Statistical Learning in the Age of "Big Data" and Machine Learning

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1 General Issues

The course "Statistical Learning in the Age of "Big Data" and Machine Learning" addresses master's students of Business Administration, Economics, Internationale Wirtschaft und Governance, and Philosophy & Economics. Advanced interested bachelor's students may also participate.

Nowadays it is not uncommon that one wants to analyse "big data", i.e. really big datasets (such as credit card transaction data, scanner data of a firm, huge firm-level balance-sheet datasets, patent data, tweets, google search queries,...). Such big datasets lead to new challenges to estimation (see Varian, 2014):

1. due to the sheer size, one may need more powerful data manipulation tools.

2. with large datasets one may end up with more potential predictors than appropriate for estimation with classical estimation methods.

3. with large datasets one may have the possibility to allow for more flexible relationships than simple linear models.

Hence, traditional estimation methods may have to be complemented or even replaced by alternative estimators or estimation strategies. A new branch

in computer science, "machine learning", provides exactly such tools, like decision trees, support vector machines, boosting, random forests, and (deep) neural networks. These methods need a lot of data, but given that, allow for more effective ways to model complex relationships.

The seminar consists of two parts:

1. Student presentations will cover the recent, and most widely used methods of statistical learning. We provide the topics for the presentation (including the respective reading material). Our seminar will mainly be based on the book James, Witten, Hastie, and Tibshirani (2021), which is available for download in our library and will be abbreviated from now on by "ISL". Chapters one, two and three will be compulsory reading for everyone. Please register in the e-learning for the seminar to obtain all information and materials. Our first **compulsory introductory meeting** will be on **27 October 2022, 10am-12am (c.t.)**, where we will discuss organizational issues and allocate topics. The date for the **presentations** of your topics is **2 and 3 December 2022** (depending on the number of participants). Please upload your **presentation slides** beforehand on e-learning (see database for presentation slides), by **30 November 2022**.

2. To practice the learned methods, you will also implement the estimator of your topic with the provided R code from the book (or, if you prefer, you can also implement your estimator in Python). Note that chapter 2 also contains an introduction to R. You will write a seminar thesis about your method, your reproduction and apply your method to an example of your choice. Datasets and suggestions are also contained in the book and the accompanying homepage (https://www.statlearning.com/).

Interested students are asked to **sign up** by sending an email to Sandra Hörath (vwl6@uni-bayreuth.de) before **21 October 2022**, indicating your previous knowledge in statistics and empirical economics. Furthermore, please give three preferences for topics, including at least one from the list of the core topics.

For further questions concerning course details please contact Simon Blöthner (simon.bloethner@uni-bayreuth.de) or Mario Larch (mario.larch@uni-bayreuth.de).

2 Requirements and Assessed Course Work

Requirements
In order to participate in the course, interest in and good knowledge of empirical economics, at least at the level of "Empirische Wirtschaftsforschung I" and ideally at the level of the course "Advanced Empirical Economics I", is expected. Ideally, this includes some programming knowledge.

Assessed Course Work
The assessed course work consists of a term paper at the end about your topic including a reproduction of the example in R with possible extensions and further sensitivity analysis regarding implementation choices. In the term paper, you should on the one hand introduce thoroughly into the topic and on the other hand explain in detail the methods used and specifically show how the specific analysis is conducted and carefully interpret (as far as possible) your results.

After the presentations you write your term paper based on the knowledge you gained in the course. The date of submission of the term paper will be 31 March 2023 (of course an earlier submission is possible at any time).

Language and Formal Requirements
The language of the course (and hence your presentation and presentation slides) is English. Hence, all the literature is in English. Your term paper can be written in German or in English, even though we suggest to write it in English. For more general details concerning the formal requirements of the written assignments please see the style sheet available in German (Hinweis zur Formatierung von Seminar- und Abschlussarbeiten) and in English (Formal requirements for seminar papers and bachelor's/master's theses at the Chair of Economics VI: Empirical Economics).

For this seminar, the term paper should consist of about 20,000 characters (including space characters) and may be written as an R Markdown document (https://rmarkdown.rstudio.com/). This ensures that your results are reproducible and helps to establish good scientific practice when you work empirically.

3   Target Group

The course addresses students from the following degree courses:

- Betriebswirtschaftslehre (MSc): as substitute for "Advanced Empirical Economics II" (which is part of the bloc "B 1 Forschungsmethoden" and of the bloc "V Empirische Wirtschaftsforschung").

- Economics (MSc): as substitute for "Advanced Empirical Economics II" (which is part of the specialization "Modelltheorie") and "International Labor Markets" (which is part of the specialization "Internationale Wirtschaft") or as "Individueller Schwerpunkt".

- Internationale Wirtschaft und Governance (MA): as substitute for "Advanced Empirical Economics II" (which is part of the specialization "Ökonomische Modellbildung und empirische Analyse") and "International Labor Markets" (which is part of the bloc "Internationale Wirtschaft") or as "Individueller Schwerpunkt".

- Philosophy and Economics (MA): as electives course.

- History and Economics (MA): as specialization.

Additionally, interested bachelor's students may participate.

4   Reading List

In order to have a common base for discussion in class, you are all required to read the first three chapters of James, Witten, Hastie, and Tibshirani (2021). As further useful general background, we provide the following reading list:

- Varian (2014),

- Hastie, Tibshirani, and Friedman (2009) (also available for download in our library),

- Efron and Hastie (2016) (available for download at https://web.stanford.edu/~hastie/CASI_files/PDF/casi.pdf),

- Taddy (2019) (not directly available for download; but examples available at https://github.com/TaddyLab/BDS and slides available at https://github.com/TaddyLab/MBAcourse),

- six articles published from a symposium on "Recent Ideas in Econometrics" published in the *Journal of Economic Perspectives*, vol. 31 no. 2, Spring 2017:

    - Athey and Imbens (2017),

    - Low and Meghir (2017),

    - Stock and Watson (2017),

    - Mullainathan and Spiess (2017),

    - Powell (2017),

    - Angrist and Pischke (2017).

5   Presentation Topics

Notes:

- When you indicate your preferences for topics, you have to choose at least one from the list of core topics.

- Depending on the number of participants, topics may be allocated to teams of two. You are therefore also free to indicate potential partners for the presentation topic.

- All section references refer to ISL if not explicitly otherwise mentioned.

- Data and code for the book ISL can be downloaded at https://www.stat-learning.com/.

- The programs are in R. R is a widely used statistical software package, that contains many machine learning algorithms. It is open source, and you can therefore download and us it for free. To do so, go to the official homepage https://www.r-project.org/. If you prefer a nice user interface, you may want to use *RStudio* (https://www.rstudio.com/). It provides you with a graphical user interface. Otherwise, it uses R. R and *RStudio* are both also available in the computer labs (if labs accessible).

- There are many books about R, which can be freely downloaded as pdf in our library, as for example Zuur, Ieno, and Meesters (2009).

- You may also want to consult the more advanced treatment of the topics dealt with in ISL in Hastie, Tibshirani, and Friedman (2009) for your chosen topic for the seminar presentation and thesis.

5.1   Core Topics

1. Cross-Validation (Sections 5.1 and 5.3.1-5.3.3).

2. Subset Selection (Sections 6.1 and 6.5.1).

3. Shrinkage Methods (Sections 6.2 and 6.5.2).

4. Dimension Reduction Methods (Sections 6.3 and 6.5.3).

5. Decision Trees (Sections 8.1, 8.3.1, and 8.3.2).

6. Bagging, Random Forests, Boosting, and Bayesian Additive Regression Trees (Sections 8.2, 8.3.3, 8.3.4, 8.3.5).

7. Support Vector Classifiers and Support Vector Machines (Sections 9.1-9.3, 9.6.1, and 9.6.2).

8. Neural Networks and Deep Learning (Chapter 10).

5.2 Further Topics

1. Logistic Regression (Sections 4.3 and 4.7.2).

2. Linear Discriminant Analysis (Sections 4.4 and 4.7.3).

3. The Bootstrap (Sections 5.2 and 5.3.4).

4. Polynomial Regression and Step Functions (Sections 7.1, 7.2 and 7.8.1).

5. Splines (Sections 7.4, 7.5 and 7.8.2).

6. Generalized Additive Models (Sections 7.7 and 7.8.3).

7. Principal Components Analysis (Sections 12.2 and 12.5.1).

8. Clustering Methods (Sections 12.4 and 12.5.3).

6 Overview of Important Dates

- 21 October 2022: registration deadline (via email: vwl6@uni-bayreuth.de).

- 27 October 2022, 10am–12am (c.t.): compulsory introductory meeting, allocation of presentation topics (presence or online, tba).

- 30 November 2022: submission deadline for presentation slides (via e-learning).

- 2 and 3 December 2022: student presentations (presence or online, tba).

- 31 March 2023: submission deadline for seminar papers (via e-learning).

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