EE 503 Statistical Signal Processing and Modeling
(Fall 2020 – 2021)

Short Description:

This course is the first course on statistical signal processing in the graduate curriculum of Department of Electrical and Electronics Engineering, Middle East Technical University (METU). Topics covered in this course are random vectors, random processes, stationary random processes, wide sense stationary processes and their processing with LTI systems with applications in optimal filtering, smoothing and prediction. A major goal is to introduce the concept of mean square error (MSE) optimal processing of random signals by LTI systems.

For the processing of the random signals, it is assumed that some statistical information about the signal of interest and distortion is known. By utilizing this information, MSE optimal LTI filters (Wiener filters) are designed. This forms the processing part of the course. The estimation of the statistical information to construct Wiener filters forms the modeling part of the course. In the modeling part, we examine AR, MA, ARMA models for random signals and give a brief discussion of Pade, Prony methods for the deterministic modeling. Among other topics of importance are decorrelating transforms (whitening), spectral factorization, Karhunen-Loeve transform.

This course is a natural pre-requisite (not a formal one) to EE5506 Advanced Statistical Signal Processing. The estimation theory topics in EE 503 is mostly limited to the moment description of random processes which forms a special, but the most important, case of EE 5506.

Outline of Topics:

1. Review
    a. Basics of Mathematical Deduction
        i. Necessary, Sufficient Conditions
        ii. Proofs via contradiction, contraposition
    b. Basics of Linear Algebra
        i. Linear independence of vectors (points in linear space)
        ii. Range and Null space of operators
        iii. Projection to Range/Null Space (orthogonality principle)
        iv. Positive Definite Matrices
    c. Basic of Probability
        i. Probability as a mapping, axioms, conditional probability
        ii. Expectation, law of large numbers
        iii. Moments, moment generating function

2. Random Processes
    a. Random variables, random vectors (or a sequence of random variables), moment descriptions (mean, variance, correlation), decorrelating transforms
    b. Random processes, stationarity, wide Sense Stationarity (WSS), power spectral density, spectral factorization, linear time invariant processing of WSS random processes, ergodicity

    Ref: Therrien, Hayes, Papoulis, Ross

3. Signal Modeling
    a. LS methods, Pade, Prony (Deterministic methods)
    b. AR, MA, ARMA Processes (Stochastic approach), Yule-Walker Equations, Non-linear set of equations for MA system fit
    c. Harmonic Processes

    Ref: Hayes, Papoulis

4. Estimation Theory Topics
    a. Random parameter estimation
        i. Cost function, loss function, square error, absolute error
        ii. Conditional mean (regression line) as the minimum mean square error (MSE) estimator, orthogonality properties
        iii. Linear minimum mean square error (LMMSE) estimators, orthogonality principle
        iv. Regression line, orthogonality
        v. FIR, IIR, Causal–IIR Wiener filters
        vi. Linear Prediction, backward prediction
        vii. Random vector LMMSE estimation (multiple parameter)
    b. Non-random parameter estimation
        i. Maximum likelihood method
        ii. Best Linear Unbiased Estimator (BLUE)
        iii. Discussion of linear estimators for the linear observation model $y = Ax + n$
    c. Karhunen – Loeve Transform

Ref: Therrien, Hayes.

References:

[Hayes]: M. H. Hayes, *Statistical Signal Processing and Modeling*, Wiley, New York, NY, 1996.

[Therrien]: C. W. Therrien, *Discrete random signals and statistical signal processing*, Prentice Hall, c1992.

[Papoulis]: A. Papoulis, *Probability, Random Variables, and Stochastic Processes*, 3rd edition, McGraw Hill, 1991.

[Ross]: S. M. Ross, *Introduction to probability models*, 7th ed. Harcourt Academic Press, 2000.

For more info: http://users.metu.edu.tr/ccandan/ee503/ee503_fall201516/ (page of previous offering)

For more info: https://youtu.be/EO7v7vxIzs4 (video description of this syllabus)

On Covid-Special Semester EE 503 Course Conduct:

Every week three 50-minute recording of lectures will be placed on youtube. Videos will be recorded in the usual METU-EE classroom environment. Students are advised to take notes during lectures as usual. Two lecture videos will be released on Monday. The third video will be released on Wednesday.

On every Monday between 15:40 and 16:30 (3rd hour of EE 503 weekly schedule), there will be an interactive session. In this session, we will discuss the contents of videos released up to that time including the videos released on that Monday. I will try to answer your questions. We may have online MATLAB experiments during the interactive sessions as well.

Exams will be online. The students will be required to use **two cameras** during the exams. The details about the required camera setup will be announced before exams.

Grading:

- 4 mini exams (each 6% of overall grade)
- 3 Homeworks (each 4% of overall grade)
- Midterm Exam (24% of overall grade)
- Final Exam (40% of overall grade)
- Bonus: Interactive session attendance/participation/effort (at most 10% overall grade)