Deep Learning Spring 2021

Course Outline

Website Link: <http://im.itu.edu.pk/deeplearning2021/>

| Class Hours **Tue**: 7:15 pm --- 8:45 pm, **Thu:** 5:30 pm --- 7:00 pm  Location Auditorium/ Computer Lab (Level 6) Office Hours and Contact Info. **Instructor: Mohsen Ali**  Office Hours; to be announced  Email: [mohsen.ali@itu.edu.pk](mailto:mohsen.ali@itu.edu.pk)  **Teaching Assistant 1:** Obaid Ullah Ahmad  TA hours: Friday 2:30 pm to 4:30 pm  *Note: Appointment via email first*  Email: [obaidullah.ahmad@itu.edu.pk](mailto:obaidullah.ahmad@itu.edu.pk)  **Teaching Assistant 2:** Hafiz Muhammad Abdullah Zia  TA hours: Wednesday 2:30 pm to 3:30 pm (During Ramadan)  *Note: Appointment via email first*  Email: [msds19087@itu.edu.pk](mailto:msds19087@itu.edu.pk)  **Teaching Assistant 3:** Muhammad Hamad Akram  TA hours: Thursday 3:30 pm to 5:30 pm  *Note: Appointment via email first*  Email: [msee19018@itu.edu.pk](mailto:msee19018@itu.edu.pk) | Course Basics Core Course for MSDS  Elective for BSCS, MSCS and MSEE  Credit Hours: 3  Being offered to both MSDS, MSCS, and BS students  Practical and hands-on approach  4 to 5 programming assignments  1 Final Project Prerequisite Enthusiasm, Energy, and Imagination  Data Structures, Probability & Statistics, Linear Algebra and Basic Calculus  Programming skills and desire to read & implement.  Being comfortable in Numerical analysis will Help.  You will be assigned Research Articles to read and write reports about. |
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**Course Overview**

We are going to take a "get your hands dirty" approach, you will be given assignments and projects to implement ideas discussed in the class. Projects and assignments will contain miniature versions of real-life existing applications and problems (e.g can you train your computer to generate dialogues in Shakespeare style or convert your image into painting as done by Monet, sentiment analysis, etc.. ).

The course will concentrate on developing both mathematical knowledge and implementation capabilities. We will start from training a single perceptron, move to train a deep neural network, study why training large networks is a problem and what could be its possible solutions. After dipping our toes in deep belief networks and recurrent neural networks we will start looking into applications of deep learning in three different areas, text-analysis, speech processing, and computer vision. The objective of this approach is to make you comfortable enough that you can understand various research problems and, if interested, can implement deep learning-based applications.

### **Course Objectives**

In the last few years, machine learning has matured from science fiction to reality. We are living in a world where we have already seen industry bringing to reality self-driving cars, face-recognizers that work on a massive scale (Facebook), speech translation systems that can translate from one language to many other simultaneously and in real-time, and more interestingly we have machines that can learn to play atari games in a similar fashion as we do.

A lot of these victories have come from the exciting field of Deep Learning; a learning methodology based on the concept that the human mind captures details at multiple levels or at multiple abstract levels. One property of deep learning is removing the responsibility of humans to design features, instead, Deep Learning is given a task to find the appropriate representation.

### **Tentative Grading Policy**

* 45% Assignments
* 20% Final Project
* 5% Class participation and Creating Notes [Link](https://docs.google.com/document/d/1wn8C3YnOZyZ8QmoyY7eiWgtuDMQ7OMeI9_sIVddgtK4/edit?usp=sharing)
* 10% Online Quizzes
* 10% Midterm Exam
* 10% Final Exam

### **Honor Code**

All cases of academic misconduct will be forwarded to the disciplinary committee. All assignments are to be done on an individual basis unless explicitly specified by the instructor. In the words of Efros, *let’s not embarrass ourselves*.

**Tentative and Rough Course Outline**

| **Weeks** | **Topics** | **Evaluations** |
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| 1 | **Introduction to Deep Learning**  Difference between Machine Learning and Deep Learning  Basic Machine Learning: Linear & Logistic Regression, |  |
| 2 | **Supervised Learning with Neural Networks**  Deep Learning, Single and Multi-Layer Neural Networks, Perceptron Rule, Gradient Descent, Backpropagation, Loss Functions, **DAG and Autograd**  *Tutorial 1: Python/Numpy Tutorial* |  |
| 1 | **Hyperparameters tuning, Regularization and Optimization**  Parameters vs Hyperparameters, Why regularization reduces overfitting? Data Augmentation, Vanishing/Exploding gradients, Weight Initialization Methods, Optimizers, **Batch Normalization**  *Tutorial 2: Building a Linear Classifier* |  |
| 2 | **Convolutional Neural Networks**  Convolutional Filters, Pooling Layers, Classic CNNs: AlexNet, VGG, GoogleNet, ResNet, DenseNet. Transfer Learning  *Tutorial 4: CNN Visualization* |  |
| 1 | **Deep Learning for Vision Problems**  Object Localization & Detection, Bounding box predictions, Anchor boxes, Region Proposal Networks, Detection Algorithms: RCNN, Faster RCNN, Yolo, SSD.  *Tutorial 5: Caffe & Object Detection* |  |
| 2 | **Sequence Models**  Recurrent Neural Networks (RNN), Gated Recurrent Unit (GRU), Long Short Term Memory (LSTM), Bidirectional RNN, Backpropagation through time. Image Caption Generation, Machine Translation, Text Generation & Summarization**, Self-Supervised Learning and word2vec**, **Transformers**  *Tutorial 6: Image Captioning & Text Generation* |  |
| 2 | **Auto-Encoders & Generative Models**  Variational Auto-Encoders, Stacked Auto-Encoders, Denoising Auto-Encoders, Concept of Generative Adversarial Networks (GANs) |  |
| 1 | **Adversarial Examples and Reinforcement Learning**  Adversarial Networks, Adversarial Attacks, Networks Generalization, Q-learning function, Reinforcement Learning |  |
| 2 | **Miscellaneous**  Capsule Networks, Convolutional LSTM, Attention Networks, Restricted Boltzmann Machine, One-Shot Learning, Siamese Networks, Triplet Loss, Graph CNN, Approximate and Energy-Efficient Design for Deep CNN (Dr. Rehan Hafiz) |  |
| 2 | **Project Presentations** |  |

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### **Text Book**

* Text Book: Deep Learning by Ian Goodfellow [Link](http://www.deeplearningbook.org/)
* Dive into Deep Learning by Aston Zhang and co. [Link](http://d2l.ai/)

### **Recommended Readings**

There is no assigned textbook, however, the following are recommended for reading.

* <http://deeplearning.net/>
* Book: <http://neuralnetworksanddeeplearning.com/>
* Courses
  + Machine Learning, Oxford – Nando de Freitas [Link](https://www.cs.ox.ac.uk/people/nando.defreitas/machinelearning/)
  + Deep Learning for Natural Language Processing, Stanford [Link](http://cs224d.stanford.edu/)
  + Convolutional Neural Networks for Visual Recognition, Stanford [Link](http://cs231n.github.io/)
  + A curated list of courses (Recommended) [Link](http://machinelearningmastery.com/deep-learning-courses/)
  + Stanford Deep Learning Tutorial [Link](http://deeplearning.stanford.edu/tutorial/)

**Toolkits**

| **PyTorch**   * [Toolkit Page](https://pytorch.org/) * [Tutorials](https://pytorch.org/tutorials/) * [Documentation](https://pytorch.org/docs/stable/index.html) * [Online Help Forum](https://discuss.pytorch.org/) * [Pretrained Models](https://pytorch.org/hub/) |
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**Some Interesting Links**

* [Linear algebra review/primer by Martial Hebert](http://www.cs.utexas.edu/~grauman/courses/378/handouts/mathprimer.pdf)
* Some of the research groups working with commercial entities
  + Machine Learning Group – Geoffrey Hinton
  + New York University – Yann Lecun
  + Stanford University – Andrew Ng, Fei-Fei Li‘s groups
  + [Microsoft Research](http://research.microsoft.com/en-us/groups/vision/)
  + Google DeepMind - Alex Graves
  + [Facebook](https://research.facebook.com/)
  + Amazon Research
* [Vision-related links on AAAI.org page](http://www.aaai.org/AITopics/html/vision.html)
* [MIT Nightmare Machine](http://nightmare.mit.edu/)
* [Major Advancements in Deep learning in 2016](https://tryolabs.com/blog/2016/12/06/major-advancements-deep-learning-2016/)
* [Google’s AI Chief Geoffrey Hinton: How Neural Networks really work?](https://www.youtube.com/watch?v=EInQoVLg_UY)
* [How Important Is Weight Symmetry in Backpropagation?](http://cbmm.mit.edu/publications/how-important-weight-symmetry-backpropagation-0)

**Top Conferences to Follow**

* International Conference on Machine Learning (ICML)
* Conference on Neural Information Processing Systems (NIPS)
* International Joint Conference on Artificial Intelligence (ICAI)
* Conference on Computer Vision and Pattern Recognition (CVPR)
* International Conference on Computer Vision (ICCV)
* British Machine Vision Conference (BMVC)