ECE 603: Statistical Signal Processing
Winter 2020

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Schedule: [redacted]
Please note there will be no lecture during the week of January 20.

Course Website: LEARN ECE603.

Pre-requisite: ECE604 or equivalent (Introduction to probability and random variables)

Aims: The principal aim of this course is to introduce the students to estimation and recursive stochastic algorithms that play an important role in modern signal processing and machine learning. The course is intended for graduate students with interests in communications, networking, and in machine learning. A course will present the salient ideas and tools associated with signal estimation and least squares theory and will emphasize the underlying structures.

The first part of the course will cover basic ideas from statistical point estimation theory introducing the concepts of efficiency and consistency of estimators. This will include minimum mean square estimates and maximum likelihood estimates and the role of the Fisher information as well as the Cramer-Rao lower bound.

The second part will deal with estimation theory for random sequences and signals. The first part will deal with wide sense stationary processes and the structure of Hilbert spaces associated with them culminating in the Wold decomposition. We will then study the problems of filtering, smoothing and prediction of stationary signals in the presence of noise. From stationary signals we will move on to non-stationary signals generated by noisy state-space models and the important ideas of Kalman filtering. We will study the asymptotic theory in detail. We will conclude with a discussion of parameter estimation for linear dynamic models.

The overall aim is to provide the student with a fundamental understanding of the structures involved in estimation and statistical inference along with the underlying algorithmic and probabilistic ideas. At the end of the course the student will be well equipped to apply the ideas to the design of statistical signal processing algorithms, develop signal and parameter estimation algorithms, and formulate and solve statistical decision problems arising machine learning.

COURSE OUTLINE

1. Review of Probability: Expectations, Conditioning, the Gaussian distribution, CLT, and SLLN.
2. Introduction to point estimation theory. Minimum mean square estimates.
3. Consistency, efficiency of estimators. Fisher information matrix and the Cramer-Rao lower bound. Sufficient statistics and the Rao-Blackwell theorem
4. Resursive estimators, maximum likelihood estimators- The EM algorithm
5. Introduction to hypothesis testing. Bayesian decision theory, The Neyman-Pearson lemma. Kullback-Liebler information. Wasserstein metric.

6. Filtering, prediction and smoothing of w.s.s. sequences. Recursive least squares. Yule-Walker equations.

7. Gauss-Markov processes and state space models. Discrete-time Kalman filtering. Asymptotic theory.

8. Mathematical tools for learning. Convergence and ode method. Stochastic gradient. Robbins-Monroe and Kiefer-Wolfowitz algorithms. Frank-Wolf.

TEXT AND REFERENCES

There is no single text that covers all the material adequately. Class notes on selected topics will be given out.

The following references are excellent for selected topics.

References:

B. Picinbono, *Random Signals and Systems*, Prentice-Hall, 1993

T. Kailath, A. Sayed, and B. Hassibi; Linear Estimation, Prentice-Hall, 1999.

V. Poor; Introduction to signal detection and estimation, Springer-Verlag

A. V. Balakrishnan, Kalman filtering theory, Optimization Software Publ, 1995

T. Hastie, R. Tibshirani and J. Friedman, The Elements of Statistical Learning, Springer 2017.

Course Evaluation

- Weekly problem sets will be handed out. You will be required to turn in selected problems.
- There will be an in-term examination. The date will be announced later.
- In addition, there will be one take home final examination.
- **Marks distribution:** HW 20%, Midterm 30% Final Exam 50%

Additional remarks

- All in term exams will be closed book. You will be allowed to bring in one page of summary.
- If you miss an in-term exam no make-up exam will be given. If you have a valid reason then your final grade will be based on your performance in the rest of the course.
- Dishonesty will be dealt with harshly.

I look forward to an exciting journey with you all.