*Course syllabus*

# Maskininlärning i beräkningsmekanik
# Machine Learning in Computational Mechanics

## FHLN40, 7,5 credits, A (Second Cycle)

**Valid for:** 2023/24
**Faculty:** Faculty of Engineering, LTH
**Decided by:** PLED M
**Date of Decision:** 2023-04-11

## General Information

**Elective for:** BME4, F4, M4-bem, Pi4-bem
**Language of instruction:** The course will be given in English

## Aim

The aim of the course is to provide the student a fundamental understanding and introduce the practical usage of methods of machine learning applicable to Computational Mechanics. This includes the ability to identify applications, like Machine
Learning for Solid Mechanics (truss and beam structures) and Material Modelling (identification of material parameters). Furthermore, we will solve problems discretized
with the Finite Element Method by Deep Energy methods and discuss the concept of Reduced Order Finite Element models.

## Learning outcomes

*Knowledge and understanding*
For a passing grade the student must

- understand the concepts of Machine Learning algorithms used in Computational Mechanics
- understand how Machine Learning algorithms are applied to problems in Computational Mechanics

- understand the differences between the different types of Machine Learning algorithms used to solve Computational Mechanics problems
- understand how common Machine Learning software frameworks can be used in Computational Mechanics

*Competences and skills*
For a passing grade the student must

- be able to solve structural problems in Solid Mechanics with Machine Learning methods
- be able to use Machine Learning methods to identify parameters in constitutive models
- be able to find data-driven solutions of the balance laws (differential equations) in Computational Mechanics
- be able to find Finite Element solutions through Deep Energy methods
- be able to apply common Machine Learning software frameworks

*Judgement and approach*
For a passing grade the student must

- have the ability to analyse, to model and simulate problems in Computational Mechanics with Machine Learning methods, as well as interpret the results critically
- have the understanding of limitations of Machine Learning algorithms like overfitting and underfitting

## Contents

The following topics will be considered in the course

- Fundamental Concepts in Machine Learning that are applied in Computational Mechanics, like Physics-Informed Neural Networks (PINNs), Deep Energy Methods, Reduced Order Models (ROM) etc.
- Approximating functions by Neural Networks for deformable truss and beam structures
- Identify parameters in constitutive models by Machine Learning applied to inverse problems
- Solving Finite Element Method problems by Deep Energy Methods
- Reduced Order Models for linear Finite Element Methods

## Examination details

**Grading scale:** TH - (U,3,4,5) - (Fail, Three, Four, Five)
**Assessment:** The examination of the course consists of one assignment and one mid-term exam.The final mark will be based on the results from both parts. The assignment will be marked with failed or passed with grades from 15-30. The mid-term examination will be marked with failed or passed with grades from 15-30. The final mark will be based on the grades divided with 10. Less than 3.0 points is failed, 3.0 - 3,9 will give the mark 3, 4,0 - 4,9 will give the mark 4 and 5,0 and more will give the mark 5.

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.

**Parts**
**Code:** 0123. **Name:** Project.
**Credits:** 4,5. **Grading scale:** UG. **Assessment:** The assignment will be marked with failed or passed with grades from 15-30. The assignment can only be made during the course but if marked with failed the student will be given the possibility to correct the assignment.

**Code:** 0223. **Name:** Mid-term Exam.
**Credits:** 3. **Grading scale:** UG. **Assessment:** The written mid-term examination will be marked with failed or passed with grades from 15-30. The mid term examination can only be made during the course but if marked with failed there will be given an extra mid-term exam about two weeks after the regular one.

## Admission

**Admission requirements:**

- Finite Element Method
- FHLF01 Finite Element Method or FHLF10 Finite Element Method and Introduction to Strength of Materials or FHLF20 Finite Element Method or FHLF25 Finite Element Method and Introduction to Strength of Materials

**The number of participants is limited to:** 40
**Selection:** Completed university credits within the programme. Priority is given to students enrolled on programs that include the course in their curriculum.

## Reading list

- Stefan Kollmannsberger, Davide D'Angella, Moritz Jokeit, Leon Herrmann: Deep Learning in Computational Mechanics, An Introductory Course. Springer, 2021, ISBN: 978-3-030-76587-3.

## Contact and other information

**Course coordinator:** Ralf Denzer, ralf.denzer@solid.lth.se
**Course homepage:** http://www.solid.lth.se