Course syllabus

Memory Technology for Machine Learning
Minnesteknologi för maskininlärning

EITP25, 7.5 credits, A (Second Cycle)

Valid for: 2026/27
Faculty: Faculty of Engineering LTH
Decided by: PLED C/D
Date of Decision: 2026-04-16
Effective: 2026-05-18

General Information

Main field: Nanoscience **Depth of study relative to the degree requirements:** Second cycle, in-depth level of the course cannot be classified
Elective for: E4-is, F4, F4-fel, MNAV1, MSOC2, N4-hn
Language of instruction: The course will be given in English

Aim

The purpose of this course is to give an in-depth understanding of how electronic memory devices can be used to accelerate computations of critical importance for machine learning. The course gives an introduction to the architectures and algorithms that are used in machine learning, to give a basic understanding for the needs that the memory devices and systems thereof need to fulfil. The physics of established memory technologies is described and particular focus lies on emerging non-volatile memory technologies, memristors, such as phase-change memory, magnetic and resistive random access memory, as well as ferroelectric memories, and their potential for multistate operation. The course also covers strategies and challenges with the design of processing-in-memory and neuromorphic technology. Finally, spiking neural networks implemented in electronic hardware is covered.

Learning outcomes

Knowledge and understanding
For a passing grade the student must

- Explain in general the memory hierarchy of a modern computer and in detail how its memory components function.
- Explain the physical processes that determine the functionality of common non-volatile memory types such as RRAM, PCM, FeRAM/FeFET/FTJ and STT-MRAM.
- Understand in general the limitations and benefits of the various memory technologies treated in the course.
- Understand in general how arrays of memory devices can be used to perform computations in the memory, with minimal data transfer.
- Explain in detail how learning occurs in a spiking neural network and how memristors can be used in such networks.
- Understand the potential in terms of energy efficiency and computational speed that processing-in-memory incur, as well as which parts of the system limits the performance.

Competences and skills
For a passing grade the student must

- perform measurement and analysis of the current-voltage characteristics of a memristor device.
- perform measurements and from a measured polarization-field diagram be able to extract important parameters for a ferroelectric capacitor.
- be able to give suggestions on how speed, reliability and energy consumption can be improved for a memristor-based system that implements processing-in-memory.
- perform simulations to evaluate the performance of a processing-in-memory system.

Judgement and approach
For a passing grade the student must

- realize the need for energy efficient and scalable neuromorphic hardware for machine learning and AI.
- Evaluate the applicability of a given memory technology for a range of application areas with respect to the pros and cons of the technology.

Contents

Memory devices of the computer: SRAM, DRAM, NAND

Memristors: Resistive memories (RRAM), phase change memories (PCM), ferroelectric memories (FeRAM), magnetic memories (MRAM), non-idealities.

Machine learning methods: Backpropagation, gradient descent, quantization.

Processing-in-memory: Cross-bar, Computational methods, design of computing core, AD/DA converters, initiation of memory, training methods

Spiking neural networks: Concept from biology - STDP, lateral inhibition, plasticity, neuronal circuits, network-on-chip.

Examination details

Grading scale: TH - (U, 3, 4, 5) - (Fail, Three, Four, Five)
Assessment: Written exam, project work, lab work with report.

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.

Modules
Code: 0119. **Name:** Written Exam.
Credits: 4.0. **Grading scale:** TH - (U, 3, 4, 5). **Assessment:** Exam **The module includes:** Written examination that will cover all the topics of the course.
Code: 0219. **Name:** Lab Exercise.
Credits: 1.0. **Grading scale:** UG - (U, G). **Assessment:** Passing grade upon participation in the lab exercise and an approved lab report. **The module includes:** Practical lab exercise with subsequent lab report. **Further information:** Lab work and report writing can be done either alone or in groups of two.
Code: 0319. **Name:** Project Assignment.
Credits: 2.5. **Grading scale:** UG - (U, G). **Assessment:** The level of understanding reflected in the written report as well as a control of the written program code will determine whether a passing grade has been achieved. **The module includes:** The project consists of designing and training a neural network to recognize at least 90% of the images from a predefined database. The project should be executed alone or in groups of two persons. The project should result in a written report and working MATLAB code.

Admission

Assumed prior knowledge: Basic knowledge in solid state physics.
The number of participants is limited to: No

Reading list

- An Chen, James Hutchby, Victor Zhirnov, George Bourianoff: Emerging Nanoelectronic Devices. Wiley, 2014, ISBN: 9781118958254.

Contact

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Further information

The course uses Canvas for communication, hand-ins and study materials.