



## Teaching Guide

| Teaching Guide           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |              |          |           |
|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|----------|-----------|
| Identifying Data         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |              |          | 2019/20   |
| Subject (*)              | Resampling Techniques                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |              | Code     | 614493022 |
| Study programme          | Mestrado Universitario en Técnicas Estadísticas (Plan 2019)                                                                                                                                                                                                                                                                                                                                                                                                                               |              |          |           |
| Descriptors              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |              |          |           |
| Cycle                    | Period                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Year         | Type     | Credits   |
| Official Master's Degree | 1st four-month period                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | First Second | Optional | 5         |
| Language                 | SpanishGalicianEnglish                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |              |          |           |
| Teaching method          | Face-to-face                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |              |          |           |
| Prerequisites            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |              |          |           |
| Department               | Matemáticas                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |              |          |           |
| Coordinador              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | E-mail       |          |           |
| Lecturers                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | E-mail       |          |           |
| Web                      | dm.udc.es/profesores/ricardo/                                                                                                                                                                                                                                                                                                                                                                                                                                                             |              |          |           |
| General description      | It is intended that students acquire skills in identifying situations in which resampling methods are adequate to solve real problems with inferential tools. To do this students will have to know how the main resampling techniques can be used. This includes the bootstrap method and its applications in major areas in statistics. It is also intended that the student is able to design and implement in a computer appropriate resampling plans for a wide range of situations. |              |          |           |

## Study programme competences

| Code | Study programme competences                                                                                                                                                |
|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A2   | Capacidade para comprender, formular, formular e resolver aqueles problemas susceptibles de ser abordados a través de modelos da estatística e da investigación operativa. |
| A4   | Coñecer algoritmos de resolución dos problemas e manexar o software axeitado.                                                                                              |
| A9   | Obter os coñecementos precisos para unha análise crítica e rigorosa dos resultados.                                                                                        |
| B6   | Capacidade para iniciar a investigación e para participar en proxectos de investigación que poden culminar na elaboración dunha tese doutoral.                             |
| B8   | Capacidade de traballo en equipo e de forma autónoma                                                                                                                       |
| B10  | Capacidade de identificar e resolver problemas                                                                                                                             |
| C1   | Ser capaz de identificar un problema da vida real.                                                                                                                         |
| C2   | Dominar a terminoloxía científica-metodolóxica para comprender e interactuar con outros profesionais.                                                                      |
| C3   | Habilidade para traballar os aspectos metodolóxicos da investigación en colaboración con outros colegas a través do Campus Virtual co foro.                                |
| C4   | Habilidade para realizar a análise estatística con ordenador.                                                                                                              |
| C5   | Escoller o deseño máis axeitado para responder á pregunta de investigación.                                                                                                |
| C6   | Utilizar as técnicas estatísticas máis axeitadas para analizar os datos dunha investigación.                                                                               |
| C7   | Planificar, analizar e interpretar os resultados dunha investigación considerando tanto os aspectos teóricos coma os metodolóxicos.                                        |
| C8   | Habilidade de xestión administrativa do proceso dunha investigación.                                                                                                       |
| C9   | Comunicación e difusión dos resultados das investigacións.                                                                                                                 |
| C10  | Lectura con xuízo crítico de artigos científicos dende unha perspectiva metodolóxica.                                                                                      |

## Learning outcomes

| Learning outcomes | Study programme competences |
|-------------------|-----------------------------|
|                   |                             |



|                                                                                                                                                                                                                                                                                                                                  |            |                    |                                                                     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|--------------------|---------------------------------------------------------------------|
| G1 - Capacidade para iniciar a investigación e para participar en proxectos de investigación que poden culminar na elaboración dunha tese de doutoramento.                                                                                                                                                                       | AC2<br>AC4 | BJ6<br>BJ8<br>BJ10 | CJ1<br>CJ2<br>CJ3<br>CJ4<br>CJ5<br>CJ6<br>CJ7<br>CJ8<br>CJ9<br>CJ10 |
| G2 - Capacidade de aplicación de algoritmos de resolución dos problemas e manexo do software adecuado.                                                                                                                                                                                                                           | AC4        |                    |                                                                     |
| G3 - Capacidade de traballo en equipo e de xeito autónomo                                                                                                                                                                                                                                                                        |            | BJ8                |                                                                     |
| G4 - Capacidade de formular problemas en termos estatísticos, e de resolvelos utilizando as técnicas axeitadas.                                                                                                                                                                                                                  | AC2<br>AC4 |                    |                                                                     |
| G6 - Capacidade de identificar e resolver problemas                                                                                                                                                                                                                                                                              |            | BJ10               |                                                                     |
| G10 - Capacidade de integrarse nun equipo multidisciplinar para a análise experimental                                                                                                                                                                                                                                           |            | BJ8                |                                                                     |
| G11 - Adquirir destreza para o desenvolvemento de software                                                                                                                                                                                                                                                                       | AC2<br>AC4 |                    |                                                                     |
| G12 - Capacidade de análise estatística crítica das mostras, os plantexamentos e resultados                                                                                                                                                                                                                                      | AC2<br>AC9 |                    |                                                                     |
| G14 - Representar un problema real mediante un modelizado estatístico axeitado.                                                                                                                                                                                                                                                  | AC2        |                    |                                                                     |
| G15 - Deseñar un plano de observación ou recollida de datos que permita abordar o problema de interese                                                                                                                                                                                                                           | AC4<br>AC9 | BJ10               |                                                                     |
| E2 - A adquisición dos coñecementos de estatística e investigación de operacións necesarios para a incorporación en equipos multidisciplinares pertencentes a diferentes sectores profesionais.                                                                                                                                  | AC2        | BJ8                | CJ1<br>CJ2<br>CJ3                                                   |
| E4 - Coñecer as aplicacións dos modelos da estatística e a investigación de operacións.                                                                                                                                                                                                                                          | AC2        |                    |                                                                     |
| E5 - Coñecer algoritmos de resolución dos problemas e manexar o software axeitado.                                                                                                                                                                                                                                               | AC4        |                    |                                                                     |
| E12 - Realizar inferencias respecto aos parámetros que aparecen no modelo.                                                                                                                                                                                                                                                       |            |                    | CJ6                                                                 |
| E19 - Tratamento de datos e análise estatística dos resultados obtidos.                                                                                                                                                                                                                                                          |            | BJ6                |                                                                     |
| E27 - Obter os coñecementos precisos para unha análise crítica e rigurosa dos resultados.                                                                                                                                                                                                                                        | AC9        |                    |                                                                     |
| E28 - Complementar a aprendizaxe dos aspectos metodolóxicos con apoio de software.                                                                                                                                                                                                                                               | AC4        |                    |                                                                     |
| E78 - Fomentar a sensibilidade cara os principios do pensamento científico, favorecendo as actitudes asociadas ao desenvolvemento dos métodos matemáticos, como: o cuestionamento das ideas intuitivas, a análise crítica das afirmacións, a capacidade de análise e síntese ou a toma de decisións racionais                    | AC2        |                    |                                                                     |
| E82 - O estudante será capaz de comprender a importancia da Inferencia Estatística como ferramenta de obtención de información sobre a poboación en estudo, a partir do conxunto de datos observados dunha mostra representativa de esta. Para iso deberá recoñecer a diferenza entre estatística paramétrica e non paramétrica. |            |                    | CJ4<br>CJ5                                                          |
| E84 - Ser quen de manexar diverso software (en particular R) e interpretar os resultados que proporcionan nos correspondentes estudos prácticos.                                                                                                                                                                                 | AC4        |                    | CJ4                                                                 |
| E86 - Soltura no manexo da teoría da probabilidade e as variables aleatorias.                                                                                                                                                                                                                                                    | AC2        |                    |                                                                     |

| Contents                                      |                                                                                                                                     |
|-----------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| Topic                                         | Sub-topic                                                                                                                           |
| 1. Motivation of the Bootstrap principle.     | Uniform bootstrap. Bootstrap distribution calculation: exact distribution and Monte Carlo approximation. Examples.                  |
| 2. Some applications of the Bootstrap method. | Application of the Bootstrap to estimate the precision and the bias of an estimator. Examples.                                      |
| 3. Motivation of the Jackknife method.        | Jackknife estimation of the precision and the bias of an estimator. Bootstrap/Jackknife relationship. Examples. Simulation studies. |



|                                                                       |                                                                                                                                                                                                                    |
|-----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 4. Variations of the uniform Bootstrap.                               | Parametric Bootstrap, symmetrized Bootstrap, smoothed Bootstrap, weighted Bootstrap and biased Bootstrap. Discussion and examples. Validity of the Bootstrap approach. Examples.                                   |
| 5. Applications of Bootstrap to construct confidence intervals.       | Percentile method, percentile-t method, symmetrized percentile-t method . Examples. Simulation studies.                                                                                                            |
| 6. Bootstrap and nonparametric density estimation.                    | Bootstrap approximation for the distribution of the Parzen-Rosenblatt estimator. The Bootstrap in the selection of the smoothing parameter.                                                                        |
| 7. Bootstrap and nonparametric estimation of the regression function. | Bootstrap approximation of the distribution of the Nadaraya-Watson estimator. Different resampling methods and results.                                                                                            |
| 8. Bootstrap with censored data.                                      | Introduction to censored data. Bootstrap resampling plans in the presence of censorship. Relations among them.                                                                                                     |
| 9. Bootstrap with dependent data.                                     | Introduction to the usual conditions of dependency and dependent data models. Parametric models of dependence. General dependence situations: Moving Block Bootstrap, Stationary Bootstrap and Subsampling method. |

| Planning                                                                                                                        |                                          |                      |                               |             |
|---------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|----------------------|-------------------------------|-------------|
| Methodologies / tests                                                                                                           | Competencies                             | Ordinary class hours | Student's personal work hours | Total hours |
| Oral presentation                                                                                                               | A2 A4 A9 B6 B10 C2<br>C3 C5 C6 C10       | 21                   | 31.5                          | 52.5        |
| ICT practicals                                                                                                                  | A4 B8 C3 C4 C6 C8                        | 14                   | 28                            | 42          |
| Multiple-choice questions                                                                                                       | A4 A9 B10 C2 C3 C5<br>C6 C7 C10          | 1                    | 11.5                          | 12.5        |
| Problem solving                                                                                                                 | A4 A9 B8 B10 C1 C4<br>C5 C6 C7 C8 C9 C10 | 4                    | 8                             | 12          |
| Personalized attention                                                                                                          |                                          | 6                    | 0                             | 6           |
| (*)The information in the planning table is for guidance only and does not take into account the heterogeneity of the students. |                                          |                      |                               |             |

| Methodologies             |                                                                                        |
|---------------------------|----------------------------------------------------------------------------------------|
| Methodologies             | Description                                                                            |
| Oral presentation         | Presentation with computer by videoconference to three campuses                        |
| ICT practicals            | Resampling algorithm implementation                                                    |
| Multiple-choice questions | Multiple-choice test on concepts.                                                      |
| Problem solving           | Design of resampling plans. Bias and variance calculation for the bootstrap analogues. |

| Personalized attention |                                                                                                                         |
|------------------------|-------------------------------------------------------------------------------------------------------------------------|
| Methodologies          | Description                                                                                                             |
| ICT practicals         | Attendance and participation in lectures.                                                                               |
| Problem solving        | Written multiple choice test.<br>Participation in workshops and seminars.<br>Practicals to be performed by the student. |

| Assessment      |                                          |                                                                       |               |
|-----------------|------------------------------------------|-----------------------------------------------------------------------|---------------|
| Methodologies   | Competencies                             | Description                                                           | Qualification |
| ICT practicals  | A4 B8 C3 C4 C6 C8                        | Using the software R to implement the bootstrap method in some setup. | 20            |
| Problem solving | A4 A9 B8 B10 C1 C4<br>C5 C6 C7 C8 C9 C10 | Original work on the bootstrap on some relevant setup.                | 40            |



|                           |                                 |                     |    |
|---------------------------|---------------------------------|---------------------|----|
| Multiple-choice questions | A4 A9 B10 C2 C3 C5<br>C6 C7 C10 | Comprehension Test. | 40 |
|---------------------------|---------------------------------|---------------------|----|

## Assessment comments

The assessment will be carried out using a written test on R labs, an individual student work, as well as a written concept test. The concept test score will be 40% of the total qualification, the test on R labs will correspond to 20% of the global score, while the remaining 40% will correspond to the individual student work, that has to be presented orally.

To pass the subject is necessary to obtain a score of at least 5 out of 10 overall.

On July opportunity, students could avoid those tests with scores of at least 4 out of 10 in January tests. Only students that didn't take any test will be qualified as NON ATTENDANT in the first opportunity (January-February). In July opportunity only students that didn't take the final exam will be qualified as NON ATTENDANT.

## Sources of information

|       |                                                                                                                                                                                                                                                                                                                                                                                                               |
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| Basic | Bibliografía básica<br>Davison, A.C. and Hinkley, D.V. (1999). Bootstrap Methods and their Application. Cambridge University Press.<br>Efron, B. (1979). Bootstrap Methods: Another look at the Jackknife. Ann. Statist., 7, 1-26.<br>Efron, B. and Tibshirani, R.J. (1993). An Introduction to the Bootstrap. Chapman and Hall.<br>Shao, J. and Tu, D. (1996). The Jackknife and Bootstrap. Springer Verlag. |
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|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Complementary | <p>Bibliografía complementaria</p> <p>Akritis, M. G. (1986). Bootstrapping the Kaplan--Meier estimator. J. Amer. Statist. Assoc. 81, 1032-1038.</p> <p>Bickel, P.J. and Freedman, D.A. (1981). Some asymptotic theory for the bootstrap. Ann. Statist. 12, 470-482.</p> <p>Bühlmann, P. (1997). Sieve bootstrap for time series. Bernoulli 3, 123-148.</p> <p>Cao, R. (1990). Órdenes de convergencia para las aproximaciones normal y bootstrap en la estimación no paramétrica de la función de densidad. Trabajos de Estadística, vol. 5, 2, 23-32.</p> <p>Cao, R. (1991). Rate of convergence for the wild bootstrap in nonparametric regression. Ann. Statist. 19, 2226-2231.</p> <p>Cao, R. (1993). Bootstrapping the mean integrated squared error. Jr. Mult. Anal. 45, 137-160.</p> <p>Cao, R. (1999). An overview of bootstrap methods for estimating and predicting in time series. Test, 8, 95-116.</p> <p>Cao, R. and González-Manteiga, W. (1993). Bootstrap methods in regression smoothing. J. Nonparam. Statist. 2, 379-388.</p> <p>Cao, R. and Prada-Sánchez, J.M. (1993). Bootstrapping the mean of a symmetric population. Statistics &amp; Probability Letters 17, 43-48.</p> <p>Efron, B. (1981). Censored data and the bootstrap. J. Amer. Statist. Assoc. 76, 312-319.</p> <p>Efron, B. (1982). The Jackknife, the Bootstrap and other Resampling Plans. CBMS-NSF. Regional Conference series in applied mathematics.</p> <p>Efron, B. (1983). Estimating the error rate of a prediction rule: improvements on cross-validation. J. Amer. Stat. Assoc. 78, 316-331.</p> <p>Efron, B. (1987). Better Bootstrap confidence intervals (with discussion), J. Amer. Stat. Assoc. 82, 171-200.</p> <p>Efron, B. (1990). More Efficient Bootstrap Computations. J. Amer. Stat. Assoc. 85, 79-89.</p> <p>Efron, B. and Tibshirani, R. (1986). Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. Statistical Science 1, 54-77.</p> <p>Freedman, D.A. (1981). Bootstrapping regression models. Ann. Statist. 9, 6, 1218-1228.</p> <p>García-Jurado, I. González-Manteiga, W., Prada-Sánchez, J.M., Febrero-Bande, M. and Cao, R. (1995). Predicting using Box-Jenkins, nonparametric and bootstrap techniques. Technometrics 37, 303-310.</p> <p>Hall, P. (1986). On the bootstrap and confidence intervals. Ann. Statist. 14, 1431-1452.</p> <p>Hall, P. (1988a). Theoretical comparison of bootstrap confidence intervals. Ann. Statist. 16, 927-953.</p> <p>Hall, P. (1988b). Rate of convergence in bootstrap approximations. Ann. Probab. 16, 4, 1665-1684.</p> <p>Hall, P. (1992). The Bootstrap and Edgeworth Expansion. Springer Verlag.</p> <p>Hall, P. and Martin, M.A. (1988). On bootstrap resampling and iteration. Biometrika 75, 661-671.</p> <p>Härdle, W. and Marron, J. S. (1991). Bootstrap simultaneous error bars for nonparametric regression. Ann. Statist. 19, 778-796.</p> <p>Künsch, H.R. (1989). The jackknife and the bootstrap for general stationary observations. Ann. Statist. 17, 1217-1241.</p> <p>Mammen, E. (1992). When does Bootstrap Work?. Springer Verlag.</p> <p>Navidi, W. (1989). Edgeworth expansions for bootstrapping regression models. Ann. Statist. 17, 4, 1472-1478.</p> <p>Politis, D.N. and Romano, J.R. (1994a). The stationary bootstrap. J. Amer. Statist. Assoc. 89, 1303-1313.</p> <p>Politis, D.N. and Romano, J.R. (1994b). Limit theorems for weakly dependent Hilbert space valued random variables with application to the stationary bootstrap. Statist. Sin. 4, 461-476.</p> <p>Politis, D.N., Romano, J.P. and Wolf, M. (1999). Subsampling. Springer Verlag.</p> <p>Reid, N. (1981). Estimating the median survival time. Biometrika 68, 601-608.</p> <p>Stine, R.A. (1987). Estimating properties of autoregressive forecasts. J. Amer. Statist. Assoc. 82, 1072-1078.</p> <p>Thombs, L.A. and Schucany, W.R. (1990). Bootstrap prediction intervals for autoregression. J. Amer. Statist. Assoc. 85, 486-492.</p> <p>Wu, C.-F. J. (1986). Jackknife, bootstrap and other resampling methods in regression analysis. Ann. Statist. 14, 1261-1350.</p> |
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## Recommendations

### Subjects that it is recommended to have taken before

Estatística Matemática/614468102

Modelos de Probabilidade/614468103

Estatística Aplicada/614468104

Modelos de Regresión/614468105

Análise Exploratoria de Dados (data mining)/614468106

Estatística non Paramétrica/614468109

Simulación Estatística/614468113

### Subjects that are recommended to be taken simultaneously

Séries de Tempo/614427111

Fiabilidade e Modelos Biométricos/614427116

### Subjects that continue the syllabus



Contrastes de Especificación/614468123

Datos Funcionais/614468124

Proxecto Fin de Carreira ou Traballo Tutelado/614468128

Other comments

(\*)The teaching guide is the document in which the URV publishes the information about all its courses. It is a public document and cannot be modified. Only in exceptional cases can it be revised by the competent agent or duly revised so that it is in line with current legislation.