feb 9)
    - Assignment 3 Submission (Mar 1)
5. Unsupervised Learning (Mar 4 - 22)
    - Intro to Unsupervised Learning and Clustering
    - Advanced Clustering
    - Gaussian Mixture Model
    - Principal Components Analysis
    - Independent Component Analysis
    - Semi-supervised Learning
    - Practice: Unsupervised Learning
    - Assignment 4 Announcement (Mar 5)
    - Assignment 4 Submission (Mar 22)
6. Overview of Deep Neural Networks (Mar 25 - Apr 7)
    - Background and Introduction to Multilayer Perceptrons
        - Fully Connected Layers
        - Activation Functions
        - Objective Functions
    - Backpropogation and Optimization
    - Practice: ANN for Image Recognition
    - Convolutional Neural Networks
    - Recurrent Neural Networks
    - AutoEncoder
    - Generative Adversarial Network
    - In-class Quiz (April 7)
7. Final Project Report Submission (April 20)

8 Grading, Assignments, and Final Project

- 4 Assignments: 60% = 4*15%
  - Conceptual and practical questions
  - Programming questions
- 2 in-class exams: 20% = 2*10%
- Final project: 20% [1]
  - A machine learning project including data collection, data preprocessing, data analysis using machine learning models. You need to submit codes together with a well structured report (at least 4 pages and no more than 10 pages). **No Teamwork allowed**.
  - *Passing the course does on conditional on if you pass the final project*
- Late submission will result in *0.8 decay per day. Extension is only accepted via applying for Academic Concession.

9 Suggested Reading Materials

- Friedman, Jerome, Trevor Hastie, and Robert Tibshirani. The elements of statistical learning. Vol. 1. No. 10. New York: Springer series in statistics, 2001.
- Müller, Andreas C., and Sarah Guido. Introduction to machine learning with Python: a guide for data scientists. " O'Reilly Media, Inc.", 2016.
- Goodfellow, Ian, Yoshua Bengio, Aaron Courville, and Yoshua Bengio. Deep learning. Vol. 1, no. 2. Cambridge: MIT press, 2016.
- Torfi, Amirsina. Deep Learning Roadmap. https://www.machinelearningmindset.com/books/

10 Acknowledgment

* Our course materials and design are referred to the the following resources, thanks for the great work done by the smart people!

- https://speech.ee.ntu.edu.tw/ tlkagk/courses.html
- http://cs231n.stanford.edu/
- http://deeplearning.cs.cmu.edu/
- https://www.deeplearningbook.org/lecture_slides.html
- https://www.cs.princeton.edu/courses/archive/spring16/cos495/

[1] You need to pass the final project to pass the course.

- http://ttic.uchicago.edu/ shubhendu/Pages/CMSC35246.html
- https://www.cc.gatech.edu/classes/AY2018/cs7643_fall
- http://introtodeeplearning.com/
- https://hrlblab.github.io/cs3891.html
- Prof. Lutz Lampe's teaching materials
- Prof. Qi Dou's teaching materials