ELEC 400M : Machine Learning Fundamentals for Engineers Spring 2022

Lecture Syllabus

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

1 Course Description

- This is a Special Topics course focusing on foundations and concepts of machine learning and its applications to engineering problems. Students are expected to have obtained a solid background in probability and random variables, as demonstrated by successfully completing one of the following courses: ELEC/STAT 321, MATH/STAT 302, MATH 318.
- This course can be applied towards the advanced electives requirement of the BASc in Electrical Engineering program and the BASc in Computer Engineering program.
- Further, credit will be granted for only one of: ELEC 400M, CPSC 330, CPSC 340.

2 Contact Information

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

3 Time and Location

- Class Meets: Tuesday & Thursday (Term 2), 12:30 pm – 14:00 pm
- Location:
  Tue || 12:30 pm – 14:00 pm || Aquatic Ecosystems Research Laboratory || Rm 120
  Thu || 12:30 pm – 14:00 pm || Earth Sciences Building || Rm 1012
- Zoom participation ID:
  https://ubc.zoom.us/j/68414644093?pwd=VFJCTk9uOTNCQzFiSDFBcXF5WkV4dz09
- TA Office Hours: Tue || 10:00 am - 11:00 am (Tentative)
  - Yinjia Huo yortka@ece.ubc.ca
  - Sadegh Mahdavi smahdavi@ece.ubc.ca
  - Chun-Yin Huang chunyinhuang17@gmail.com
- Instructor Office Hours: Thursday afternoon (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. Introduction to Machine Learning (Jan 11)
2. Machine Learning Basics
   - Announce Assignment 1 (Jan 15)
   - Linear Regression and Shrinkage(Jan 13 and Jan 18)
   - Logistic Regression and Optimization (Jan 20 and Jan 25)
   - Cross-Validation (Jan 27)
   - Evaluation Metrics (Jan 27)

- Assignment 1 Submission (Jan 25)

3. Supervised Learning
    - Announce Assignment 2 (Feb 8)
    - Introduction to Supervised Learning and K-Nearest Neighbors (Feb 1)
    - Support Vector Machines (Feb 3, Feb 8, Feb 10)
    - Decision Tree and Random Forest (Feb 10, Feb 15 and Feb 17)
    - Assignment 2 Submission (Feb 22) [1]
4. Unsupervised Learning
    - Announce Assignment 3 (March 1)
    - Clustering (March 1)
    - Principal Components Analysis (March 3)
    - Assignment 3 Submission (March 8)
5. Overview of Deep Neural Networks (March 8, March 10, and March 15)
    - Announce Assignment 4 (March 8)
    - Background
    - Introduction to Multilayer Perceptrons
        - Fully Connected Layers
        - Activation Functions
        - Objective Functions
    - Backpropogation
    - Deep Learning Frameworks
    - Assignment 4 Submission (March 25)
6. Introduction to Deep Learning Models and their Applications
    - Convolutional Neural Networks (March 17 and March 22)
        - Overview and Motivation
            * Image Classification
            * Object Detection
            * Image Segmentation
        - Layers
            * Convolutional Layers
            * Pooling Layers
            * Batch Normalization and Dropout
        - Popular Architectures
            * VGG [SZ14] and ResNet [HZRS16] for Image Classification
            * YOLO [RDGF16] and Mask-RCNN [HGDG17] for Object Detection

[1] Feb 21-25 UBC Midterm Break

        * UNet [RFB15] for Image Segementation
    - Recurrent Neural Networks (March 24)
    - Background and Applications
    - Architectures
        - Vanilla RNN [She20]
        - LSTM [KKTK16]
    - Deep Generative Model (March 29)
        - Background and Applications
        - Architectures
            * PixleCNN and PixleRNN [VdOKE+16]
            * Variational Autoencoder [KW13]
            * Generative Adversarial Network [GPAM+14]
    - Natural Language Processing (NLP) (April 5)
        - Background
        - NLP Tasks
            * Sentence/Document Classification
            * Token-wise Classification
            * Translation
        - Archietectures
            * Transformer [VSP+17]
    - Overview of ML for Applications in Engineering Fileds (April 7)
    - Report Submission (March 31)
    - Final Project Report Submission (April 20)

8 Grading, Assignments, and Final Project

- 4 Assignments: 60% = 4*15%
    - Conceptual and practical questions
    - Programming questions
- Article reading and report:15%
    - Comment on the recent AI topics: fairness, privacy, ...
    - Comment on the recent AI products: Alexa, Apple keyboard, ...
    - For Teamwork, no more than 3 people.
- Final project: 25%
    - 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 2 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/
- 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

References

[GPAM+14] Ian J Goodfellow, Jean Pouget-Abadie, Mehdi Mirza, Bing Xu, David Warde-Farley, Sherjil Ozair, Aaron Courville, and Yoshua Bengio. Generative adversarial networks. *arXiv preprint arXiv:1406.2661*, 2014.

[HGDG17] Kaiming He, Georgia Gkioxari, Piotr Dollár, and Ross Girshick. Mask r-cnn. In *Proceedings of the IEEE international conference on computer vision*, pages 2961–2969, 2017.

[HZRS16] Kaiming He, Xiangyu Zhang, Shaoqing Ren, and Jian Sun. Deep residual learning for image recognition. In *Proceedings of the IEEE conference on computer vision and pattern recognition*, pages 770–778, 2016.

[KKTK16] Jihyun Kim, Jaehyun Kim, Huong Le Thi Thu, and Howon Kim. Long short term memory recurrent neural network classifier for intrusion detection. In *2016 international conference on platform technology and service (PlatCon)*, pages 1–5. IEEE, 2016.

[KW13] Diederik P Kingma and Max Welling. Auto-encoding variational bayes. *arXiv preprint arXiv:1312.6114*, 2013.

[RDGF16] Joseph Redmon, Santosh Divvala, Ross Girshick, and Ali Farhadi. You only look once: Unified, real-time object detection. In *Proceedings of the IEEE conference on computer vision and pattern recognition*, pages 779–788, 2016.

[RFB15] Olaf Ronneberger, Philipp Fischer, and Thomas Brox. U-net: Convolutional networks for biomedical image segmentation. In *International Conference on Medical image computing and computer-assisted intervention*, pages 234–241. Springer, 2015.

[She20] Alex Sherstinsky. Fundamentals of recurrent neural network (rnn) and long short-term memory (lstm) network. *Physica D: Nonlinear Phenomena*, 404:132306, 2020.

[SZ14] Karen Simonyan and Andrew Zisserman. Very deep convolutional networks for large-scale image recognition. *arXiv preprint arXiv:1409.1556*, 2014.

[VdOKE+16] Aaron Van den Oord, Nal Kalchbrenner, Lasse Espeholt, Oriol Vinyals, Alex Graves, et al. Conditional image generation with pixelcnn decoders. *Advances in neural information processing systems*, 29, 2016.

[VSP+17] Ashish Vaswani, Noam Shazeer, Niki Parmar, Jakob Uszkoreit, Llion Jones, Aidan N Gomez, Lukasz Kaiser, and Illia Polosukhin. Attention is all you need. *arXiv preprint arXiv:1706.03762*, 2017.