SIGNAL THEORY engineering physics

Department: Signal Theory and Communications
Lecturer in charge: Antonio Pascual Iserte
Other lecturers: Francesc Rey Micolau
Academic Period: 3A
ECTS credits: 6

CONTENTS

1. **SIGNALS AND SYSTEMS IN THE TIME DOMAIN**
   a. Analog and discrete-time signals. Basic signals. Energy and power.
   b. Analog and discrete-time systems. Examples (including transformations over the time variable) and properties/classification.
   c. Linear time invariant systems:
      i. impulse response and convolution: properties
      ii. differential equations for analog systems
      iii. finite differences equations for discrete-time systems (FIR/IIR systems)

2. **SIGNALS AND SYSTEMS IN TRANSFORM DOMAINS**
   a. Analog signals and systems:
      i. Laplace transform and transfer function
      ii. Fourier transform/series and frequency response (analog filters)
      iii. examples and properties
   b. Discrete-time signals and systems:
      i. Z transform and transfer function
      ii. Fourier transform and frequency response (digital filters)
      iii. DFT and FFT
      iv. examples and properties

3. **A/D AND D/A CONVERSION**
   a. Sampling and alias generation: antialiasing filter.
   b. Quantization noise.
   c. Change of the sampling frequency: decimation and interpolation.
   d. Signal reconstruction: ideal and zero-order hold (ZOH) interpolators.

4. **STOCHASTIC PROCESSES – RANDOM SIGNALS**
   a. Statistical characterization.
   b. Strict-sense and wide-sense stationary processes. Cyclo-stationary processes.
   c. Ergodicity in mean and correlation.

d. Autocorrelation and power spectral density. Wiener-Khinchin theorem.
e. Filtering of random signals.
f. Gaussian processes.

5. FUNDAMENTALS OF ESTIMATION THEORY

a. Introduction to estimation theory:
   i. definition of estimator
   ii. quality criteria: bias, variance, mean square error (MSE), consistency
   iii. example: estimation of the mean of a process
b. Classical estimation theory:
   i. minimum variance unbiased estimator (MVUE)
   ii. efficient estimators: Cramer-Rao bound
   iii. maximum likelihood (ML) estimation
c. Bayesian estimation theory:
   i. parameter characterization: prior distribution
   ii. Bayesian risk: maximum-a-posteriori (MAP), posterior mean

6. SPECTRAL ESTIMATION

a. Non-parametric spectral estimation:
   i. periodogram: bias (leakage), variance, and consistency
   ii. smoothing the periodogram through windowing (Blackman-Tukey): Bartlett, Hamming, Kaiser, Blackman, etc.
   iii. Bartlett-Welch spectral estimation techniques: average of periodograms
b. Parametric spectral estimation:
   i. linear models of processes: AR, MA, ARMA
   ii. Yule-Walker equations

7. OPTIMAL WIENER FILTERING

a. Linear Bayesian estimator of minimum MSE.
b. Wiener filter and Wiener-Hopf equations.
c. Adaptive implementation (steepest descent-SD, least mean square-LMS, normalized LMS-NLMS).
d. Linear predictors. Examples.

LAB SESSIONS

The course will contain around 6 lab sessions (2 hours each session and most of them using MATLAB) that will be carried out jointly by 2 students. The contents of the lab sessions will cover some concrete topics of the course and will be organized in small groups of 20 students at most. The evaluation will be based on the previous work, the work performed during the session at class, the delivered reports, and/or some exam.

EVALUATION METHOD

PE: partial exam
FE: final exam (including all the contents of the course)
LS: lab sessions

Final mark = max { 0,60·FE + 0,25·PE + 0,15·LS , 0,85·FE + 0,15·LS }

Only when the final mark is not passed in the ordinary period, an extraordinary exam (**EE**) will be carried out including all the contents of the course. In this case, the final mark will be calculated as follows, where it is taken into account that the 15% corresponding to the lab sessions (LS) cannot be re-evaluated:

Final mark = max { 0,60·FE + 0,25·PE + 0,15·LS , 0,85·FE + 0,15·LS , 0,85·EE + 0,15·LS }

LANGUAGE

Material: all the material used in class will be in English
Classes: Spanish, Catalan
Previous work and lab reports: English, Spanish, Catalan

BIBLIOGRAPHY

BASIC BIBLIOGRAPHY

- Alan V. Oppenheim, Alan S. Willsky, S. Hamid Nawab, *Signals and Systems.* Ed. Prentice-Hall.
- Monson H. Hayes, *Statistical Digital Signal Processing and Modeling.* Ed. Wiley.
- Steven M. Kay, *Fundamentals of Statistical Signal Processing: Estimation Theory.* Ed. Prentice-Hall.

COMPLEMENTARY/SPECIFIC BIBLIOGRAPHY

- Athanasios Papoulis, *Probability, Random Variables, and Stochastic Processes.* Ed. Mc-Graw-Hill.
- Dimitris G. Manolakis, Vinay K. Ingle, Stephen M. Kogon, *Statistical and Adaptive Signal Processing: Spectral Estimation, Signal Modeling, Adaptive Filtering, and Array Processing.* Ed. Artech House.
- John G. Proakis, Dimitris G. Manolakis, *Digital Signal Processing: Principles, Algorithms, and Applications.* Ed. Prentice-Hall.
- Simon Haykin, Barry Van Veen, *Signals and Systems.* Ed. Wiley.
- Alan V. Oppenheim, Ronald W. Schafer, *Discrete-Time Signal Processing.* Ed. Prentice-Hall.
- Louis L. Scharf, *Statistical Signal Processing: Detection, Estimation, and Time Series Analysis.* Ed. Addison-Wesley.