CS-568 – Deep Learning

Instructor: Dr. Nazar Khan **Semester: Fall 2020** **Campus: Quaid-e-Azam**

Course Webpage: http://faculty.pucit.edu.pk/nazarkhan/teaching/Fall2020/CS568/CS568.html

To get a feel for the course, please see the previous course offering and accompanying video lectures.
Previous Webpage: http://faculty.pucit.edu.pk/nazarkhan/teaching/Spring2020/CS568/CS568.html
Video Lectures: https://youtube.com/playlist?list=PLjUnRJIutnlLpDwjWv8yTVd390dYQplCw

Course Description:

The ability of biological brains to sense, perceive, analyse and recognise patterns can only be described as stunning. Furthermore, they have the ability to learn from new examples. Mankind's understanding of how biological brains operate exactly is embarrassingly limited. However, there do exist numerous 'practical' techniques that give machines the 'appearance' of being intelligent. This is the domain of statistical pattern recognition and machine learning. Instead of attempting to mimic the complex workings of a biological brain, this course aims at explaining mathematically well-founded techniques for analysing patterns and learning from them.

Artificial Neural Networks as extremely simplified models of the human brain have existed for almost 75 years. However, the last 25 years have seen a tremendous unlocking of their potential. This progress has been a direct result of a collection of network architectures and training techniques that have come to be known as Deep Learning. As a result, Deep Learning has taken over its parent fields of Neural Networks, Machine Learning, Artificial Intelligence and has become must-have knowledge in many academic disciplines as well as in the industry. Some areas permanently affected by deep learning include:

- artificial intelligence,
- computer vision,
- document analysis,
- cloud and edge computing,
- medical image analysis,
- natural language processing

This course is a mathematically involved introduction to the wonderful world of deep learning. The basic idea is simple: given lots of training examples, a mathematical model learns how to transform from inputs to outputs. The details are not so simple and that is what we will cover in the course.

Goals and Objectives:

This course will prepare students for further study/research in the areas of Pattern Recognition, Machine Learning, Computer Vision, Data Analysis, Natural Language Processing and other areas attempting to solve Artificial Intelligence (AI) type problems.

Texts:

Deep Learning by Ian Goodfellow, Yoshua Bengio, Aaron Courville, 2017. Available online
Pattern Recognition and Machine Learning by Christopher Bishop, 2006
Neural Networks and Deep Learning by Michael Nielsen, 2016. Available online
Deep Learning with Python by J. Brownlee
Deep Learning with Python by Francois Chollet

Prerequisites:

The course is designed to be self-contained. **So the required mathematical details will be covered in the lectures**. However, this is a math-heavy course. Students are encouraged to brush up on their knowledge of

- calculus (differentiation, partial derivatives)
- linear algebra (vectors, matrices, inner-product, orthogonality, eigenvectors)
- probability (random variables (Bernoulli, Binomial, Gaussian), independence)

This is not a theoretical course. Students are also expected to be (or become) good at programming.
The students should know that the only way to benefit from this course is to be prepared to **spend lots of hours reading the text book(s) and attempting exercises** (preferably) alone or with a class-fellow**.**

Scheme of Study:

- Basics of Machine Learning
- Neural Networks
- Deep Neural Networks
- Convolutional Neural Networks
- Generative Adversarial Networks
- Recurrent Neural Networks
- Attention-based Models
- Variational Autoencoders

Syllabus:

1. Introduction to Deep Learning (0.5 Week)
2. Introduction to Neural Computation (0.5 Week)
3. History of Neural Computation (0.5 Week)
4. Matrix and Vector Calculus (0.5 Week)
5. Multilayer Perceptron (MLP) (0.5 Week)
6. Universal Approximation Theorem (0.5 Week)
7. Perceptron Training (0.5 Week)
8. Neural Networks (0.5 Week)
9. Loss Functions for Machine Learning (0.5 Week)
10. Backpropagation (1 Week)
11. Automatic Differentiation (0.5 Week)
12. Gradient Descent Variations (1 Week)
13. Regularization (1.5 Weeks)
14. Convolutional Neural Networks (CNN) (1.5 Weeks)
15. CNN Variations (1 Week)
16. Generative Adversarial Networks (GAN) (0.5 Week)
17. Variational Autoencoders (VAE) (0.5 Week)
18. Recurrent Neural Networks (RNN) (1.5 Weeks)
19. LSTM and GRU: RNNs with long-term memory (0.5 Week)
20. Language Modelling (1 Week)
21. Attention (0.5 Week)
22. Self-Attention and Transformer Networks (0.5 Week)

Recitations:

1. Anaconda Installation and Virtual Environments
2. Jupyter Notebooks
3. Python basics
4. Numpy basics
5. Google Colab
6. Keras basics
7. Handwritten digits recognition
8. Training a perceptron
9. Linear Regression using Numpy
10. Linear Regression using Autograd
11. Evaluation metrics (accuracy, precision, recall, F-score, confusion matrix, mAP, ROC curve, AUC, IOU)
12. PyTorch basics
13. MLP in PyTorch
14. MLP training tips
15. Convolution
16. CNN in PyTorch
17. CNN Architectures and Transfer Learning
18. Deep Learning for Computer Vision
19. Image-to-image translation using Cycle-GAN
20. Name Generation using CharRNN
21. Sentiment Analysis using RNN and LSTM

Grading Scheme/Criteria:

Please note that sessional activities will constitute 50% of the grade. Remaining 50% will be covered by the mid-term and final exams.

- Assignments - 30%
- Quizzes - 5%
- Project - 15%
- Mid-term exam - 25%
- Final exam - 25%

Grading Policy:

- Homework has to be submitted **before the lecture** on the due date.
- There will be no make-up for any missed quiz.
- Make-up for a mid-term or final exam will be allowed only under **exceptional** circumstances provided that the instructor has been notified beforehand.
- Instructor reserves the right to deny requests for any make-up quiz or exam.
- Worst score on quizzes may be dropped.
- Worst score on assignments may be dropped.