GHENT UNIVERSITY

Course Specifications

Valid as from the academic year 2026-2027

Advanced Machine Learning (E061335)

Course size *(nominal values; actual values may depend on programme)*

Credits 6.0 **Study time 180 h**

Course offerings in academic year 2026-2027

A (semester 2)	English	Gent
B (semester 2)	Dutch	Gent

Lecturers in academic year 2026-2027

Dhaene, Tom	TWO5	lecturer-in-charge
Dhoedt, Bart	TWO5	co-lecturer

Offered in the following programmes in 2026-2027	crdts	offering
Bridging Programme Master of Science in Bioinformatics(main subject Engineering)	6	A
Bridging Programme Master of Science in Computer Science Engineering	6	A
Master of Science in Bioinformatics(main subject Engineering)	6	A
Master of Science in Operations Research Engineering(main subject Manufacturing and Supply Chain Engineering)	6	A
Master of Science in Operations Research Engineering(main subject Transport and Mobility Engineering)	6	A
Master of Science in Computer Science	6	A
Master of Science in Computer Science Engineering	6	B
Master of Science in Computer Science Engineering	6	A
Master of Science in Operations Research Engineering	6	A
Exchange Programme in Bioinformatics (master's level)	6	A
Exchange Programme in Computer Science (master's level)	6	A

Teaching languages

English, Dutch

Keywords

Machine learning, neural networks, deep learning, kernel methods, ensemble learning, probabilistic modelling, Bayesian learning, Gaussian processes, active learning, generative models

Position of the course

This advanced ML course builds on the foundations of *Artificial Intelligence (E016350)* and *Machine Learning: Learning from Data* (E061331).
It offers a unified, in-depth treatment of modern ML methods, integrating rigorous theory with practical implementation. The course emphasises mathematical foundations and hands-on Python work, preparing students for applications in research and engineering.

Contents

Part I – Advanced Machine Learning

- Review of key ML principles and mathematical foundations
- Advanced supervised learning: regression and classification
  - Kernel methods
  - Ensemble learning
- Advanced unsupervised learning: clustering and dimensionality reduction
  - EM algorithm, latent variable models
- Probabilistic and Bayesian learning

- Variational learning and sampling methods
- Gaussian processes
- Active learning and Bayesian optimisation

Part II – Deep Generative Models

- Overview of generative modelling and probabilistic foundations
- Generative autoregressive models
  - recap: LSTM, GRU
  - Transformers
- Variational Autoencoders (VAE)
- Invertible models
  - Normalizing Flows (NF)
  - Diffusion Models
- Energy-based Models
- Generative Adversarial Networks (GANs)
- Applications in vision, language, and physics-informed learning

Initial competences

Strong background in mathematics: calculus, linear algebra, probability, and statistics
Programming skills in Python
Prior knowledge of fundamental machine learning techniques (e.g., *Artificial Intelligence (E016350), Machine Learning: Learning from Data* (E061331), or equivalent)

Final competences

1 Understand the mathematical background, critically analyse, and clearly explain advanced machine learning methods, and apply them to complex data problems.
2 Compare and justify ML model choices by weighing assumptions, data/compute requirements, generalisation, uncertainty quantification and calibration, and robustness; select the most appropriate ML method for a given application.
3 Critically read, synthesise, and communicate research literature in advanced machine learning and generative modelling.

Conditions for credit contract

Access to this course unit via a credit contract is determined after successful competences assessment

Conditions for exam contract

This course unit cannot be taken via an exam contract

Teaching methods

Seminar, Lecture, Independent work

Extra information on the teaching methods

The course combines on-campus theoretical lectures with programming assignments.
Coaching and feedback are available during contact hours and via online consultation.

Study material

Type: Handbook

Name: Probabilistic Machine Learning: Advanced Topics
Indicative price: Free or paid by faculty
Optional: no
Additional information: Murphy, (2023). Probabilistic Machine Learning: Advanced Topics. MIT Press - free PDF

Type: Slides

Name: Lecture slides and Jupyter notebooks
Indicative price: Free or paid by faculty
Optional: no
Additional information: Available on Ufora

Type: Software

Name: Python, PyTorch, Scikit-Learn, and Jupyter notebook
Indicative price: Free or paid by faculty
Optional: no

References

- Murphy, (2023). Probabilistic Machine Learning: An Introduction. MIT Press.
- Murphy, (2023). Probabilistic Machine Learning: Advanced Topics. MIT Press.
  - https://probml.github.io/pml-book/book2.html - **free PDF**
- Deisenroth, Faisal, & Soon Ong, (2020). Mathematics for Machine Learning. Cambridge Univ. Press.
- Goodfellow, Bengio, & Courville (2016). Deep Learning. MIT Press.
- Barber (2012). Bayesian Reasoning and Machine Learning. Cambridge Univ. Press.

Extra references (to recent and online available sources) will be given during lectures and made available through Ufora, if necessary.

Course content-related study coaching

Support and feedback by teaching assistants and lecturers, before or after lectures, by appointment or online (MS Teams / Ufora).

Assessment moments

end-of-term and continuous assessment

Examination methods in case of periodic assessment during the first examination period

Oral assessment, Written assessment

Examination methods in case of periodic assessment during the second examination period

Oral assessment, Written assessment

Examination methods in case of permanent assessment

Assignment

Possibilities of retake in case of permanent assessment

examination during the second examination period is possible in modified form

Extra information on the examination methods

Written closed-book exam complemented with oral examination: testing both conceptual understanding and mathematical insight
During the semester: graded assignments

Calculation of the examination mark

Final grade = 0.8 × Exam + 0.2 × Assignments
To pass, students must obtain at least 9/20 on both components.
Non-participation in the practical assignments automatically results in failure.