UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Dynamic Models and Machine Learning Forecasting M

2627-1-F8206B035

Learning objectives

The objective of the course is to provide the theoretical and applied foundations of dynamic linear models for time series and machine learning forecasting. The fundamentals of forecasting theory, the state space form, and related filtering methods will be illustrated, in addition to machine learning techniques useful for forecasting complex time series.

The course is delivered in *blended learning* mode, combining video lectures with face-to-face sessions in a computer laboratory. All models are implemented on real economic data and problems using the open-source R environment.

The teaching completes the statistical-economic preparation of students across all tracks of the Master's degree program, providing statistical tools for working with macroeconomic, corporate, financial, and other types of time series.

Upon completion of the course, the expected learning outcomes are as follows:

Knowledge and understanding (DdD 1): Students will be able to build ad-hoc dynamic linear models to forecast and filter real-world time series. Furthermore, they will be able to use machine learning methods for time series forecasting and produce the most suitable features to allow these models to learn characteristics such as trends and seasonality.

Applying knowledge and understanding (DdD 2): Students will be able to use the R language and packages related to the state space form and machine learning models at an advanced level to implement solutions to real problems.

Making judgements (DdD 3): Students will be able to critically analyze model results, evaluating their accuracy and consistency with respect to the stated objectives.

Communication skills (DdD 4): Students will acquire the ability to communicate analysis results to industry

experts using appropriate technical language, in both Italian and English.

Learning skills (DdD 5): Students will develop the skills necessary to independently explore new models and computational procedures essential for the professional activity of statisticians and forecasters.

Contents

- Prediction theory
- State space form of dynamic linear models and Kalman filtering
- Unobserved Component Models
- Machine learning forecasting
- Real world applications with R/KFAS

Detailed program

- Optimal predictor
- Optimal linear predictor
- State-space form / Dynamic linear models
- Unobserved Components Models (UCM) (trend, cycle, seasonality)
- ARIMA and UCM models in state-space form
- Kalman filter and maximum likelihood estimation
- Initialization of state variables
- Smoothing of state variables and disturbances
- Main machine learning (ML) algorithms
- Extrapolation problems of many ML algorithms and solutions
- Construction of temporal features for ML models
- Exercises and case studies using R

Prerequisites

Knowledge of statistical inference and matrix algebra, as well as the fundamentals of time series analysis (stationary processes, integrated processes, ARIMA).

Fundamentals of R.

Teaching methods

The course is taught in blended learning mode: 50% of the teaching takes place in person (in the laboratory) and 50% takes place remotely through video lectures, web applications, online tests and exercises, and Q&A forums.

In-person lessons are always held in the laboratory and operationalize, through applications to real-world data, the theory acquired independently by the student via video lectures, the textbook, and other teaching aids available on the e-learning page. Furthermore, in-person sessions provide an opportunity for students to express their doubts

and ask questions about what they have learned independently, allowing the instructor to provide alternative explanations for anything that remains unclear

The duration of in-person lessons is two or three hours, for a total of 23 hours.

Video lectures consist of delivery-based teaching, and various self-assessment questionnaires and web-apps allow for the verification and improvement of learning.

In-person lessons are a mix of delivery-based teaching (approximately 30%) and interactive teaching (approximately 70%).

The lessons are taught in English.

Assessment methods

The exam consists of a written test on theoretical questions and exercises (1-hour duration) and a practical lab exam using R (1-hour duration). Each part accounts for 50% of the final grade.

Details of the parts:

- **Written test**: assesses theoretical knowledge regarding forecasting theory, unobserved component models, the state-space form, and machine learning forecasting through five open-ended questions. Each question carries equal weight in the written assessment.
- **Practical test**: requires building and estimating models on a provided time series, including generating the required diagnostics.
- **Group project**: the instructor may offer attending students the option to replace the practical test with an original group project.

Assessed skills:
Theoretical understanding of state-space modeling and the use of machine learning models for forecasting (DdD 1).
Ability to solve forecasting and signal extraction problems using R code (DdD 2).
Critical analysis and diagnostic skills regarding results (DdD 3).

Evaluation and grading criteria: The assessment considers the accuracy of theoretical answers (50%) and the correct implementation and interpretation of statistical models in the practical test (50%). Excellence (30 cum laude) requires full achievement of all learning objectives and exceptional mastery of computational tools.

In-itinere tests: No mandatory mid-term tests are provided during the course; however, attending students may be offered optional home assignments that can contribute to the final grade.

Textbooks and Reading Materials

Pelagatti (2015) *Time Series Modelling with Unobserved Components*, Chapman and Hall/CRC (freely available under IP address of Bicocca)
Hyndman, R.J., & Athanasopoulos, G. (2018) *Forecasting: principles and practice*, 2nd edition, OTexts: Melbourne, Australia. OTexts.com/fpp2
Notes of the instructor for the machine learning forecasting part

Semester

4th term (May - June)

Teaching language

Italian

Sustainable Development Goals