Lund University

Faculty of Science

FYTN14, Theoretical Physics: Introduction to Artificial Neural Networks and Deep Learning, 7.5 credits

Teoretisk fysik: Introduktion till artificiella neuronnätverk och deep learning, 7,5 högskolepoäng

Second Cycle / Avancerad nivå

Details of approval

The syllabus was approved by Study programmes board, Faculty of Science on 2017-05-11 and was last revised on 2022-12-06. The revised syllabus applies from 2022-12-06, autumn semester 2023.

General Information

The course is an elective course for second-cycle studies for a degree of Master of Science with a specialisation in Physics. The course is also included in a degree of Master of Science in Computational Science and a Master of Science in Applied Computational Science. The course can also be included as an elective course for a Bachelor or masterdegree of Science.

Language of instruction: English and Swedish
If needed the course is given in English.

Main field of studies	*Depth of study relative to the degree requirements*
Physics	A1N, Second cycle, has only first-cycle course/s as entry requirements
Computational Science	A1N, Second cycle, has only first-cycle course/s as entry requirements
Applied Computational Science	A1N, Second cycle, has only first-cycle course/s as entry requirements

Learning outcomes

The overall aim of the course is to give students a basic knowledge of artificial neural networks and deep learning, both theoretical knowledge and how to practically use them for typical problems in machine learning and data mining.

Knowledge and understanding

On completion of the course, the student shall be able to:

- describe the construction of the multi-layer perceptron
- describe different error functions used for training and techniques to numerically minimize these error functions
- explain the concept of overtraining and describe those properties of a neural network that can cause overtraining
- describe the construction of different types of deep neural networks
- describe neural networks used for time series analysis as well as for self-organization.

Competence and skills

On completion of the course, the student shall be able to:

- produce update equations for a multi-layer perceptron with given specific error and activation functions
- prove basic properties of the multi-layer perceptron, such as non-linearity, probability interpretation of the output and the advantage of using an ensemble of neural networks
- implement a multi-layer perceptron to solve a typical classification or regression problem, including systematic choice of suitable model parameters to optimize the generalization performance
- show how to use a convolutional neural network to classify images, including suitable choices of layers and kernel sizes
- use a recurrent network, both deep and shallow, for time series problems.

Judgement and approach

On completion of the course, the student shall be able to:

- analyse a typical problem within the subject area and deduce which method or methods that are most suitable to solve it
- identify possible loopholes in an analysis that can affect its reproducibility.

Course content

The course covers the most common models in artificial neural networks with a focus on the multi-layer perceptron. The course also provides an introduction to deep learning. Selected topics:

- *Feed-forward neural networks:* the simple perceptron and the multi-layer perceptron, choice of suitable error functions and techniques to minimize them, how to detect and avoid overtraining, ensembles of neural networks and techniques to create them, Bayesian training of multi-layer perceptrons.
- *Recurrent neural networks*: simple recurrent networks and their use in time series analysis, fully recurrent for both time series analysis and associative memories (Hopfield model), the simulated annealing optimization technique
- *Self-organizing neural networks*: networks that can extract principal components, networks for data clustering, learning vector quantization (LVQ), self-organizing feature maps (SOFM).
- *Deep learning*: Overview of deep learning, convolutional neural networks for classification of images, different techniques to avoid overtraining in deep

networks, techniques to pre-train deep networks.

Course design

The teaching consists of lectures, exercises and compulsory computer exercises.

Assessment

The examination consists of a written reports on the computer exercises and a written test at the end of the course.

In special cases the test can be oral. Students who do not pass the regular exam are offered a re-exam shortly after the regular exam.

The examiner, in consultation with Disability Support Services, may deviate from the regular form of examination in order to provide a permanently disabled student with a form of examination equivalent to that of a student without a disability.

Subcourses that are part of this course can be found in an appendix at the end of this document.

Grades

Marking scale: Fail, Pass, Pass with distinction.
To pass the entire course, a passed test as well as passed reports on the computer exercises are required.

The grading scale for computer exercises is Fail, Pass, whereas the written test is graded according to the scale Fail, Pass, Pass with Distinction.

The final grade is decided by combining the results on the different parts of the examination, with the test as the dominating part.

Entry requirements

The prerequisites for admission to the course are: general requirements, English 6/B and knowledge equivalent to 90 credits in science of which at least 45 credits is in mathematics.

Further information

The course may not be credited towards a degree together with FYTN06 Theoretical Physics: Artificial Neural Networks, 7.5 credits or EXTP80 Artificial Neural Networks, 7.5 credits.

Subcourses in FYTN14, Theoretical Physics: Introduction to Artificial Neural Networks and Deep Learning

Applies from H17

1701 Test, 6,0 hp
Grading scale: Fail, Pass, Pass with distinction
1702 Computer Exercises, 1,5 hp
Grading scale: Fail, Pass