02456 Deep learning 2017 - course plan and information

Time and location: Mondays 13-17. We will be in building 306/aud. 33 for both lectures and exercises.

During all 13 weeks in the term the teacher and teachings assistants will be on location Monday afternoon to supervise labs and project work.

The six first weeks of the course follows this structure:

1. A brief lecture to give an overview of this week's topic (~5-10 min).
2. Possibility to ask questions for this week's video lecture (~20 min).
3. Short introduction to this week's exercises (~5 min).
4. Written and computer exercises (3.5 hours).

Todo before course starts: Sign up for credits at AWS Educate

We will use AWS Educate for GPU computation. Please go to AWS Educate and sign up as a student. The most important step is that you must use your DTU email address. In worst case it takes some days to get registered so please do this as soon as possible. You will receive free credits when you sign up that come especially handy for experiments during the project period. To make these last longer you can use so called spot instances.

Topics in the first six weeks

1. Introduction to statistical machine learning, feed-forward neural networks (FFNN) and error back-propagation.
2. Convolutional neural networks (CNN), presentation of student projects.
3. Recurrent neural networks (RNN), selection and start of student projects.
4. Tricks of the trade and data science with TensorFlow.
5. Variational learning and generative adversarial networks for unsupervised and semi-supervised learning.
6. Reinforcement learning - policy gradient and deep Q-learning.

Week 7-13 will be only project work

In the seven project weeks we will still meet on Mondays for project work and supervision.

Reports and peer evaluated during the course

The course will be evaluated by both a report handed in during the course and a final project presentation. Peer grading will be used throughout the course to ensure more accurate evaluation and better feedback. Graders get 4 reports at each deadline and have one week to carry out the feedback. *Handing in and peer grading five of the six labs reports is required for being able to make the project presentation and eventually pass the course*.

The following reports should be handed in jupiter notebook format:

1. Week 1 computer exercise and 1 exercise of own choice from course material week 1. Deadline: Monday week 2.
2. Week 2 computer exercise and 1 exercise of own choice from course material week 1. Deadline: Monday week 3.
3. Week 3 computer exercise and 1 exercise of own choice from course material week 1. Deadline: Monday week 4.
4. Week 4 computer exercise and 1 exercise of own choice from course material week 1. Deadline: Monday week 5.
5. Week 5 computer exercise and 1 exercise of own choice from course material week 1. Deadline: Monday week 6
6. Week 6 computer exercise and 1 exercise of own choice from course material week 1. Deadline: Monday week 7.
7. Project synopsis. Deadline: Wednesday week 8
8. Project presentations. Monday week 13 will be two-track, peer evaluated and of course teacher graded.
9. Final report. Monday week 15

Detailed content

Links to individual video lectures and lecture slides are given below. Here is a link to all video lectures as a playlist and a Google doc folder with all the lecture slides. A handful of new videos will be added during September to cover new topics.

Week 1 - Introduction and feed-forward neural networks

1. Watch week 1 video lectures:
    a. Part 0 Overview
    b. Part 1 Deep learning
    c. Part 2.1 Feed-forward neural networks
    d. Part 2.2 Feed-forward neural networks
    e. Part 3 Error Backpropagation
    f. Part 4 Optimization

and take notes for at least 3 questions to ask. Link to lecture slides is here.
2. Reading material Michael Nielsen, Neural networks and deep learning http://neuralnetworksanddeeplearning.com/ Chapters 1-3 (stop when reaching section called Overfitting and regularization) and browse Chapter 4. Note that this is a lot of reading material so it is completely alright if you read over the next few weeks. All topics are also covered in the deep learning book that may be read as a supplement.
3. One exercise from the book chapters. At home and in class we will work on the Exercises in the Chapters. There are lots of exercises so select those that deepen your understanding of the text material. Don't do the Problems. They may be used later for inspiration for projects.
4. Install software on your laptop or go directly to cloud installation. Installation guide for both may be found here.
5. Carry out computer exercises week 1. Note that the computer exercises may experience minor change up to 3 days before the actual session.

Week 2 - Convolutional neural networks

1. Watch week 2 video lectures
    a. Part 1 Introduction to CNNs (PART 1/2)
    b. Part 1 Introduction to CNNs (PART 2/2)
    c. Part 2 CNNs the details (PART 1/2)
    d. Part 2 CNNs the details (PART 2/2)
    e. To be added video on latest developments in CNNs
    f. To be added video on image segmentation

   and take notes for at least 3 questions to ask. Link to lecture slides is here.
2. Reading material Michael Nielsen, Neural networks and deep learning http://neuralnetworksanddeeplearning.com/ Chapter 6 (stop when reaching section called Other approaches to deep neural nets).
3. One exercise from the book chapters.
4. Carry out computer exercises week 2.

Week 3 - Recurrent neural networks

1. Watch week 3 video lectures
    a. 02456week3 1 RNN (PART 1 of 3)
    b. 02456week3 1 RNN (PART 2 of 3)
    c. 02456week3 1 RNN (PART 3 of 3)
    d. 02456week3.2_RNN_training (PART 1 of 3)
    e. 02456week3.2_RNN_training (PART 2 of 3)
    f. 02456week3 2 RNN training (PART 3 of 3)

    g. 02456week3 3 Attention (PART 1 of 2)
    h. 02456week3 3 Attention (PART 2 of 2)
    i. 02456week3 4 Supervised learning recap
    j. To be added video on CNNs and attention as replacement for RNNs

   and take notes for at least 3 questions to ask. Link to lecture slides is here.
2. Reading material Alex Graves book, Supervised Sequence Labelling with Recurrent Neural Networks Chapters 3.1, 3.2 and 4. Browse Michael Nielsen, Neural networks and deep learning Chapter 6 section Other approaches to deep neural nets) and onwards. Andrej Karpathy has a nice blogpost that gives a good flavour of the whats and hows of RNNs.
3. One exercise from the book chapters.
4. Carry out computer exercises week 3.
5. Selection of project.

Week 4 - Tricks of the trade and data science with TensorFlow

1. Watch week 4 video lectures
    a. 02456week4 1 1 Initialization and gradient clipping
    b. 02456week4 1 2 batch normalization
    c. 02456week4 2 1 regularization
    d. 02456week4 2 2 regularization methods
    e. 02456week4 2 3 data augmentation
    f. 02456week4 2 4 ensemble methods and dropout
    g. 02456week4 3 recap

   and take notes for at least 3 questions to ask. Link to lecture slides here.
2. Reading material Michael Nielsen, Neural networks and deep learning http://neuralnetworksanddeeplearning.com/ Chapter 3 from section Overfitting and regularization and Chapter 5. This blog lists advice on why training will not converge.
3. One exercise from the book chapters.
4. Computer exercises week 4 using TensorFlow on the Kaggle competition leaf classification.
5. Project work.

Week 5 - Un- and semi-supervised learning

1. Watch week 5 video lectures
    a. 02456week5 1 1 unsupervised learning
    b. 02456week5 1 2 unsupervised learning latent variables
    c. 02456week5 2 1 autoencoders
    d. 02456week5 2 2 autoencoders layerwise pretraining

    e. 02456week5 3 1 variational autoencoders
    f. 02456week5 3 2 semisupervised variational autoencoders
    g. Video to be added on GANs.

   and take notes for at least 3 questions to ask. Link to lecture slides here.
2. Reading material DL Chapter 14 and 20.10.3
3. One exercise from the book chapters.
4. Carry out computer exercises week 5 on autoencoder un- and semi-supervised.
5. Project work.

Week 6 - Reinforcement learning

1. Watch week 6 video lectures
    a. 02456week6 1 1 reinforcement learning
    b. 02456week6 1 2 reinforcement learning approaches
    c. 02456week6 2 1 AlphaGo policy and value networks
    d. 02456week6 2 2 AlphaGo steps 1 to 4
    e. 02456week6 3 policy gradients
    f. 02456week6 4 a few last words
    g. Video to be added on Deep Q learning.

   and take notes for at least 3 questions to ask. Link to lectures here.
2. Reading: another nice blog post by Andrei Karpathy and OPenAIs tutorial. Optional reading material on the connection between variational and reinforcement learning.
3. One exercise from the book chapters.
4. Computer exercises on reinforcement learning methods (policy gradient, deep Q learning, evolutionary strategies) in the openAI Gym. Carry out computer exercises week 6.
5. Project work.

Evolving list of projects

Below is a list of suggested projects. Groups of 3-4 students are preferred to smaller 1-2 student groups. It is possible to suggest own projects and come with own datasets. Given the little time we have for the project, the only requirement is that data is ready so that we can focus on working on the methods. A lot of these projects may also later be expanded into special courses and/or master thesis projects.

1. Super resolution for ultrasound imaging - collaboration with Jørgen Arendt Jensen, DTU Elektro.
2. Deep learning for autonomous systems - collaboration with Ole Ravn and his group, DTU Elektro.

   a. MBZIRC Challenges 1 (live set-up available) and 2 (competition and generated data available).
   b. Brio labyrinth ConvNet (CNN) segmentation of ball under challenging light conditions.
3. Deep learning for pollen classification. Supervised by Janne Kool, DTU Compute.
4. Computer-aided diagnostics in dermatology. CNNs will be used on images from a Danish dermatological database, aiming to help doctors differentiate between diagnoses. Supervisors Ole Winther and MD Kenneth Thomsen.

Projects from 2016 edition

Some of these projects will in an updated version be available this year as well:

1. End-to-end object tracking in high-resolution videos. Tracking of ball and players in images and video with fixed camera position. Supervised by Philip Henningsen, Sportcaster.
2. Matching of two input images using deep neural networks in the context of fingerprint verification. Supervised by Pedro Højen-Sørensen, Morten Pedersen and Lars Christensen, Fingerprint Cards.
3. End-to-end speech recognition system using RNNs and the CTC loss function. References: https://arxiv.org/abs/1512.02595 and original CTC paper ftp://ftp.idsia.ch/pub/juergen/icml2006.pdf. Supervised by Michael Reibel Boesen, Corti reibel@cortilabs.com and Ole Winther.
4. Multi-modal integration with deep generative models. Supervised by Ole Winther, Lars Maaløe and Casper Kaae Sønderby.
5. Constructivity prediction with RNN's. At Peergrade we collect a large amount of text-feedback coupled with indications of how constructive it is. We are interested in testing out whether recurrent neural networks can predict whether a piece of feedback will be rated as constructive. Supervised by David Kofoed Wind, DTU Compute and Peergrade.io.
6. Reparameterizing deep generative models. Methodological work on improving Variational autoencoders for image generation. Supervised by Marco Fraccaro.
7. Variational autoencoders (VAE) with convolutional (CNN) layers. Image applications usually benefit a lot from CNN layers. We will try to improve VAE semi-supervised performance from http://arxiv.org/abs/1602.05473 using CNN layers. Supervisors Lars Maaløe and Ole Winther.
8. Semi-supervised ladder VAE. In http://arxiv.org/abs/1602.02282 we have proposed a new variational approximation for VAE called ladder VAE and tested it in an unsupervised setting.
   a. Project a: Extend the ladder VAE for semi-supervised learning. Supervised by Casper Kaae Sønderby and Ole Winther.

    b. Extend the ladder VAE to support convolutions. This should increase the performance on image data. Supervised by Casper Kaae Sønderby and Ole Winther.
9. RNNs with stochastic layers. Implement our recent proposal for variational models for sequential data http://arxiv.org/abs/1605.07571 and apply it to text data (learning to generate text). Supervisors Marco Fraccaro and Ole Winther.
10. Unsupervised learning on genomic data. Train a deterministic generative RNN and/or our recently proposed sequential variational model on genomic data to investigate the feasibility of generative modelling of genomic data.
Supervisor: Casper Kaae Sønderby
11. CNNs for text image segmentation. Using CNNs Supervised by Rasmus Berg Palm DTU Compute and Tradeshift.
12. Semi-supervised learning on text. Apply one or several of the recent state-of-the-art semi-supervised models (https://arxiv.org/abs/1606.03498, https://arxiv.org/abs/1507.02672 or https://arxiv.org/abs/1602.05473) parametrized by convolutional or recurrent neural nets on the datasets from https://arxiv.org/abs/1502.01710. Supervised by Lars Maaløe.
13. Generating text from images by applying VAEs, parametrized by CNNs or RNNs, to the MSCOCO dataset (http://mscoco.org). Supervised by Lars Maaløe.
14. "Why Should I Trust You?": Explaining the Predictions of Any Classifier http://arxiv.org/abs/1602.04938. Supervised by Lars Kai Hansen.
15. Convergent Learning: Do different neural networks learn the same representations? http://yosinski.com/convergent. Supervised by Lars Kai Hansen.
16. On the resilience of deep neural networks to weight damage. Things you can do with deep network Hessians. Supervised by Lars Kai Hansen.
17. Reinforcement learning. Work on selected reinforcement problems from the OpenAI gym. Supervisors Jonas Busk and Ole Winther.
18. Learning from where we look: Saliency weighted auto encoding. Learning perceptually more appealing generative models https://arxiv.org/abs/1606.00110 and http://www.cns.nyu.edu/pub/lcv/laparra16a-preprint.pdf. Supervisor Casper Kaae Sønderby.
19. Image recognition research with CNNs, based on https://arxiv.org/abs/1608.06993 . Supervised by Alexander Johansen teaching assistant (github.com/alrojo).
20. Image recognition research with CNNs, RNNs and spatial transformers, using an adaptive amount of spatial transformers to analyse images, based on http://arxiv.org/abs/1509.05329 (Lasagne code will be supplied) and inspired byhttp://arxiv.org/abs/1603.08575 . Supervised by teaching assistant Alexander Johansen (github.com/alrojo).
21. Machine translation research with RNNs and SparseMax: implement SparseMax (https://arxiv.org/abs/1602.02068) in TensorFlow and use it to do sparse attention in an encoder-decoder model (state-of-the-art encoder-decoder model will be supplied). Supervised by teaching assistant Alexander Johansen (github.com/alrojo).

22. Semantic image segmentation of high resolution packshots. Supervised by Jacob Schack Vestergaard, Anders Boesen Lindbo Larsen, and Toke Jansen, CloudCutout (an ML company who strive to fully automate the task of removing the background from studio photos; a task that traditionally is carried out by human professionals).