

## 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](mailto: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](mailto:yortka@ece.ubc.ca)
  - Sadegh Mahdavi [smahdavi@ece.ubc.ca](mailto:smahdavi@ece.ubc.ca)
  - Chun-Yin Huang [chunyinhuang17@gmail.com](mailto: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 (Jan 13 and Jan 18) and Logistic Regression (Jan 20)
  - Overfitting/Underfitting (Jan 25)
  - Regularization (Jan 25)
  - Cross-Validation (Jan 27)

- Evaluation Metrics (Jan 27)
  - **Assignment 1 Submission** (Jan 25)
  - Optimization (Feb 1)
3. Supervised Learning
- Decision Tree and Random Forest (Feb 3 and Feb 10)
  - **Announce Assignment 2** (Feb 10)
  - K-Nearest Neighbors (Feb 10)
  - Support Vector Machines (Feb 15 and Feb 17)
  - **Assignment 2 Submission** (Feb 20) <sup>1</sup>
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
  - Backpropagation
  - Deep Learning Frameworks
  - **Assignment 4 Submission** (March 18)
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

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<sup>1</sup>Feb 21-25 UBC Midterm Break

- \* VGG [SZ14] and ResNet [HZRS16] for Image Classification
  - \* YOLO [RDGF16] and Mask-RCNN [HGDG17] for Object Detection
  - \* UNet [RFB15] for Image Segmentation
- Generative Model (March 24 and March 29)
  - Background and Applications
  - Architectures
    - \* Autoencoder [Ben09]
    - \* Generative Adversarial Network [GPAM<sup>+</sup>14]
    - \* Flow-based Generative Model [RM15]
- Natural Language Processing (NLP) (March 31 and April 5)
  - Background
  - NLP Tasks
    - \* Sentence/Document Classification
    - \* Token-wise Classification
    - \* Translation
  - Architectures
    - \* Recurrent Neural Networks [MKB<sup>+</sup>10]
    - \* Transformer [VSP<sup>+</sup>17]
  - 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\*\*.
- 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.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](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

- [Ben09] Yoshua Bengio. *Learning deep architectures for AI*. Now Publishers Inc, 2009.
- [GPAM<sup>+</sup>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<sup>+</sup>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<sup>+</sup>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.