

**Module Description, available in: EN**

## *Bayesian Machine Learning*

**General Information****Number of ECTS Credits**

3

**Module code**

TSM\_BayMachLe

**Valid for academic year**

2025-26

**Last modification**

2023-10-11

**Coordinator of the module**

Cedric Huwyler (FHNW, cedric.huwyler@fhnw.ch)

**Explanations regarding the language definitions for each location:**

- Instruction is given in the language defined below for each location/each time the module is held.
- Documentation is available in the languages defined below. Where documents are in several languages, the percentage distribution is shown (100% = all the documentation).
- The examination is available 100% in the languages shown for each location/each time it is held.

	Lausanne			Lugano	Zurich		
<b>Instruction</b>					X E 100%		
<b>Documentation</b>					X E 100%		
<b>Examination</b>					X E 100%		

**Module Category**

TSM Technical scientific module

**Lessons**

2 lecture periods and 1 tutorial period per week

**Entry level competences****Prerequisites, previous knowledge**

Basic probability and statistics, basic programming skills (R and/or Python), linear algebra and multivariate calculus, basic concepts of machine learning.

## Brief course description of module objectives and content

Bayesian statistics provides an alternative viewpoint to the classical 'frequentist' statistics by using a different, more subjective interpretation of probability. This brings various advantages in solving typical industry problems, such as the inclusion of prior knowledge, more intuitive hypothesis tests or modeling uncertainty given small amounts of data. With increasing computational power, the popularity of Bayesian statistics and machine learning has grown significantly over the past decade. This course provides students with a solid understanding of the fundamental concepts of Bayesian statistics, introduces various computational methods required in Bayesian statistics and Bayesian machine learning, and discusses numerous examples and applications of Bayesian machine learning. Bayesian as well as Gaussian process regression models are introduced and explored, with a particular focus on graphical models and Bayesian networks to model relationships and to infer causality. In addition, advanced topics and their applications are covered, such as Bayesian optimisation, non-parametric mixture models for clustering, and Bayesian neural networks.

## Aims, content, methods

### Learning objectives and acquired competencies

Students are able to formulate their problem setting on the basis of Bayesian models and to include their prior understanding. They are able to explain how Bayesian models balance between prior understanding and data towards a posterior understanding of a problem. They are aware of the advantages and disadvantages of the Bayesian approach and know in which situation it is better suited than standard frequency statistics. Since Bayesian models can rarely be computed in closed form, they are experienced in approximating posterior distributions by means of sampling-based approaches

### Contents of module with emphasis on teaching content

*Fundamental concepts of Bayesian statistics:* Reasoning under uncertainty, probability theory, Bayes theorem, prior, likelihood, posterior, conjugate families (beta-binomial, gamma-poisson, normal-normal), sequential learning, inference, prediction

*Sampling methods:* Markov chains, Metropolis algorithm, Gibbs sampling, Hamiltonian MC, sequential MC

*Bayesian and Gaussian Process regression:* kernels, model selection, state-space models, variational inference

*Bayesian networks:* graphical models, causality

*Selection of advanced topics:* Bayesian optimisation, Bayesian non-parametric mixture modeling, Bayesian neural networks, physics-informed ML models

### Teaching and learning methods

Lecture and practical work on computer.

### Literature

Lecture notes and notebooks will be available in addition to recommended book chapters.

## Assessment

### Additional performance assessment during the semester

The module does not contain an additional performance assessment during the semester

### Basic principle for exams

**As a rule, all the standard final exams for modules and also all resit exams are to be in written form**

### Standard final exam for a module and written resit exam

Kind of exam

written

Duration of exam

120 minutes

**Permissible aids**

*Aids permitted as specified below:*

**Permissible electronic aids**

personal computer (open book, no communication, no AI-based chatbot assistance)

**Other permissible aids**

written summary of 8 pages (4 sheets)

**Exception: In case of an electronic Moodle exam, adjustments to the permissible aids may occur. Lecturers will announce the final permissible aids prior to the exam session.**

**Special case: Resit exam as oral exam**

**Kind of exam**

oral

**Duration of exam**

30 minutes

**Permissible aids**

*Aids permitted as specified below:*

**Permissible electronic aids**

None

**Other permissible aids**

None