# 02456 Deep learning 2018 - course plan and information

Time and location: Mondays 13-17. First session is September 3rd. We will be in building 306 auditoria A033 and A036 for both lectures and exercises.

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

Bring laptop.

The six first weeks of the course follows this structure:

1. A brief session with practical information (~5 min).
2. Short introduction to this week's exercises (~5 min).
3. Written and computer exercises (3 hours and 50 minutes).

## 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. You don't need AWS for weekly exercises. In order to get access to the AWS servers you have register a credit card. This is will not be charged anything as long as you don't use more than your free credits. In order to monitor that you don't use more than the free credits you can set up budget as described in the budget guide Mikkel has made. To make these last longer you can use so called spot instances as described in Mikkel Vilstrup AWS guide that can be found here.

An alternative to the budget guide is to use the 'Billing Alarm' feature. A guide for setting up such may be found here.

Access to GPU instances are not default. Here is what AWS Support recommends: "A Limit Increase can be requested if a customer needs access to more resources than their current limit allows. Keep in mind that GPU instances are a high-performance and expensive resource, so it is best to request the minimum necessary increase, such as 1 p2.xlarge instance".

## Communication

We use Slack for communication. Here is the invite link.

## 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).
3. Recurrent neural networks (RNN), presentation of student projects.
4. Tricks of the trade and data science with PyTorch. Deadline for selection of student projects.
5. Variational learning and generative adversarial networks for unsupervised and semi-supervised learning. Start of student projects.
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 jupyter 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 1-2. Deadline: Monday week 3.
3. Week 3 computer exercise and 1 exercise of own choice from course material week 1-3. Deadline: Monday week 4.
4. Week 4 computer exercise and 1 exercise of own choice from course material week 1-3. Deadline: Monday week 5.
5. Week 5 computer exercise and 1 exercise of own choice from course material week 1-3. Deadline: Monday week 6
6. Week 6 computer exercise and 1 exercise of own choice from course material week 1-3. Deadline: Monday week 7.

7. Project synopsis. Deadline: Wednesday week 8. The synopsis should be approximately half a page and maximum one page with a project title, motivation, background, milestones and references. It is important that the plan is realistic.
8. Project presentations. Monday December 17th from 13.00 to 17.00 building 308 auditoria 11 and 12. It will be group presentations followed by questions to the group in front of teachers and fellow students. Remember that it is important for the overall impression that you divide the presentation and answering of the questions more or less equally between you. There are 5 minutes set aside for each participant including questions and swapping. So plan on 3-4 minutes for each for presentation. 1 minute per slide is a good rule of thumb.
9. Final report deadline January 3rd 2018 23.59. The report should be maximum 6 pages plus references using this conference paper format. The report should also contain a link to your project code Github repository. Among the files in the repository should be a jupyter notebook that should recreate the main results of your report.

# Detailed content

*Under construction for 2018. Computer exercises will change to Pytorch.*
Links to individual video lectures and lecture slides are given below. Here is a link to all 2016 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. A very good alternative video resource is Hugo Larochelle's YouTube playlist.

## 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.
3. One exercise from the book chapters. At home and in class we will work on the Exercises in the chapters of the book. 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. The exercise should be handed in the notebook as an extra notebook cell in markdown.

4. Alternative textbook: All topics are also covered in the deep learning book that may be read as a supplement. Feed-forward neural networks are covered in this chapter. Chapter 1 gives an introduction to deep learning and Part II gives the necessary background on linear algebra, probability, numerical computation and machine learning.
5. Install software on your laptop or go directly to cloud installation. Installation guide for both may be found here.
6. Carry out computer exercises week 1. Note that the computer exercises may experience minor change up to 3 days before the actual session.
7. Hand in the notebook marked with EXE on peergrade.io. It should contain your added code in the five exercises and the answer of one exercise from Michael Nielsen's book (see point 3. above). The answer to the book exercise should be in a markdown cell at the bottom of the notebook. (You can find information about markdown here. To get a cell to be markdown you choose the type of the cell in menu at the top of the notebook.)
8. Peergrade exercise from three other students through peergrade.io. You will receive instructions about this from peergrade.io.

## 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. 2017 CNN update
   f. 2017 Activation functions update
   g. 2017 Image segmentation

   and take notes for at least 3 questions to ask. Link to lecture slides is here and here for 2017 updates.
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. Alternative textbook chapter in the deep learning book.
4. One exercise from the book chapters.
5. 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. 2017 Quasi RNN
k. 2017 Non-recurrent sequence to sequence models
l. 2017 Text summarization

and take notes for at least 3 questions to ask. Link to lecture slides is here and here for the 2017 updates.

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.
3. Alternative textbook chapter in the deep learning book. Andrej Karpathy has a nice blogpost that gives a good flavour of the whats and hows of RNNs.
4. One exercise from the book chapters.
5. Carry out computer exercises week 3. Hand in and peergrade on peergrade.io like in previous week.
6. Project presentation.

## 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
    h. 2017 37 reasons your nn working (part 1 of 2) Walk through of the 37 reasons why your neural network is not working blog post.
    i. 2017 37 reasons you not working (part 2 of 2)

    and take notes for at least 3 questions to ask. Link to lecture slides here and here for link to blog post.

2. Reading material Michael Nielsen, Neural networks and deep learning http://neuralnetworksanddeeplearning.com/ Chapter 3 from section Overfitting and regularization and Chapter 5.
3. Alternative textbook chapters on regularization, optimization, deep learning practice and applications from the deep learning book.
4. One exercise from the book chapters.
5. Computer exercises week 4 using TensorFlow on the Kaggle competition leaf classification. Hand in and peergrade on peergrade.io like in previous weeks.
6. Project selection.

## 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. 2017 Generative adversarial networks

    and take notes for at least 3 questions to ask. Link to lecture slides here and here for 2017 updates.
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. Hand in and peergrade on peergrade.io like in previous weeks.
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. 2017 Deep Q learning
    h. 2017 Evolutionary strategies

and take notes for at least 3 questions to ask. Link to lectures here and here for 2017 update.
2. Reading: another nice blog post by Andrei Karpathy. 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. Hand in and peergrade on peergrade.io like in previous weeks.
5. Project work.

# Project list 2018

*Under construction for 2018. More projects will be added in the coming weeks.*
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.

This list is under construction and will be expanded during the first week of the term. Below you can see the list of project from last year.

1. Come with your own project. Requirements: data and problem statement are in place so that time will be spend on modelling. Ideally team up with other students but one student teams may be accepted in special circumstances.
2. Projects with Corti.ai supervised by Lars Maaløe lm@corti.ai.
    a. Word-level End-to-End Automatic Speech Recognition (ASR)
    b. Optimizing Automatic Speech Recognition (ASR) by Sampling
    c. Sequence-to-Sequence Networks for Automatic Speech Recognition (ASR)
    d. Generating translated audio from ground-truth transcripts

    Detailed project description may be found here.
3. Projects with Hedia.dk supervised by Jonas Meinertz Hansen jonas@hedia.dk
    a. Food recognition from photos
    b. Improve insulin dosage suggestions.

    Detailed project description may be found here.
4. Projects with Søren Hauberg, sohau@dtu.dk, DTU Compute
    a. Variational autoencoders in Julia.
    b. Geometry of latent variable models
    c. Uncertainty quantification.

    Detailed project descriptions may be found here.
5. Reinforcement learning (RL). Work on selected reinforcement problems from the OpenAI gym with different algorithms policy gradient, deepQ and evolutionary strategies. Supervisors Jonas Busk and Ole Winther. Note that RL is in general hard

to get to work so project synopsis should contain both a safe and more ambitious objective.

6. Deep generative modelling. Supervised by Ole Winther, Valentin Lievin and Jesper Wohlert Hansen
    a. Flow models, e.g. https://arxiv.org/pdf/1807.03039.pdf
    b. Discrete latent with Gumbel softmax/ConCrete distribution.
    c. Memory models, e.g. https://arxiv.org/pdf/1709.07116.pdf
    d. Generative query networks
7. Deep learning for autonomous systems - collaboration with Ole Ravn and Nils Axel Andersen, DTU Elektro
8. Natural language processing with deep learning supervised by Alexander Rosenberg Johansen, alexander@herhjemme.dk
    a. Contextual entailment.
9. Deep learning for human mobility and beyond. Supervised by Francisco Pereira, camara@dtu.dk, Carlos Azevedo, cami@mit.edu, Filipe Rodrigues (rodr@dtu.dk) and Patrizio Mariani pat@aqua.dtu.dk:
    a. Mode detection using the GPS data GeoLife database (paper).
    b. Predicting phone usage while travelling using Lifelog smartphone base dataset Ubiqlog (paper).
    c. Predicting vehicle trajectories from already processed video-based detection data set here.
    d. Detecting vehicle trajectories from images (aerial remote sensing of A44 in Portugal (paper, paper).
    e. Spatio-temporal deep learning models for predicting car-sharing demand data (Green Mobility and DriveNow data).
    f. Graph convolutional LSTMs for traffic short-term forecasting (high-resolution traffic data provided by Google Research for the Copenhagen road network).
    g. Mixture-density networks (MDNs) or Bayesian Normalising Flows (BNFs) for estimating 2-D conditional density of mobility demand (e.g. taxi demand).
    h. Deep generative models (e.g. VAEs and GANs) for outlier detection in large-scale high-resolution oceanographic data.
10.

# Deep learning student jobs

*Under construction for 2018.*

List of student jobs postings will appear below

1.

# Project list 2017 edition as a reference

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.

11. Come with your own project. Requirements: data and problem statement are in place so that time will be spend on modelling. Ideally team up with other students but one student teams may be accepted in special circumstances.
12. Deep learning super resolution for ultrasound imaging - collaboration with Jørgen Arendt Jensen, DTU Elektro. Velocity estimation using networks trained on simulated and measured data from flow rigs and phantoms.
13. 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.
14. Deep learning for pollen classification. Supervised by Janne Kool, DTU Compute.
15. 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.
16. Deep learning for food industry automation. Supervised by Rufus Blas, rufus.blas@sensomind.com working with
    a. Mask-RCNN's
    b. Generative adversarial networks
    c. Unsupervised deep embedding for clustering analysis
17. Convolutional neural network image recognition web server. Supervised by Erik David Johnson, Netcompany.
18. Deep learning for fact checking. Supervisors Marie Rask Glerup, DR and Ole Winther. Inspiration: company homepage and YouTube lecture starting from 24:10.
19. Bioinformatics sequence analysis. Supervisors José Armenteros, Henrik Nielsen and Ole Winther. Example projects:
    a. Learning the blossom substitution matrices
    b. RNA subcellular localization.
20. Deep Neural Networks for Interpretable Analysis of EEG Sleep Stage Scoring. Supervisors Sirin W. Gangstad and Albert Vilamala. Creation of visually interpretable images of sleep patterns from EEG signals to be used as inputs to a state-of-the-art

deep convolutional network to accurately classify sleep stages, with a strong focus on interpreting the obtained network. Subprojects:

a. Evolve the current convolutional network to a Recurrent Neural Network.
b. Semi-supervised domain adaptation of our current convolutional network to a related domain.

21. Detection in soccer video. Supervised by Jesper Taxbøl jesper@sportcaster.dk . VEO has collected a dataset of one million panoramic video frames where a ball is annotated. (video, config, annotation) Use this dataset to:
    a. Detect ball position. Manipulate video into a form that can be fed to a neural network for detecting the ball position or special events.
    b. Super resolution. How well can self similarity in perspective content be used as basis for increasing resolution in longer ranges?
    c. Explore Audio. Can the audio track say something about the state of the game. (No annotated dataset)
22. Audio event research using deep learning. By constructing a deep neural network of convolutional and recurrent neural networks, the task is to label a vast amount of different audio events. Supervised by Lars Maaløe and Corti.
23. Variational auto-encoders (VAE) and convolutions for building a generative model that outputs crisp images. Build a PixelVAE that use PixelCNN layers to perform autoregressive sampling. Analyse and compare the output to a regular VAE with convolutions. Supervised by Lars Maaløe.
24. Semi-supervised ladder VAE. Extend the ladder VAE to semi-supervised learning. Supervised by Lars Maaløe and Ole Winther.
25. Bayesian neural networks for
    a. Transfer learning
    b. Online learning

    Supervised by Casper Sønderby
26. Probabilistic Discrete Latent Variable models, Supervised by Casper Sønderby.
27. Understanding what contributes to a prediction. Supervised by Lars Kai Hansen and Ole Winther. Theoretical and applied projects are possible. Good sources of information here, here and here.
28. Semantic image segmentation of selfies. Supervised by Toke Faurby and Toke Jansen Hansen, spektral.com.
29. Image segmentation for road scenes with SegNet and Bayesian Segnet. Supervised by Maximilian Vording and Tommy Alstrøm.
30. Autoencoders for deep part-based learning with application to deconvolution of spectra. Supervised by Maximilian Vording and Tommy Alstrøm.
31. Sound and speech projects with Oticon. Supervised by Maciej Korzepa and Lars Bramsløv, Oticon. Subprojects
    a. Classifying acoustic scenes by means of transfer learning based on VGG-type model trained on AudioSet as inspired by retraining of ImageNet networks.

b. Speech separation for smartphones.

32. Customer-specific Neural Machine Translation (NMT). Supervised by Maciej Korzepa and Jin, EasyTranslate. Use customer-specific resources 1) Translation memory (TM) containing the source and target (translated) segments (which are sentences, headings, bullet points from list etc.) from all past translations. 2) Phrase bases which contain strict rules how specific phrases should be translated. There are some papers proposing how to include 2) in NMT Papers for inspiration 1, 2, 3, 4.
33. Reinforcement learning (RL). Work on selected reinforcement problems from the OpenAI gym with different algorithms policy gradient, deepQ and evolutionary strategies. Supervisors Jonas Busk and Ole Winther. Note that RL is in general hard to get to work so project synopsis should contain both a safe and more ambitious objective.