Modern theory of detection and estimation

Academic Year: (2019 / 2020) **Review date: 22-04-2019**

Department assigned to the subject: Signal and Communications Theory Department

Coordinating teacher: GOMEZ VERDEJO, VANESSA

Type: Compulsory ECTS Credits : 6.0

Year : 3 Semester : 1

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Statistics, Calculus II, Systems & Circuits

OBJECTIVES

After this course students will understand the principles of estimation and decision problems. Students will understand that, for the correct understanding of these problems, it is necessary to master three basic probability theory elements: 1) the likelihood, 2) the difference between a priori and a posteriori uncertainty, and 3) Bayes' Theorem. They will also understand the concepts of generalization and sufficient statistics. Finally, it will become apparent the advantages (both analytical and computational) inherent to Gaussian problems and linear solutions. (PO a)

From a practical point of view, students will learn to identify the convenience of following an analytical or machine approach for concrete situations. They will acquire the necessary knowledge to face an analytical resolution of a decision or estimation problem when complete statistical information is available, knowing also some semianalytical approaches for scenarios with partial information. When no statistical information is available, they will know how to design a regression or classification model, using data sets for learning its parameters: splitting the available data into training, validation and test sets, and applying algorithms for model order selection and parameter adjustment. Furthermore, different criteria for measuring the quality of deciders and estimators, as well as their generalization capabilities, will be introduced. Finally, students will study how these tools for estimation and detection can be adapted to deal with temporal series, and to implement adaptive solutions. (PO b)

During the course, students will study the previous concepts from a theoretical point of view, and will also apply them for the resolution of several study cases in practical sessions. During these sessions, students' work will help them improve the following general skills:
* Ability to identify and understand particular estimation and decision problems, and to propose practical solutions taking into account the characteristics of such problems (availability of historic data, possible computational constraints, etc) (PO e)
* Ability to design the experiments for the evaluation of the implemented estimators and deciders. (PO b)
* Knowledge of a simulation and mathematical modeling software application, which is widely used in engineering (Matlab) (PO k)

DESCRIPTION OF CONTENTS: PROGRAMME

Block 0 - Introduction to Statistical and Machine Learning
- 0.1. Estimation and classification concepts
- 0.2. Examples of application of estimators and classifiers
- 0.3. Previous knowledge

Block 1 - Classification
- 1.1. General view of the decision problem
- 1.2. Decision Theory
  - * The concept of decision-maker
  - * False Alarm, Miss, and Detection Probabilities. Error and success probability
  - * ML and MAP decision
  - * Minimisation of the expected cost: Optimal Bayesian decider
  - * LRT tests.
  - * Characteristic Curves (OC).

Block 2 - Estimation and Filtering

2.1. General view of the estimation problem
2.2. Estimation Theory¿
* Characterization: Calculation of average cost¿
* Design: Minimization of average cost¿
* Estimate MSE, MAD, MAP
* Design of estimators with restrictions: case without restrictions vs. case with restrictions
* LMSE estimate
* Estimation with Gaussian distributions
* ML estimate¿
2.3. Linear Filtering
* ML linear estimation problem subject to Gaussian noise
* Signal filtering with the previous model:¿
- Formulation of the signal filtering problem¿
- Construction of the observation matrices from the signals¿
* Iterative minimization of the average square error: LMS

LEARNING ACTIVITIES AND METHODOLOGY

THEORY
Theory sessions consist of lectures in which the basic concepts of the course will be introduced, illustrating them with a large number of examples (POs a and e)

PROBLEMS
Exercises and problems similar to those to be proposed in the exam will be solved. Students will have problem statements available at the beginning of the course, so that they can work on them before they are solved in class. (POs a and e)

PRACTICAL SESSIONS
Sessions in which students will apply the concepts presented in the course with the help of a computer. Students will deal with estimation and classification problems with real data, and will have to evaluate the performance of the implemented systems (PO b). During these practical sessions students will use Matlab as the simulation tool. (PO k)

ASSESSMENT SYSTEM

Students will be graded according to:

a) Exercises and theory questions to be solved by the students during some sessions along the course: 20% of the course mark (POs a and e)

b) The practical work carried out during the practicals will be assessed with lab exams: 20% of the course mark (POs b, e, and k)

c) Final exam consisting of a theory part with questions and short exercises, followed by several problems: 60% of the course mark (POs a and e)

Students who do not follow the continuous evaluation procedure, will be assessed according to the general rules established by the University.

% end-of-term-examination:	60
% of continuous assessment (assigments, laboratory, practicals…):	40

BASIC BIBLIOGRAPHY

- H. L. Van Trees Detection, Estimation and Modulation Theory (vol. 1), Wiley, 1968.
- R. O. Duda, P. E. Hart, D. G. Stork Pattern Classification, Wiley, 2001.
- S. Haykin Adaptive Filter Theory, Prentice-Hall, 2002.

ADDITIONAL BIBLIOGRAPHY

- A. Papoulis Probability, Random Variables and Stochastic Processes, McGraw-Hill, 2002.
- H. V. Poor An Introduction to Signal Detection and Estimation, Springer, 1998.
- M. H. Hayes Statistical Digital Signal Processing and Modelling, Wiley, 1996.
- S. M. Kay Fundamentals of Statistical Signal Processing. Detection Theory., Prentice-Hall, 1998.