

MODERN DEEP LEARNING

2016-2017

Instructor: Mark Hamilton	Time: F 2:30 – 3:30
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Description

Deep learning is a vibrant field that brings together many areas of mathematics to solve problems previously deemed impossible. Studying this material will give you several complementary perspectives on intelligence, information, and cognition through a mathematical lens. In this course we will investigate a wide breadth of topics from the fields of deep learning, statistics, machine learning, and mathematics in general. We will begin with humble linear regression, and work our way into architectures for solving problems in a variety of real world domains such as speech, vision, text, etc. We will push back against the notion that machine learning is all about regression or classification and actively explore other domains like unsupervised, semi-supervised, and reinforcement learning.

The course assumes a basic grounding in math and linear algebra. I will focus on the intuition behind these tools, and I would much rather give students a deep intuition than muck through a proof on the board. The course is optimized for content delivery, and the lectures will be fast paced. However, I aim to include a real application in each week's lectures to keep the material relevant to a broad group. The goal is to bring those with little to no knowledge of machine learning to a level where they can actively contribute to modern research efforts.

Course Pages:

1. <https://microsoft.sharepoint.com/teams/NeuralNetworkDiscussionGroup>

Syllabus with Resources:

This is brief description of the lectures given. Videos can be found on the course page and are currently Microsoft internal. If you would like to help edit and improve the quality of these videos please do not hesitate to contact.

Semester 1

Week 1: From Linear Regression to Auto-Encoders

- Gradient Descent
- RMSE loss function
- Linear regression
- Multivariable regression
- Matrix regression
- Multi-Layer Perceptrons
- Auto-encoders
 - http://www.iro.umontreal.ca/~vincentp/Publications/denoising_autoencoders_tr1316.pdf
- Brief note on universality and no free lunch
 - https://en.wikipedia.org/wiki/Universal_approximation_theorem
 - https://en.wikipedia.org/wiki/No_free_lunch_theorem
 - http://www.zabaras.com/Courses/BayesianComputing/Papers/lack_of_a_priori_distinctions_wolpert.pdf
- Brief into to recurrent nets
 - Research Topic: Regularized recurrent auto-encoders

Week 2: Backprop and Deep Dream

- Forward + Reverse mode differentiation
<http://colah.github.io/posts/2015-08-Backprop/>
- Neural Network Inversion
<http://www.sciencedirect.com/science/article/pii/S0893608006001730>
Sorry this isn't free
- Deep Dream for visualizing platonic forms
<https://www.robots.ox.ac.uk/~vedaldi/assets/pubs/mahendran15understanding.pdf>
- Total Variation/ Naturalness priors
<https://www.robots.ox.ac.uk/~vedaldi/assets/pubs/mahendran15understanding.pdf>
- Deep Dream: maximizing layer activations
<https://research.googleblog.com/2015/06/inceptionism-going-deeper-into-neural.html>

Week 3: Convolutional Nets

- Image Filters
- Convolutional Layers
<http://colah.github.io/posts/2014-07-Conv-Nets-Modular/>
<http://cs231n.github.io/convolutional-networks/>
- Max Pooling Layers
- Walkthrough of all of the steps from "a neural algorithm for artistic style"
<https://arxiv.org/abs/1508.06576>
Reconstruction Loss: Content Loss
Texture Reconstruction: Style Loss

Week 4: Distribution Metrics and Generative Adversarial Nets

- Generative Models
- Images of random variables
- Earth Mover Distance
https://en.wikipedia.org/wiki/Earth_mover%27s_distance
http://homepages.inf.ed.ac.uk/rbf/CVonline/LOCAL_COPIES/RUBNER/emd.htm
- Maximum Mean Discrepancy Distance
http://alex.smola.org/teaching/iconip2006/iconip_3.pdf
- Generative Adversarial Nets
<https://arxiv.org/pdf/1406.2661v1.pdf>
https://github.com/Newmu/dcgan_code
- Minimax games
- Convergence of GAN
- Brief Description of Information Regularized GANs
<https://arxiv.org/abs/1606.03657>
- Brief Description of Disentangled Code Spaces
- Brief Discussion of research topics
4d convolutions, brain decoders, and multi-task learning
Message marhamilmicrosoft.com to collaborate

Week 5: Information Theory and infoGAN

- Information Theory
<https://colah.github.io/posts/2015-09-Visual-Information/>
- Prob+Stats review
- Coding Theory
- Entropy + Differential Entropy

- Brief Intro to information geometry and the fisher information metric
https://en.wikipedia.org/wiki/Information_geometry
<http://www.cs.cmu.edu/~lebanon/pub/thesis/thesis-2x1.pdf>
- Cross Entropy, KL-Divergence
- Conditional, joint, and Mutual Entropy
- Information Regularized GAN
<https://arxiv.org/abs/1606.03657>

Semester 2

Week 6: Recurrent Nets and Language Models

- Brief review of neural nets
- Turing Completeness
- Recurrent Nets
- Latent information channels
<http://karpathy.github.io/2015/05/21/rnn-effectiveness/>
- One-Hot encoding
- Embedding layers
- Sparse Matrix lookups
- Interpreting embeddings
<http://colah.github.io/posts/2014-07-NLP-RNNs-Representations/>
- The softmax layer
<http://cs231n.github.io/linear-classify/#softmax-classifier>
- Language modelling
<http://sebastianruder.com/word-embeddings-1/index.html>

Week 7: Modern Word Embedding

- Brief review of recurrent nets
- Sequence to sequence translation
<https://www.tensorflow.org/tutorials/seq2seq/>
<https://papers.nips.cc/paper/5346-sequence-to-sequence-learning-with-neural-networks.pdf>
- Brief mention of bidirectional RNNs
https://en.wikipedia.org/wiki/Bidirectional_recurrent_neural_networks
- Feed Forward Language Models
- Bilinear Language Models (Word2vec)
- Skipgram
- CBOW
<http://sebastianruder.com/word-embeddings-1/index.html>
<https://arxiv.org/abs/1301.3781>
- Gradient of the softmax
<http://sebastianruder.com/word-embeddings-softmax/index.html>
- Monte-Carlo Integration
https://en.wikipedia.org/wiki/Monte_Carlo_integration
- Importance sampling
<http://sebastianruder.com/word-embeddings-softmax/index.html>

Week 8: Word2Vec and Stochastic Matrix Factorization

- Review of Skipgram
<http://sebastianruder.com/word-embeddings-1/index.html>
<https://arxiv.org/abs/1301.3781>
- Negative Sampling
<http://sebastianruder.com/word-embeddings-softmax/index.html>
http://demo.clab.cs.cmu.edu/cdyer/nce_notes.pdf

- Negative Sampling as PMI factorization
<http://sebastianruder.com/secret-word2vec/>
<https://papers.nips.cc/paper/5477-neural-word-embedding-as-implicit-matrix-factorization.pdf>
- Matrix Factorization for Recommender Systems
- Netflix Challenge
<https://datajobs.com/data-science-repo/Recommender-Systems-%5BNetflix%5D.pdf>
<https://www.youtube.com/watch?v=gCa0a3W9kM0&t=2s>
- Matrix Factorization for Auto-ML
- Matrix Factorization for Clustering
- Matrix Factorization Grammars
<https://www.cs.toronto.edu/~rgrosse/uai2012-matrix.pdf>

Week 9: Intro to Reinforcement Learning

- Review of Supervised Learning
- The Reinforcement Learning Paradigm
- Markov Decision Processes
https://en.wikipedia.org/wiki/Markov_decision_process
- Policy Gradient Methods:
- Playing Atari Games
<http://karpathy.github.io/2016/05/31/rl/>
- Experience Replay
- Advantage/Reward Functions
- Epsilon Greedy Exploration and Annealing
- Derivation using score expectations
- Policy Gradient as a Nondifferentiable Component
<https://arxiv.org/pdf/1506.05254v1.pdf>

Week 10: Deep Q-Learning

- Review of Supervised learning
- Review of Policy Gradient Learning
- Markov Decision Processes
https://en.wikipedia.org/wiki/Markov_decision_process
- Optimal Policies and Q-Functions
<https://www.nervanasys.com/demystifying-deep-reinforcement-learning/>
- Table based Q-Learning:
<https://medium.com/emergent-future/simple-reinforcement-learning-with-tensorflow-part-0-.qimruxaea>
- Brief note on convergence:
<http://users.isr.ist.utl.pt/~mtjspaam/readingGroup/ProofQlearning.pdf>
- Deep-Q Learning
<https://www.nervanasys.com/demystifying-deep-reinforcement-learning/>
<http://www.nature.com/nature/journal/v518/n7540/full/nature14236.html>
- Brief note on Experience replay
- Brief note on epsilon greedy exploration
- Actor Critic Method for Continuous Control:
- Unifying Policy Gradient + Deep Q learning
<https://arxiv.org/pdf/1509.02971.pdf>
- Briefly Mentioned AlphaGo:
<https://storage.googleapis.com/deepmind-media/alphago/AlphaGoNaturePaper.pdf>

Extra Material for Week 10

- Great Video About Most of Deep Reinforcement Learning:
http://videlectures.net/rldm2015_silver_reinforcement_learning/
- Double Q learning:
<https://arxiv.org/pdf/1509.06461v3.pdf>
- Prioritized Experience Replay:
<https://arxiv.org/pdf/1511.05952v4.pdf>

Week 11: AlphaGo and LSTMS

- Sketching Out The Alpha Go Architecture:
<https://storage.googleapis.com/deepmind-media/alphago/AlphaGoNaturePaper.pdf>
- Deep Supervised Policy
- Rollout Supervised Policy
- Deep Policy Gradient Policy
- Value Network Trained with Policy Gradient Games
- Monte Carlo Tree Search
- Brief review of RNNs
- Vanishing and Exploding Gradients
https://en.wikipedia.org/wiki/Vanishing_gradient_problem
<http://jmlr.csail.mit.edu/proceedings/papers/v28/pascanu13.pdf>
- LSTMs:
<http://colah.github.io/posts/2015-08-Understanding-LSTMs/>
- Forget, Add and Output Gates
- Applications to Text
<http://karpathy.github.io/2015/05/21/rnn-effectiveness/>
- Applications to Handwriting
<https://www.cs.toronto.edu/~graves/handwriting.html>
<https://arxiv.org/abs/1308.0850>

Week 12: Neural Turing Machines

- <https://arxiv.org/abs/1410.5401>
- Overview of LSTM and RNN memory capabilities
- Discussion of Memory Addressing
- Location Based Addressing
- Content Based Addressing
- Differentiable Memory Reads
- Differentiable Writes
- Differentiable Addressing
- Controller Networks
- Experimental Exploration
- Examining the Activations and weights

Week 13: Optimization Methods

- Random Search
- Simulated Annealing
- Gradient Descent + SGD
- Momentum and Nesterov Momentum
- RMSProp, ADAM, Adagrad, Adadelta
- Second Order Methods: Newton and LBFGS
- Recurrent Neural Descent Methods

Week 14: Image Processing with Danil Kirsanov

- Image Processing Basics
- Depth Prediction
- Next Frame Prediction
- Optical Flow