COMMUNICATION ENGINEERING AND ELECTRONIC TECHNOLOGIES

(Lecce - Università degli Studi)

Teaching STATISTICAL SIGNAL PROCESSING AND LEARNING

GenCod A006426

Owner professor Giuseppe RICCI

Teaching in italian STATISTICAL SIGNAL PROCESSING AND LEARNING

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SSD code ING-INF/03

Reference course COMMUNICATION ENGINEERING AND ELECTRONIC

Course type Laurea Magistrale

Credits 9.0

Teaching hours Front activity hours: 81.0

For enrolled in 2022/2023

Taught in 2022/2023

Course year 1

Language ENGLISH

Curriculum PERCORSO COMUNE

Location Lecce

Semester First Semester

Exam type Oral

Assessment Final grade

Course timetable https://easyroom.unisalento.it/Orario

BRIEF COURSE DESCRIPTION

Course Content.

Introduction: examples of statistical reasoning (7 hours). Review of probability theory and rudiments of multivariate normal theory (7 hours). Solution to assigned problems (3 hours). Estimation Theory: Classical and Bayesian Parameter Estimators (ML, LS, WLS, ILS, MAP, MMSE, and LMMSE estimators). How to measure the performance of an estimator. Cramer-Rao bounds (17 hours). Solution to assigned problems (18 hours). Computer generation of random vectors and moment estimation (3 hours). Application of LMMSE estimation to filtering and beamforming. Minimum variance and minimum power distortionless beamformers. Linearly constrained minimum variance and minimum power beamformers. Generalized sidelobe canceler (5 hours). Steepest-descent algorithm: derivation and analysis. Least-mean-square algorithm: derivation and analysis (4 hours). An introduction to supervised learning. The expectation-maximization algorithm (6 hours). Detection Theory: Neyman-Pearson Lemma, Testing of composite binary hypotheses, UMP tests, GLRT, Constant False Alarm Rate property (6 hours). Solution to assigned problems (2 hours). A topic selected by each group of students as for instance: direction of arrival estimation, discrete-time Kalman filter and extended Kalman filter, etc.

REQUIREMENTS

Prerequisites: sufficiency in calculus, probability theory, and linear algebra.

COURSE AIMS	**Overview.** This is a course in estimation and detection theory; it is aimed at providing principles and tools to solve problems in signal processing, radar, sonar, and communication. It will also serve as the necessary prerequisite for more advanced courses in communication engineering. **Learning Outcomes**. ***Knowledge and understanding*** After the course the student should understand the main aspects of estimation and detection theory. ***Applying knowledge and understanding*** After the course the student should be able to *formulate and solve parameter estimation problems and derive corresponding Cramer-Rao lower bounds. *Formulate and solve detection problems resorting to the optimum (i.e., Neyman-Pearson test or UMP test) if possible or to a suboptimum one (GLRT). *Evaluate the performance parameters and discuss complexity issues associated with different solutions. ***Making judgements*** Students should acquire the ability to compare pros and cons of different approaches to the solution of a specific problem through examples and problems. ***Communication*** The ability to communicate on technical topics should be acquired by elaborating on methods of detection and estimation theory. ***Learning skills*** Selected problems will be proposed that require elaborating on introduced concepts and methods, also with the help of selected readings suggested by the instructor (from the list of references). Identifying solutions to non trivial problems will be important to be ready for autonomous lifelong learning.
TEACHING METHODOLOGY	Lectures, exercises, and computer projects. Problem-solving skills are of paramount importance and are gained via assigned homeworks.
ASSESSMENT TYPE	Written exam (70%). The exam consists of two cascaded parts (maximum overall duration: two hours and a half): the first part is closed book (suggested duration 50 minutes); the student is asked to illustrate two theoretical topics; it is aimed to verify to what extent the student has gained knowledge and understanding of the selected topics of the course and is able to communicate about his/her understanding (the maximum score for illustrating each topic is typically 5/30); the second part, that starts when the student has completed the first part, is open book and requires solving two (or three) problems; it is aimed to determine to what extent the student has: 1) the ability to identify and use data to formulate responses to well-defined problems, 2) problem solving abilities and the capacity to integrate different concepts and tools (the maximum score for the solution of each problem is typically 10/30 or 6-7/30 if the second part of the exam requires solving three problems). Homeworks (30%). Students will work in groups on specified topics based on textbooks and articles. The topics will be discussed during classes.
OTHER USEFUL INFORMATION	**Office Hours:** by appointment; contact the instructor by email or at the end of class meetings.

REFERENCE TEXT BOOKS

[1] Handouts (in progress).
[2] L. L. Scharf, ``Statistical Signal Processing: Detection, Estimation, and Time Series Analysis,'' Addison-Wesley, 1991.
[3] H. L. Van Trees, ``Detection, Estimation and Modulation Theory,'' Part. 1, John Wiley & Sons, 1968.
[4] H. L. Van Trees, ``Optimum Array Processing. Part. 4 of Detection, Estimation, and Modulation Theory," John Wiley & Sons, 2002.
[5] S. M. Kay: ``Fundamentals of Statistical Signal Processing: Estimation Theory,'' Volume I, Prentice-Hall, 1993.
[6] S. M. Kay: ``Fundamentals of Statistical Signal Processing: Detection Theory,'' Volume II, Prentice-Hall, 1998.
[7] Y. Bar-Shalom, T. E. Fortmann, ``Tracking and Data Association, Academic Press'', 1988.
[8] Y. Bar-Shalom, X., Rong Li, T. Kirubarajan, ``Estimation with Applications to Tracking and Navigation. Theory Algorithms and Software,'' John Wiley & Sons, 2001.
[9] S. Haykin, ``Adaptive Filter Theory,'' Prentice-Hall, 1996.