# Time series and spatial data analysis

## Prof. David Conesa; Prof. Luigi Spezia

***COURSE AIMS AND INTENDED LEARNING OUTCOMES***

The aim of the course is to provide students with an advanced knowledge in time series analysis and spatial statistics, from both a theoretical and a practical perspective. The course is split into two modules. The first introduces models and methods to analyse sequences of data correlated in time. The second focuses on the analysis and modelling of geo-referenced data, including spatial visualisation, regression and interpolation.

By the end of the course, students will be able to:

1. achieve advanced knowledge of the main statistical methods in time series and spatial data analysis (*knowledge and understanding*);
2. visualise temporal and spatial data sets; formalise data problems within the statistical framework; develop an implementation plan; apply inferential tools and identify trends, structures, and patterns in time series and spatial data; produce accurate temporal predictions and spatial interpolations (*applying knowledge and understanding*);
3. evaluate the goodness of fit of a model and detect violations of the model assumptions; interpret the results of an empirical analysis (*making judgements*);
4. use an appropriate statistical language and describe the model assumptions; communicate the results of empirical statements and findings of the conducted study (*communication skills*);
5. independently develop and implement time series and spatial regression models and analyse real data sets (*learning skills*).

***COURSE CONTENT***

Module I

* *Introduction to temporal correlated data:* examples, terminology, and objectives of time series analysis;
* *Simple descriptive statistics*: stationary time series, time plots, transformations;
* *Probability models for time series*: moving averages models, autoregressive models, mixed models;
* *Estimation in the time domain*;
* *Forecasting*;
* *Introduction to multivariate time series.*

Module II

* *Introduction to spatial data:* overview of spatial data problems; types of spatial data; maps and data visualisation;
* Modelling spatial data problems: inference in spatial models; the Bayesian approach with INLA;
* *Areal data analysis*: exploratory data analysis, spatial association; conditionally autoregressive models; disease mapping;
* *Point-referenced data analysis*: spatial regression; Gaussian processes; spatial interpolation and Bayesian Kriging;
* *Point pattern analysis*: introduction to point patterns, modelling point patterns; Marked point pattern models and preferential sampling;
* *Introduction to spatio-temporal data.*

***READING LIST***

Class notes, papers, slides, codes, and further material will be posted on the University platform Blackboard. Useful readings are:

- Banerjee, S. - Carlin B. P. - Gelfand A. E. *Hierarchical modeling and analysis for spatial data, 2nd Edition*, CRC Press, 2014

- Bivand, R. S. - Pebesma, E. - Gómez-Rubio V. *Applied spatial data* *analysis with R*, Springer, 2013.

- Cryer J. D and Chan K.-S. *Time series analysis: with applications in R, 2nd Edition*, Springer, 2010.

- Shumway R. H. - Stoffer D. S, *Time series analysis and its applications: with R Examples, 4th Edition*, Springer, 2017.

***TEACHING METHOD***

Lectures integrated with practical classes, discussion of case studies, and lab sessions using R. Attending the lectures with an active participation and ongoing private study is strongly recommended.

***ASSESSMENT METHOD AND CRITERIA***

The assessment is based on both parts of the course, evaluated in a single written test. To pass the exam the student needs to get the pass mark in both parts; the final mark is the average of the marks in the two parts.

Both parts of the course are assessed using a written examination aiming at evaluating student’s knowledge according to the learning outcomes of the course. For the time series analysis half an assignment is also required.

***NOTES AND PREREQUISITES***

Students enrolling in this course are expected to know the foundations of algebra, probability, data analysis, statistical inference, linear models, and computational statistics, i.e., the topics covered in the courses “Mathematical methods and probability”, “Statistical Inference”, “Applied linear models”, and “Computational statistics” taught in the first year. Students are also expected to be skilled at using R statistical software. Knowledge of the Bayesian approach is recommended for Module II but not mandatory.

*Meetings with students*

Prof. David Conesa and Prof. Luigi Spezia will meet students after the lectures in the Buonarroti buildings. Meetings in the Department or online are also possible upon an email request.