

## Probabilistic Graphical Models (E016340)

Due to Covid 19, the education and assessment methods may vary from the information displayed in the schedules and course details. Any changes will be communicated on Ufora.

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

**Credits 4.0**                      **Study time 120 h**                      **Contact hrs**                      30.0h

### Course offerings and teaching methods in academic year 2021-2022

A (semester 2)	English	Gent	lecture	15.0h
			seminar: practical PC room classes	15.0h

### Lecturers in academic year 2021-2022

Pizurica, Aleksandra	TW07	lecturer-in-charge
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### Offered in the following programmes in 2021-2022

	crdts	offering
<a href="#">Bridging Programme Master of Science in Bioinformatics(main subject Engineering)</a>	4	A
<a href="#">Bridging Programme Master of Science in Industrial Engineering and Operations Research</a>	4	A
<a href="#">Bridging Programme Master of Science in Industrial Engineering and Operations Research</a>	4	A
<a href="#">Master of Science in Bioinformatics(main subject Engineering)</a>	4	A
<a href="#">Master of Science in Computer Science Engineering</a>	4	A
<a href="#">Master of Science in Computer Science Engineering</a>	4	A
<a href="#">Master of Science in Industrial Engineering and Operations Research</a>	4	A
<a href="#">Master of Science in Industrial Engineering and Operations Research</a>	4	A

### Teaching languages

English

### Keywords

Probabilistic graphical models, Bayesian networks, Markov Random Fields, Bayesian inference, Markov Chain Monte Carlo samplers, Iterated conditional modes, Message passing, Belief propagation, Loopy belief propagation, Bethe approximation, Junction trees, Expectation propagation, Structure learning

### Position of the course

Probabilistic graphical models are powerful tools for representing complex inference problems and incorporating uncertainty into the reasoning process. As such, they find numerous applications in many domains, including machine learning, computer vision, natural language processing and computational biology. Incorporating uncertainties into reasoning and decision-making processes is especially important in high-stakes applications (e.g., health), where data is scarce, or the model structure is uncertain. The course gives a strong theoretical basis as well as practical insights into probabilistic graphical models and the corresponding inference mechanisms.

### Contents

- Recapitulation: basics of reasoning under uncertainty (including the concepts of random variables, discrete and continuous distributions, Monte Carlo approximations, foundations of Bayesian inference and its links to information theory)
- Bayesian statistics: MAP estimation, Bayesian model selection (Occam's razor), choice of prior
- Directed graphical models (Bayesian networks): Markov and Hidden Markov Models
- Non-directed graphical models (Markov Random Fields), Latent Variable models, Latent Linear models

- A unified treatment of probabilistic graphical models (directed and non-directed) as factor graphs; explaining connections to information-theoretic approaches.
- Inference approaches: Exact inference, Markov Chain Monte Carlo (MCMC) sampling, Variational inference, Expectation Propagation, Belief propagation, Loopy belief propagation, Bethe approximation, Junction trees
- Structure learning; selected advanced topics

#### **Initial competences**

- The student has a good grasp of linear algebra, statistics, applied probability and general mathematical basis (mandatory)
- The student has a basic knowledge of machine learning (recommended) and basic knowledge of artificial intelligence foundations (recommended)
- The student is familiar with scientific programming and is able to program in Python.

#### **Final competences**

- 1 A very firm grasp of probability and information theory and how it is applied for learning
- 2 Be able to view a probabilistic model in its components (prior, likelihood, etc.) and how they interact with each other
- 3 Properly train a probabilistic model: choose a prior, inference method and likelihood for the problem at hand
- 4 Be able to represent a complex inference problem as a probabilistic graphical model and apply appropriate inference mechanisms to solve it (like message passing and sampling)
- 5 A strong foundation for comprehending unseen probabilistic techniques from literature and quickly notice their limitations

#### **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**

Lecture, Seminar: practical pc room classes

#### **Extra information on the teaching methods**

Classroom lectures; Hands-on experience through a project

#### **Learning materials and price**

- Recommended book: Bayesian Reasoning and Machine Learning by David Barber (freely available online)
- Slides (free of charge) available on Ufora

#### **References**

- [1] Daphne Koller and Nir Friedman, Probabilistic Graphical Models: Principles and Techniques
- [2] Christophe M. Bishop, Pattern Recognition and Machine Learning
- [3] David J.C. Mackay, Information Theory, Inference, and Learning Algorithms
- [4] Martin J. Wainwright and Michael I. Jordan, Graphical models, exponential families, and variational inference

#### **Course content-related study coaching**

#### **Assessment moments**

end-of-term and continuous assessment

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

Oral examination, Open book examination

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

Oral examination, Open book examination

#### **Examination methods in case of permanent assessment**

Report, Participation

#### **Possibilities of retake in case of permanent assessment**

examination during the second examination period is possible in modified form

(Approved)

**Extra information on the examination methods**

- During examination period: open-book oral exam.
- During semester: graded project report and participation. A project involving a research component (evaluated based on the code demonstration and written report).

**Calculation of the examination mark**

The oral exam counts for 2/3, and the project for 1/3 of the final grade, provided that all parts are above given minimum requirements as follows:

- oral exam is at least 9/20
- project is at least 9/20.

If these conditions are not met and the total score is still 10/20 or above, the final grade will be brought to the highest non-passing grade (9/20). Only the non-passing parts need to be retaken. Failing to participate in one or more parts of the evaluation results in the non-passing final grade.