University of St.Gallen

Course and Examination Fact Sheet: Spring Semester 2021

10,378: Theoretical Aspects of Machine Learning

ECTS credits: 4

Overview examination/s

(binding regulations see below)
Decentral - Written examination (100%)
Examination time: term time

Attached courses

Timetable -- Language -- Lecturer
10,378,1.00 (GSERM) Theoretical Aspects of Machine Learning -- Englisch -- Bonev Petyo

Course information

Course prerequisites

Probability theory at a good level (e.g. knowledge what convergence in distribution and probability is), affinity to mathematical problems, advanced econometrics.

Hardware: Laptops for the pc sessions.

Software: Exercises will require the usage of the statistical software R.

Learning objectives

The goal of this course is to provide a comprehensive overview of the mathematical theory behind machine learning. How can we characterize a good prediction? How can we construct good predictions based on Machine Learning methods? What is the relationship between (1) estimation error, (2) sample size and (3) model complexity? How do these abstract concepts apply in particular Machine Learning methods such as Boosting, Support Vector Machine, Ridge and LASSO? The objective of the course is to give detailed and intuitively clear answers to those questions. As a result, participants will receive a good preparation for theoretical and empicial work with/on Machine Learning methods.

Course content

1. Principles of statistical theory (loss function and risk, approximation vs estimation error, no free lunch theorems)

2. Concentration inequalities for bounded loss functions (Hoeffding's Lemma, Azuma-Hoeffding's inequality, Bounded difference inequality, Bernstein's inequality, McDiarmid inequality)

3. Classification (binary case and its loss function, Bayesian classifier, Optimality of the Bayesian Classifier, Oracle inequalities for the Bayesian classifier, Finite dictionary learning case, The impact of noise on convergence rates, infinite dictionary)

4. General case (general loss functions, symmetrization, Rademacher complexity, Covering numbers, Chaining)

5. Applications Part 1: Vector Machine support, boosting

6. The mathematics and statistics of regularization methods (LASSO, Ridge, elastic net)

7. Applications Part 2: LASSO and Ridge

Course structure

Part I. Concepts of statistical learning:Concentration inequalities, concepts of statistical theory (topics 1 and 2 from the course

content)

Part II. The math of Machine learning and Classification. (topic 3 from course content)

Part III. The Machine learning methods and the general case (topics 4 and 5 from the course content)

Part IV. LASSO and Ridge (topics 6 and 7 from the course content).

Course literature

Obligatory: there will be a lecture script.

Supplementary / voluntary:

- The book "Elements of statistical learning" by Hastie, Tibshirani and Friedman gives a nice introduction intro Boosting and Vector Support Machines.

Further topic-specific nonobligatory references will be given during the lecture.

Additional course information

Only for PhD students of the University of St.Gallen

PEF students may register via regular bidding for the courses offered together by PEF and Global School in Empirical Research Methods (GSERM). Enrolment in a course is binding: students have to attend the course and take the exam. The credits will be shown on the scorecard.

All other PhD students should register for the courses offered by Global School in Empirical Research Methods (GSERM), both via bidding and via GSERM for:

- courses for the curriculum and
- optional courses with an examination. These will be listed on the scorecard under optional work (only possible if all required elective courses have already been completed).

Please register only via GSERM for:

- optional courses without an examination and
- optional courses if not all required elective courses have been completed (not shown on the scorecard)

In the case of the President's Board having to implement new directives due to the SARS-CoV-2 pandemic in SpS2021, the course information listed above will be changed as follows:

- The course is conducted online via the platform ZOOM;
- The recordings of the course are available for 30 days;
- The lecturer informs via Canvas and/or e-mail on the changed implementation modalities of the course;
- There are no changes necessary to the course information!

The examination information listed below would be changed as follows:

- The written examination is conducted online;
- Further information is communicated via Canvas and/or e-mail.

Examination information

Examination sub part/s

1. Examination sub part (1/1)

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Examination time and form
Decentral - Written examination (100%)
Examination time: term time

Remark
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Examination-aid rule
Extended Closed Book
The use of aids is limited; any additional aids permitted are exhaustively listed under "Supplementary aids". Basically, the following is applicable:

- At such examinations, all the pocket calculators of the Texas Instruments TI-30 series and mono- or bilingual dictionaries (no subject-specific dictionaries) without hand-written notes are admissible. Any other pocket calculator models and any electronic dictionaries are inadmissible.
- In addition, any type of communication, as well as any electronic devices that can be programmed and are capable of communication such as notebooks, tablets, mobile telephones and others, are inadmissible.
- Students are themselves responsible for the procurement of examination aids.

Supplementary aids
Pencil and paper should be enough...

Examination languages
Question language: English
Answer language: English

Examination content
While the content of the course is very technical, the exam will ask only about INTUITIONS! The following concepts will be required (their intuitions, i.e. what are the assumptions and intuitively why they are necessary): Calculating a loss function, giving intuition for concentration inequalities, showing optimality of the Bayesian classifier, understanding the intuition behind the finite dictionary case, understanding the intuition of the impact of noise (Massart's noise condition, Mammen-Tsybakov's noise condition), describing the infinite dictionary learning problem, being able to define and explain Rademacher complexity, its relation to cardinality, calculating the VC-dimension, applications to empirical risk, being able to explain symmetrization, its relation to Rademacher complexity in the general case, and giving the intuition of how these concepts apply to Vector Support Machines and Boosting; the mathematical intuition behind the LASSO and Ridge methods, in particular in the orthonormal design.

Examination relevant literature
The same as for the course.

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Please note

Please note that only this fact sheet and the examination schedule published at the time of bidding are is binding and takes precedence over other information, such as information on StudyNet (Canvas), on lecturers' websites and information in lectures etc.

Any references and links to third-party content within the fact sheet are only of a supplementary, informative nature and lie outside the area of responsibility of the University of St.Gallen.

Documents and materials are only relevant for central examinations if they are available by the end of the lecture period (CW21) at the latest. In the case of centrally organised mid-term examinations, the documents and materials up to CW 12 are relevant for testing.

Binding nature of the fact sheets:

- Course information as well as examination date (organised centrally/decentrally) and form of examination: from bidding start in CW 04 (Thursday, 28 January 2021);
- Examination information (regulations on aids, examination contents, examination literature) for decentralised examinations: in CW 12 (Monday, 22 March 2021);
- Examination information (regulations on aids, examination contents, examination literature) for centrally organised mid-term examinations: in CW 12 (Monday, 22 March 2021);
- Examination information (regulations on aids, examination contents, examination literature) for centrally organised examinations: two weeks before the end of the registration period in CW 14 (Thursday, 8 April 2021).