**Time Schedule for**

**Module 2: Deep Neural Networks Teacher**: Saikat Chatterjee, KTH

Date: Nov 21, 2021.

* 11 lectures (and accompanied pre-recorded video) (total time for lectures 10x2+3+3 = 26 hours, the video making will take extra 20-25 hours.)
* 7 tutorial sessions (total time 7x3 = 21 hours)
* Project work – 3 hours

Time for a typical lecture class: 2 hours. (50 mins – 10 mins gap – 45 mins – 15 mins Q/A)

List of main topics:

* + - 1. Mathematical basics
      2. Non-linear transformation concept for exploiting non-linear correlation (Kernel trick and neural networks)
      3. Neural networks from user perspective
      4. Training of neural networks (problems, tricks and algorithms)
      5. Structured neural networks
      6. Generative models
      7. Machine learning for time series
      8. Incremental learning and transfer learning

Assessment: 1. Assignments 4 hp. Project work 1 hp. In total, 4+1=5 hp.

Schedule:

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| Day | Date | Lecture, Time Slot: 15:00 – 17:00 CET | Lab (Tutorial) |
| Wed | Jan 12, 2021 | Lecture 1: On Neural Networks |  |
| Wed | Jan 19 | Lecture 2: Data-limited scenarios |  |
| Fri | Jan 21 |  | Tutorial 1: Data-limited scenarios  Time slot: 15:00-18:00 |
| Wed | Feb 2 | Lecture 3: Implementation and structures of DNN |  |
| Wed | Feb 9 | Lecture 4: Implementation and structures of DNN |  |
| Fri | Feb 11 |  | Tutorial 2: Imp & structures of DNN  Time slot: 15:00–18:00 |
| Wed | Feb 16 | Lecture 5: Implementation and structures of DNN |  |
| Fri | Feb 18 |  | Tutorial 3: Imp & structures of DNN  Time slot: 15:00–18:00 |
| Wed | Feb 23 | Lecture 6: Generative models |  |
| Wed | Mar 2 | Lecture 7: Generative models |  |
| Fri | Mar 4 |  | Tutorial 4: Generative models  Time slot: 15:00- 18:00 |
| Wed | Mar 9 | Lecture 8: Generative models |  |
| Fri | Mar 11 |  | Tutorial 5: Generative models  Time slot: 15:00- 18:00 |
| Wed | Mar 16 | Lecture 9: Sequential data analysis |  |
| Wed | Mar 23 | Lecture 10: Sequential data analysis |  |
| Fri | Mar 25 |  | Tutorial 6: Sequential data analysis  Time slot: 15:00-18:00 |
| Wed | Mar 30 | Lecture 11: Complex learning scenarios  Time slot: 15:00-18:00 |  |
| Fri | Apr 1 |  | Tutorial 7: Complex learning scenarios  Time slot: 15:00-18:00 |
| Fri | Apr 8 | Project work (1hp)  Time slot: 15:00-18:00 |  |

Prerequisites (mathematics):

1. Linear algebra basics (linear system, matrix-vector product, rank, etc.) – Please read the following literature –

<https://www.ekof.bg.ac.rs/wp-content/uploads/2016/09/Ponavljanje-matematike-Wayne-Winston-Operations-Research-Applications-and-Algorithms-4-edition.pdf>

1. Probability and statistics (Gaussian distribution, multi-variate distribution, statistical moments) – Please read the following – Mainly follow the Pattern Recognition and Machine Learning book of Christopher Boshop. Chapter 1, from the beginning of the chapter up to section 1.4 (Curse of dimensionality). Then chapter 2.3 (The Gaussian Distribution) – from the beginning of the chapter up to section 2.3.4.
2. Convex optimization (least-squares, over and under-determined scenarios, sparsity, LASSO) -

<https://en.wikipedia.org/wiki/Convex_optimization>

<https://en.wikipedia.org/wiki/Least_squares>

<https://en.wikipedia.org/wiki/Lasso_(statistics)>

Details with subtopics, time schedule and assignments.

1. *Neural Networks (a general seminar style class by the teacher):*

Goal: To set the stage for the teacher and students

a. On ability and inability of neural networks from a critical perspective.

b. Discriminative learning, data-driven approaches, generative models.

c. Trust, reliability and social acceptance

d. Short details of the rest of classes, tutorials, assignments, projects, passing requirements.

Lecture no: 1

Lecture time requirement: 2 hours. (50 mins – 10 mins gap – 45 mins – 15 mins Q/A)

Tutorial and assignments: No tutorial and assignment.

1. *Data-limited scenario:* Goal: To know formal way to handle data-limited scenarios, that means when training data is limited.  
     
    a. Importance of data-limited scenarios

b. Optimal target prediction

c. Machine learning is non-linear

d. A fundamental structure for neural networks

e. Kernel substitution as the non-linear transform  
 f. Variable / feature selection. (extra material if time permits)

g. Random feature-based methods (extreme learning machine (ELM))

Lecture no: 2.

Lecture time requirement: 2 hours. (50 mins – 10 mins gap – 45 mins – 15 mins Q/A)

Tutorial no: 1 (3 hours)

Tutorial and assignments: Multi-class classification problems using Kernel substitution, Extreme Learning Machine (ELM) and Support Vector Machine (SVM).

3) *Implementation and structures of deep neural networks:*  Goal: Practical training and knowledge of using modern ML methods

a. Optimisation setups

b. Gradient descent

c. Types of gradient descent

d. Momentum for gradient descents

e. Practical aspects for training

f. Convolutional neural networks

g. Various structures of deep neural networks: Convolutional Neural Network (CNN), AlexNet, VGG-16, ResNet, DenseNet, Inception, U-Net

h. Robustness – Adevrsarial attacks, stability

Lecture no: 3, 4 and 5. (together 2+2+2=6 hours)

Tutorial no: 2 and 3 (together 3+3 = 6 hours)

Tutorial and assignments: Coding for multi-class classification problems, implementation of CNN and various gradient search methods, data augmentation and cross-validation, implementation of deep architectures such as LeNet-5, ResNet, DenseNet, etc. The students require GPUs/clusters for the tutorials and assignments.

1. *Generative models*:  
    Goal: Practical training on sample generation and likelihood computation, followed by their use in classification  
   1. Concept of generative models
   2. Mathematical formalization of generative models for machine learning
   3. About distribution functions
   4. Probability distributions using neural networks
   5. Auto-encoder
   6. Normalizing flows

Lecture no: 6, 7 and 8. (together 2+2+2=6 hours)

Tutorial no: 4 and 5 (together 3+3=6 hours)

Tutorial and assignments: Same way like point 3. Sample generation, interpolation, classification problems.

1. *Sequential data analysis*:   
    Goal: Practical training of machine learning for time series data in prediction and classification problems  
   1. Preliminaries of sequential data analysis
   2. Vector auto-regressive process
   3. Recursive neural networks
   4. Probabilistic formulation and Hidden Markov Models

Lecture no: 9 and 10. (together 2+2=4 hours)

Tutorial no: 6 (3 hours)   
Assignment: Same way like point 3. The dataset will be dynamical signals.

1. *Complex learning scenarios:*

Goal: How to design systems with human like learning capabilities

a. Transfer learning

* 1. Incremental learning
  2. Few-shot learning
  3. Online-learning and learning over networks

Lecture no: 11 (3 hours)

Tutorial no: 7 (3 hours)   
Assignment: Same way like point 3.

Project work: 1 hp