EE583: Statistical Signal Processing
Spring 2018
Syllabus

Ming Hsieh Department of Electrical Engineering
University of Southern California

Time: 3.30 – 4.50pm TuTh
Location: TBD
Instructor: Richard Leahy
Office Hours: 5.00-6.00pm TuTh
Office: EEB400c
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Midterm: 3.30-4.50pm Tuesday, March 6^{th}.
Final: 2-4pm, Tuesday, May 8^{th}.

Descriptive Text
Characterization of discrete time random processes, parametric and non-parametric spectral estimation, adaptive filtering, signal subspace methods, independent components analysis, non-Gaussian signal processing.

Prerequisites: EE483, EE441, EE503

Intended Audience: This course is intended for MS and PhD graduate students in EE with an interest in signal processing or digital communications. The material draws on the core skills developed in linear algebra (EE441), probability and statistics (EE503) and digital signal processing (EE483) to explore the range of statistically-based methods that are used for analyzing and characterizing signals and systems.

Course Overview: The class begins with an introduction to discrete random processes, concepts of widesense stationarity and egodicity, and how these processes are characterized by the covariance and the power spectral density. We then describe parametric representations of random processes through the idea of passing white noise through linear time invariant filter. We then introduce concepts of parameter estimation (linear estimators, maximum likelihood, and Bayesian estimation) and their properties. We will study the Wiener filter for optimal signal filtering. Parametric and nonparametric spectral estimation methods will be described. We then study adaptive filters, starting with the LMS algorithm and progressing to RLS. We will then explore concepts of spatial filtering, beamforming and the extension of adaptive filtering to adaptive beamforming. Finally we will explore non-parametric approaches to data analysis based on orthogonality and statistical independence through the use of Principal Components and Independent Components Analysis. As time permits we will also explore other aspects of non-Gaussian signal processing and other extensions of the material outlined above. Throughout the course we will use Matlab or Python exercises to explore the practical applications of the methods described.

Learning Objectives:
The primary goal of this course is to introduce graduate students to the mathematical ideas that form the basis for modern statistically-based analysis of signals and systems. These methods are used in a wide range of engineering applications including: the analysis of the frequency content of signals, noise cancellation, compensation for multipath effects in communication channels, identification of structured signals in noise, and separation of unknown signals with unknown mixing matrix (the cocktail party problem). On completion students will be familiar with the mathematics underlying these techniques, and with the problems to which they can be applied, and they will have practical experience with a cross-section of these methods through implementation and experimentation using Matlab.

Required Texts:

1. Statistical Digital Signal Processing and Modeling, Monson Hayes, J Wiley and sons. ISBN 0-471 59431-8.

Recommended Books

1. Digital Processing of Random Signals: Theory and Methods, Boaz Porat, Dover Books on Electrical Engineering, First Ed. 2008, ISBN-13: 978-0486462981
2. Fundamentals of Statistical Signal Processing: Estimation Theory, Steven M. Kay, Prentice Hall, 1st edition, 1993, ISBN-13: 978-0133457117.

Grading:
1. *Home Works 30%*
Weekly home works will be given for students that will include a mixture of theoretical and practical (matlab-based) questions. .

2. *Mid-Term Exam: 30% each*
80 minute midterm exams will be given in class during the 8th week. The exams will test student comprehension of concepts and techniques presented through week 7.

3. Final Exam: 40%
A 2 hour final exam will be given according the university's final schedule. The exam will be comprehensive, emphasizing core concepts introduced throughout the course.

Course Outline

Part 1: Fundamentals

Week 1: Discrete time random processes, stationarity and ergodicity

Reading assignment: Hayes, Chapter 2 (except 2.3.10) – review; Chapter 3-1-3.3

Week 2: The covariance and power spectral density. Cross covariance and spectral density. Filtering of random processes.

Reading assignment: Hayes, Chapter 3.4.

Week 3: Poles, zeroes and spectral factorization. Wold decomposition.

Reading assignment: Hayes, Chapter 3-5-3.6.

Week 4: Matrices and SVD, Optimization using real and complex vectors. Wirtinger derivatives. SVD

Reading assignment: Hayes, Chapter 2.3. Supplemental material

Week 5: Estimators and their properties. Maximum likelihood, Fisher Information and the Cramer Rao bound. Bayes theorem, MAP estimation and minimum mean squared estimation.

Reading assignment: supplemental materials

Part 2: Spectral estimation

Week 6: Nonparametric spectral estimation: Periodogram and beyond (windowing, zeropadding, averaging, multi-taper methods)

Reading assignment: Hayes, chapter 8.1-8.2, supplemental material

Reading assignment: Hayes Chapter 7.2. Supplemental material

Week 7: The Wiener filter. Parametric spectral estimation: AR and ARMA modeling, the Yule-Walker equations

Reading assignment: Hayes, chapter 7.2, chapter 8.4, 8.5.

Week 8: Minimum variance, MUSIC and other signal subspace analysis methods

Reading assignment: Hayes chapter 8.3-8.6, supplemental material

Part 4: Adaptive filtering

Week 9: **MIDTERM (march 6).** Adaptive filtering: the LMS algorithm

Reading assignment: Hayes chapter 9.1-9.2

Week 10: Adaptive filtering: recursive least squares, the constant modulus algorithm

Reading assignment: Hayes chapter 9.4 and supplemental notes.

Week 11: Spatial filtering and beamforming

Reading assignment: supplemental materials

Week 12: Adaptive beamforming and generalized side-lobe canceller.

Reading assignment: supplemental materials

Part 6: Non-Gaussian signal processing and other generalizations

Week 13: The cocktail party problem, independent components analysis and blind source separation

Reading assignment: supplemental material

Week 14: Connectivity, partial correlations and the concentration matrix. Granger and other causality measures.

Reading assignment: supplemental material.

Week 15: Review.

Statement for Students with Disabilities
Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

Statement on Academic Integrity
USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. *Scampus,* the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A: http://www.usc.edu/dept/publications/SCAMPUS/gov/. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at: http://www.usc.edu/student-affairs/SJACS/.