Subject: Temporal Information Processing (TIP)
Code:
Institution: Escuela Politécnica Superior
Degree: Master's program in Research and Innovation in Information and Communications Technologies (I^2-ICT)
Level: Master
Type: Elective [computational intelligence]
ECTS: 6

COURSE GUIDE: Temporal Information Processing (TIP)

Academic year:	2012-2013
Program:	Master's program in Research and Innovation in Information and Communication Technologies (I^2-CIT)
Center:	Escuela Politécnica Superior
University:	Universidad Autónoma de Madrid
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1. ASIGNATURA / COURSE (ID)

Procesamiento de información temporal
Temporal information processing (TIP)

1.1. Programa / program

Máster Universitario en Investigación e Innovación en Tecnologías de la Información y las Comunicaciones (I^2-TIC)

Master in Research and Innovation in Information and Communication Technologies (I^2-CIT) [Officially certified]

1.2. Course code

XXX

1.3. Course areas

Computer Science and Artificial Intelligence

1.4. Tipo de asignatura / Course type

Optativa [itinerario: Inteligencia computacional]
Elective [itinerary: Computational Intelligence]

1.5. Semester

Second semester

1.6. Credits

6 ETCS

1.7. Language of instruction

The lecture notes are in English. The lectures are mostly in Spanish. Some of the lectures and seminars can be in English.

1.8. Recommendations / Related subjects

Knowledge of probability and statistics at an introductory level is useful to follow the course.

Related subjects are:

- Aprendizaje Automático: teoría y aplicaciones [Machine Learning: theory and applications]
- Métodos bayesianos aplicados [Applied Bayesian Methods]
- Procesamiento de señales biomédicas y sus aplicaciones [Biomedical signal processing and its applications]
- Procesamiento de audio y voz para biometría y seguridad [Speech and Audio Processing for Biometrics and Security]
- Técnicas de análisis de secuencias vídeo para videovigilancia [Techniques of Analysis of Video Sequences for Surveillance]

1.9. Lecturers

Add @uam.es to all email addresses below.

Lectures and labs:

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1.10. Objetivos de la asignatura / Course objectives

En esta asignatura se estudian las herramientas para el análisis, modelización, predicción y simulación de series temporales, incluyendo técnicas de modelización avanzadas (modelos no lineales, modelos no paramétricos, redes neuronales, modelos bayesianos, etc.). Se abordan asimismo problemas de aprendizaje, control y procesamiento de información en entornos dinámicos y con incertidumbre. La presentación se estructura en torno aplicaciones prácticas que involucran el análisis de series temporales medio-ambientales, financieras, biológicas o médicas.

This subject introduces the tools for the analysis, modeling, prediction and simulation of time series. The models considered include advanced modeling techniques, such as non-linear models, non-parametric models, neural networks, Bayesian methods, etc. We will also consider learning, control and information processing problems in dynamical environments and in the presence of uncertainty. The presentation is structured around practical applications that involve the analysis of environmental, financial, biological or medical time series.

At the end of each unit, the student should be able to:

UNIT BY UNIT SPECIFIC OBJECTIVES	
UNIT 1.- Introduction to time series	
1.1.	Provide examples of time series in different areas of applications.
1.2.	Know different techniques available to analyze and model deterministic and stochastic time series.
1.3.	Characterize a random walk, simulate it and estimate its statistical properties from empirical or simulated data.
1.4.	Characterize a Brownian process, simulate it and estimate its statistical properties from empirical or simulated data.
1.5.	Characterize a general Itô process, simulate it and estimate its statistical properties from empirical or simulated data.
UNIT 2.- Time series analysis	
2.1.	Preprocess temporal data for its posterior analysis.
2.2.	Understand the properties of weak and strong stationarity and their relevance to time series analysis and modeling.
2.3.	Identify, model and eliminate non-stationary components and perform transformations to render the time series stationary or quasi-stationary.
2.4.	Characterize a stationary process, simulate it and estimate its statistical properties from empirical or simulated data.
UNIT 3.- Linear time series modeling and prediction	
3.1.	Use Box-Jenkins methodology for time series modeling.
3.2.	Select among alternative models.
3.3.	Determine the parameters of the selected model.
3.4.	Validate the model and assess its quality.
3.5.	Use the model to make predictions and quantify their uncertainty.
3.6.	Characterize a linear process of the types AR, MA, ARMA, ARIMA, ARCH, GARCH, or VAR, simulate it and estimate its statistical properties from empirical or simulated data.
3.7.	Determine the order of the AR, MA, ARMA models.
3.8.	Identify the level of differencing in ARIMA models.
3.9.	Determine whether the series has a heteroscedastic structure.
3.10.	Understand how to formulate and analyze time series models in state space.
3.11.	Formulate an AR(p) process as a state space model.

3.12.	Use the Kalman filter and understand its practical applications
UNIT 4.- Advanced models for time series	
4.1.	Use feed-forward and recurrent neural networks for time series modeling and determine the parameters from data.
4.2.	Use support vector machines for time series modeling and determine their parameters from data.
4.3.	Formulate Bayesian models for time series modeling and determine their parameters from data using different inference techniques.
UNIT 5.- Markov processes	
5.1.	Understand what Markov processes are and their relevance in practical applications.
5.2.	Generate samples from arbitrary distributions using MCMC.
5.3.	Be familiar with some applications of MCMC, such as simulated annealing, or Bayesian inference.
5.4	Use HMM to model time series data in some application domain, such as speech recognition.
UNIT 6.- Spectral analysis	
6.1.	Spectral representation of time series. Duality of the representation. Properties
6.2	Other orthogonal transformations
6.3	Multispectral analysis and applications
UNIT 7.- Time-series analysis based on dynamical systems	
7.1	Deterministic dynamics. Integrable systems. Volume evolution and dissipative systems. Chaotic systems
7.2	Experimental analysis. Experimental set-up. Mass analysis.
7.3	Differences between deterministic dynamical processes and stochastic processes.
UNIT 8.- Advanced topics	
8.1.	Depending on the interests of the students in the course, different advanced research topics in the area of time series analysis will be covered during the course. Possible topics are causality, optimal control, reinforcement learning or online learning.

1.11. Course contents

PART I

1. Introduction to time series [1 week]
    a. Examples of times series
    b. Dynamical systems
        i. Discrete time: Difference equations
           Example: Discrete maps
        ii. Continuous time: Differential equations
           Examples: The harmonic oscillator, non-linear oscillators
    c. Stochastic processes
        i. Discrete time: Stochastic difference equations

Example: Random walk

ii. Continuous time: Stochastic differential equations
Examples: Brownian motion, Itô processes

2. Time series analysis [1 week]
   a. Preprocessing of data
      i. Data smoothing
      ii. Outlier detection
      iii. Transformations
      iv. Modeling and elimination of non-stationary terms
         1. Trends
         2. Seasonality
   b. Stationary processes
      i. Strong and weak stationarity
      ii. Statistical properties
         1. Expected values
         2. Autocorrelations

3. Time series modeling and prediction [2 weeks]
   a. Linear models for time series
      i. Linear models: AR, MA, ARMA
      ii. Integrated models: ARIMA
      iii. Heteroscedasticity: ARCH, GARCH
      iv. Models in several dimensions: VAR models
      v. State space models: The Kalman filter
   b. Modeling
      i. Model selection
      ii. Model estimation
      iii. Model validation
   c. Prediction

4. Advanced models for time series [2 weeks]
   a. Neural networks for time series
      i. Feed-forward networks
      ii. Recurrent networks
   b. Support Vector Machines
   c. Bayesian models

5. Markov processes [1 week]
   a. Introduction to Markov processes
   b. Markov Chain Monte Carlo
   c. Hidden Markov Models

PART II

6. Spectral analysis for time series [3 weeks]
   a. Fourier analysis
   b. Other orthogonal transformations

    c. Multispectral analysis and applications. Detecting non-linear processes.

7. Time-series analysis based on dynamical systems [2,5 weeks]
    a. Deterministic dynamics
        i. Integrable systems
        ii. Chaotic systems
    b. Experimental analysis
        i. Experimental set-up. Dimensionality.
        ii. Differences and differentiating between deterministic dynamical processes and stochastic processes.
        iii. Analysis of the system as a repetitive process. Link with complexity.
8. Advanced topics [1 week]
    a. Causality
    b. Optimal control
    c. Reinforcement learning
    d. Online learning

1.12. Course bibliography

1. Introduction to time series and forecasting , P.J. Brockwell, R. A. Davis, Springer Texts in Statistics (1996)
2. Time series analysis, J. D. Hamilton Princeton University Press, Princeton, NJ (1994)
3. Nonlinear Time Series Analysis, 2nd Edition, Holger Kantz and Thomas Schreiber, Cambridge University Press, Cambridge (2003)
4. Time Series Prediction, A.S. Weigend and N. A. Gershenfeld eds. Addison-Wesley, Reading, MA, (1994)
5. Time Series: Theory and Methods, 2nd. Ed. P.J. Brockwell and R. A. Davis Springer-Verlag, (1991)
6. Non-linear Time Series, H. Tong, Oxford Science Publications (1996)
7. Modelling nonlinear economic relationships, C. W. J. Granger and T. Teräsvirta , Oxford University Press, Oxford (1993)
8. Dynamic Programming and Optimal Control, Dimitri P. Bertsekas, Athena Scientific (2007)
9. Markov Decision Processes: Discrete Stochastic Dynamic Programming, Martin L. Puterman, Wiley
10. Reinforcement Learning. Richard S. Sutton and Andrew G. Barto,
11. Prediction Learning and Games. N. Cesa-Bianchi and G. Lugosi. Cambridge University Press, 2006.
12. Holger Kantz, Thomas Schreiber; Non-Linear time series analysis; 2nd ed.; Cambridge University Press, 2003.
13. Saeid Sanei, J. Chambers; EEG Signal Processing (chap.2); Wiley, 2007,UK

14. Rao; Bispectral Analysis of non-linear Time Series; in Handbook of Statistics; Amsterdam 1993

1.13. Coursework and evaluation

The course involves lectures, weekly assignments, lab assignments, a seminar presentation and two exams.

In both the ordinary and the extraordinary exam period it is necessary to have a pass grade (≥ 5) in each of the exams to pass the course.

- In the ordinary exam period, the evaluation will be made according to the following scheme
    - 20 % Exercises and class participation
    - 20 % Lab assignments
    - 10 % Seminar presentation on a research topic in time series
    - 25 % Exam 1 [mid-term]
    - 25 % Exam 2 [end of term]

  The grades of the individual parts are kept for the extraordinary exam period.

- In case of a fail grade in the ordinary exam period, in the extraordinary exam period, the student has the opportunity to
    - Turn in all the exercises with corrections
    - Turn in all the lab assignments with corrections.
    - Turn in a report on a research topic in time series.

  The grade will be determined by
    - Oral examination
        - 20 % Exercises [only if the exercises are turned in]
        - 20 % Lab assignments [only if the lab assignments are turned in]
        - 10 % Report [only if the report are turned in]

      If the student does not turn in some of these items, the grades used will be those corresponding to the ordinary exam period.

    - 50 % written exam [mandatory]