COURSE GUIDE: Temporal Information Processing (TIP)

Academic year:	2015-2016
Program:	Master's program in Research and Innovation in Information and Communications Technologies (i^2-ICT)
Center:	Escuela Politécnica Superior
University:	Universidad Autónoma de Madrid
Last modified:	2016/05/10
Status:	Approved 2016/xx/xx

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 Communications Technologies (i^2-ICT) [Officially certified]

1.2. Course code

32422

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 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:

Dr. Alberto Suárez (Coordinator)
Departamento de Ingeniería Informática
Escuela Politécnica Superior
Office: B-312
Tel.: +34 914977531
e-mail: alberto.suarez
Web: http://www.eps.uam.es/~asuarez

Dr. José R. Dorronsoro Ibero
Departamento de Ingeniería Informática
Escuela Politécnica Superior
Office: B-358
Tel.: +34 914972329
e-mail: jose.dorronsoro
Web: http://www.eps.uam.es/~gaa

Dr. Kostadin Koruchev
Departamento de Ingeniería Informática
Escuela Politécnica Superior
Office: B-355
Tel.: +34 914973210
e-mail: k.koroutchev
Web: http://www.eps.uam.es/~kostadin

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.- 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.- Spectral analysis	
4.1	Spectral representation of time series. Duality of the representation. Properties
4.2	Other orthogonal transformations
4.3	Multispectral analysis and applications
UNIT 5.- Time-series analysis based on dynamical systems	
5.1	Deterministic dynamics. Integrable systems. Volume evolution and dissipative systems. Chaotic systems.
5.2	Experimental analysis. Experimental set-up. Mass analysis.
5.3	Differences between deterministic dynamical processes and stochastic processes.
UNIT 6.- Advanced models for time series	
6.1	Use neural networks for time series modeling and determine the parameters from data.
6.2	Use support vector machines for time series modeling and determine their parameters from data.
UNIT 7.- Online learning	
7.1	View learning as an optimization process
7.2	Understand the differences between batch learning and online learning.
7.3	Understand the relation between online learning and linear filters.
7.4	Use stochastic gradient and subgradient descent methods for online learning.
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

PART II

4. Spectral analysis for time series [2 weeks]
   a. Fourier analysis
   b. Other orthogonal transformations
   c. Multispectral analysis and applications. Detecting non-linear processes.

5. Time-series analysis based on dynamical systems [2 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.

PART III

6. Advanced models for time series [2 weeks]
   a. Neural networks for time series
      i. Feed-forward networks
      ii. Recurrent networks
      iii. Deep networks
   b. Support Vector Machines

7. Online learning [2 weeks]
   a. Learning as optimization
   b. Batch learning vs. online learning
   c. Linear processes and linear filters
   d. Online learning of linear filters. The ADALINE algorithm
   e. Online learning and stochastic gradient descent
   f. Online learning of multilayer perceptrons
   g. Stochastic convex subgradient descent

ADVANCED TOPICS

8. Advanced topics [1 week]
   a. Causality
   b. Optimal control
   c. Reinforcement learning
   d. Bayesian models for time series
   Note: Only some of the subjects will be treated in a particular year.

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. Saeid Sanei, J. Chambers; EEG Signal Processing (chap.2); Wiley, 2007,UK
13. Rao; Bispectral Analysis of non-linear Time Series; in Handbook of Statistics; Amsterdam 1993
14. C.M. Bishop: Pattern Recognition and Machine Learning. New York, NY: Springer; 2006.
15. B. Schölkopf, Learning with kernels support vector machines, regularization, optimization, and beyond, MIT Press.
16. Le Cun, Bottou, Orr, Müller, Efficient Backprop. http://yann.lecun.com/exdb/publis/
17. L. Bottou, Stochastic Gradient Descent Tricks; http://leon.bottou.org/papers/bottou-tricks-2012

1.13. Coursework and evaluation

The course involves lectures, weekly assignments, lab assignments, a seminar presentation and three 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 by averaging the weights in each of the parts of the course
    - 1/3 Part I
    - 1/3 Part II
    - 1/3 Part III

  The evaluation for each part will include exercises, lab assignments and reports on research topics in time series.

  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 or written examination on the following material
  - Exercises [only if the exercises are turned in]
  - Lab assignments [only if the lab assignments are turned in]
  - Report [only if the reports 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.

- Written exam [mandatory]