Course unit English denomination	Theory and Methods of Inference
SS	STAT-01/A
Teacher in charge (if defined)	• Alessandra Salvan • Nicola Sartori
Teaching Hours	64
Number of ECTS credits allocated	10
Course period	03/2026-06/2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (100% minimum of presence, apart from exceptional absences that must be justify in advance) ☐ No
Course unit contents	• Statistical models and uncertainty in inference. Paradigms of inference: the Bayesian and frequentist paradigms. Model specification in Bayesian and frequentist inference. Frequentist evaluation of uncertainty and distribution problems. Simulation. Asymptotic approximations and delta method. • Generating functions, moment approximations, transformations. Moments, cumulants and generating functions. Edgeworth and Cornish-Fisher expansions. Notations Op(·) and op(·). Approximations of moments and transformations. Laplace approximation. • Data and model reduction. Dominated statistical models and density factorizations. Sufficiency. Distribution constant statistics. Completeness. Data and model reduction with nuisance parameters. • Exponential and group families. Exponential families and exponential tilting. Mean value mapping and variance function. Multiparameter exponential families. Sufficiency and completeness in exponential families. Marginal and conditional distributions. Exponential dispersion families. Generalized linear models. Groups of transformations. Orbits and maximal invariants. Simple group families. Composite group families. • Likelihood inference. Observed and expected likelihood quantities, exact properties. Observed likelihood quantities in exponential and group families. Examples with various models and observation schemes: grouped data, censored data, sequential sampling, stochastic processes. Invariance properties. Likelihood and sufficiency. Expected quantities and exact sampling properties. Universal bounds. Orthogonal parameters and mixed parameterization in exponential families. Reparameterizations. Ancillary statistics. Conditional inference in scale and location families. Consistency. First-order asymptotics and related inference procedures. Profile likelihood. Asymptotically equivalent forms and one-sided versions. First-order asymptotic theory in exponential families.

	Non-regular models. Approximate conditional inference and higher-order asymptotics. • Bayesian inference. Asymptotic approximations. Non-informative priors. Empirical Bayes methods. Inference based on the posterior distribution: point estimation and credibility regions, hypothesis testing and the Bayes factor. Prediction. Linear models. • Likelihood and Bayesian inference in R. Scalar and vector parameter examples. Parameters of interest and profile likelihood. Likelihood and parametric bootstrap. EM algorithm. Bayesian inference (basics). • Estimating equations and pseudo-likelihoods. Misspecification. Estimating equations. Quasi likelihood. Pseudo-likelihoods. Composite likelihood. Empirical likelihood. Conditional and marginal likelihood in exponential and group families. Profile and integrated likelihoods. • Decision paradigms. Statistical decision problems. Optimality in estimation. Optimal tests and confidence regions. Procedures with finite sample optimality properties in exponential and group families.
Learning goals	The course aims at offering students an advanced understanding of the theory of statistical inference, both Bayesian and frequentist, with emphasis on unifying ideas as well as on specific aspects. Problem solving abilities are strengthened with weekly homework, assigned to small groups and subsequently discussed with all the students. Students are also introduced to the study of various bibliographic sources, including scientific articles. Enhancing writing and presentation skills is also part of the programme.
Teaching methods	• Lectures • Group homework • Student's written and oral presentations • 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)	First year Master courses at the level of the courses Probability Theory and Statistics (Advanced) at the Department of Statistical Sciences
Examination methods (in applicable)	Homework, final written exam, written and oral presentation rewiewing recent research papers
Suggested readings	• Course material available on the course web page

- Davison, A. C., Statistical Models. Cambridge University Press, 2003
- Pace, L., Salvan, A., Principles of Statistical Inference, from a Neo-Fisherian Perspective. World Scientific Publishing Company, 1997
- Severini, T. A., Likelihood Methods in Statistics. Oxford University Press, 2000
- Severini, T. A., Elements of Distribution Theory. Cambridge University press, 2005
- Young, G. A., Smith, R. L., Essentials of Statistical Inference. Cambridge University Press, 2005

Additional information

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