

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: **TBA**

3 Time and Location

- Class Meets: Tuesday & Thursday (Term 2), 12:30 pm – 14:00 pm
- Location: **TBA**
- TA Office Hours: **TBA**
- Instructor Office Hours: **TBA**

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
2. Machine Learning Basics
 - Linear Regression and Logistic Regression (statistical view)
 - Overfitting/Underfitting
 - Regularization
 - Cross-Validation
 - Evaluation Metrics
 - Optimization
3. Supervised Learning
 - Decision Tree and Random Forest
 - K-Nearest Neighbors
 - Naive Bayes
 - Support Vector Machines
4. Unsupervised Learning
 - Clustering
 - Principal Components Analysis

5. Overview of Deep Neural Networks

- Background
- Introduction to Multilayer Perceptrons
 - Fully Connected Layers
 - Activation Functions
 - Objective Functions
- Backpropagation
- Deep Learning Frameworks

6. Introduction to Deep Learning Models and their Applications

- Convolutional Neural Networks
 - 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
 - * UNet [RFB15] for Image Segmentation
- Generative Model
 - Background and Applications
 - Architectures
 - * Autoencoder [Ben09]
 - * Generative Adversarial Network [GPAM⁺14]
 - * Flow-based Generative Model [RM15]
- Natural Language Processing (NLP)
 - Background
 - NLP Tasks
 - * Sentence/Document Classification
 - * Token-wise Classification
 - * Translation
 - Architectures
 - * Recurrent Neural Networks [MKB⁺10]
 - * Transformer [VSP⁺17]

8 Grading, Homework, Mid Term Exam, and Final Project

TBA

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

References

[Ben09] Yoshua Bengio. *Learning deep architectures for AI*. Now Publishers Inc, 2009.

- [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.
- [MKB⁺10] Tomáš Mikolov, Martin Karafiát, Lukáš Burget, Jan Černocký, and Sanjeev Khudanpur. Recurrent neural network based language model. In *Eleventh annual conference of the international speech communication association*, 2010.
- [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.
- [RM15] Danilo Rezende and Shakir Mohamed. Variational inference with normalizing flows. In *International Conference on Machine Learning*, pages 1530–1538. PMLR, 2015.
- [SZ14] Karen Simonyan and Andrew Zisserman. Very deep convolutional networks for large-scale image recognition. *arXiv preprint arXiv:1409.1556*, 2014.
- [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.