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| Course unit English denomination | Statistical Models |
| SS | STAT-01/A, STAT-01/B, STAT-02/A, STAT-03/A, STAT-03/B |
| Teacher in charge (if defined) | • Bruno Scarpa<br>• Mauro Bernardi<br>• Stefano Mazzuco<br>• Davide Risso |
| Teaching Hours | 90 |
| Number of ECTS credits allocated | 15 |
| Course period | 02/2026-06/2026 |
| Course delivery method | ☒ In presence<br>☐ Remotely<br>☐ Blended |
| Language of instruction | English |
| Mandatory attendance | ☒ Yes (100% minimum of presence, apart from exceptional absences that must be justify in advance)<br>☐ No |

Course unit contents

*What is a statistical model*

*Nonparametric statistics*
- Nonparametric estimation of functions
- Nonparametric regression
- Nonparametric classification
- Multivariate nonparametric regression

*Experimental design*
- Basic techniques
- Modern techniques

*Statistical models for high-dimensional data*
- Extensions of lasso
- Inference in the context of the lasso
- Graphical models

*Reproducible research and R best practices*

*Random effects, multilevel models, hierarchical models*
- Linear and generalized mixed models inference
- Bayesian and frequentist estimators
- Hierarchical nonparametric methods
- Nonlinear mixed models

*Models for dependent observations*
Gaussian process regression;
- Modelling time series
- Dynamic autoregressive models;

– Bayesian inference for autoregressive models;
– Prior shrinkage and variable selection;
– Factor analysis

In each topic there will be a focus to analytical development of models and to computational methods (introduction to optimization theory, convex optimization and duality, MCMC algorithms, variational methods).

## Learning goals

The course aims to provide students with an advanced understanding of statistical modeling, from the development of models, through their estimation using both Bayesian and frequentist approaches, to their application in interpretation, knowledge enhancement, and prediction. Problem-solving skills are strengthened through weekly homework, assigned to small groups and subsequently discussed with the entire class. Students are also introduced to the study of various bibliographic sources, including books and scientific articles. Enhancing writing and presentation skills is also part of the program.

## Teaching methods

- Lectures
- Group homework
- Student's written and oral presentations (posters)
- Problem solving
- Project work
- Feedback
- Assessment activities during the course
- Develop collaborative and supportive peer relationships

## Course on transversal, interdisciplinary, transdisciplinary skills

☐ Yes
☒ No

## Available for PhD students from other courses

☒ Yes
☐ No
Students from other PhD courses may be admitted subject to CV evaluation by the Faculty Board

## Prerequisites (not mandatory)

• Linear models and their generalizations: generalized linear models (GLM), nonlinear models, models for ordinal and categorical data, maximum likelihood estimation principle and its properties, least squares estimation paradigms and their penalised generalizations, Lasso, Ridge, etc., (Davison 2003, ch. 8, 10; Agresti 2015, ch. 1–8).

• Basic treatment of linear models with random effects (multi-level, hierarchical models) (Gelman and Hill, 2007, ch. 11–14).

• Introduction to nonparametric modelling: trade-off bias-variance, univariate smoothing methods (local regression, loess, regression splines, smoothing splines, etc.), standard nonparametric modesl such as, regression trees, additive models, random forests, bagging, boosting and neural networks, (Azzalini and Scarpa, 2012).

• Univariate and multivariate time series analysis: univariate ARMA models, stationary and non-stationary vector autoregressive models, cointegration analysis, introduction to state space modelling, introduction to spectral analysis (Brockwell and Davis 2016; Lutkepohl 2005, ch 1–8).

*References*

Agresti, A. (2015). *Foundations of linear and generalized linear models*. John Wiley & Sons, Inc., Hoboken, NJ.

Azzalini, A. and Scarpa, B. (2012). *Data analysis and data mining. An introduction*. Oxford University Press, Oxford.

Brockwell, P. J. and Davis, R. A. (2016). *Introduction to time series and forecasting*. Springer, third edition.

Davison, A. C. (2003). *Statistical models*, Cambridge University Press, Cambridge.

Gelman, A. and Hill, J. (2007). *Data analysis using regression and multi-level/hierarchical models*, Cambridge University Press, New York.

Lutkepohl, H. (2005). *New introduction to multiple time series analysis*. Springer.

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| Examination methods (in applicable) | Homework, final written exam, poster preparation and presentation. |
| Suggested readings | • Course material available from the instructors |
| Additional information | max 3750 caratteri |