ECE 792-041 Statistical Methods for Signal Analytics

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Objective: (1) To introduce various statistical tools and prepare students with solid background in signal processing related research, and (2) to engage students in real-world signal analytics tasks.

Prerequisites: Any signal processing course. Basic programming skills.

Corequisites: Random Processes. **Time & Location:** 2 meetings per week @ EB2

Textbooks:

S. Haykin, Adaptive Filter Theory, Eds. 3, 4, or 5, Pearson.

M. Hayes, Statistical Digital Signal Processing and Modeling, Wiley, 1996.

P. Stoica, R. L. Moses, Spectral Analysis of Signals, Prentice Hall, 2005. [Online]

T. Hastie et al., The Elements of Statistical Learning, Ed. 2, Springer, 2009. [Online]

H. Scheffe, The Analysis of Variance, Wiley, 1959.

J. J. Faraway, Linear Models with R, Taylor & Francis, 2005. [Online]

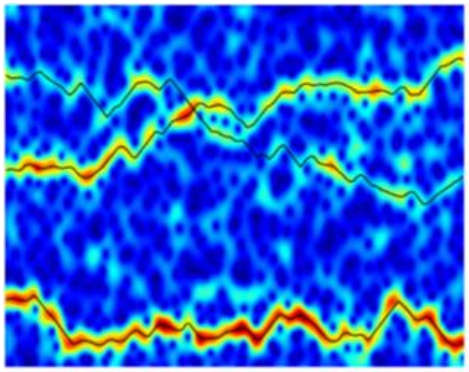
Topics:

I. Fundamentals

- Statistics & Random processes: method of moments, maximum likelihood (MLE), least-squares (LS), orthogonality principle, normal equations; stationarity, ergodicity, power spectral density (PSD), autocorrelation function (ACF), partial autocorrelation function (PACF).
- Numerical: condition number, eigendecomposition, singular-value decomposition (SVD), Levinson-Durbin algorithm, gradient descent, Newton's method, Quasi-Newton methods.
- Model selection: cross-validation (CV), analytical methods (AIC, BIC, MDL, etc.)

II. Signal Modeling and Optimum Filtering

- Time series models: autoregressive (AR), moving average (MA), ARMA. Yule-Walker equations, Wold decomposition.
- Discrete Wiener filtering: forward and backward linear predictions.
- Lattice prediction filter, joint-process estimation.



Spectrogram of a multi-trace signal

III. Adaptive Filtering

- Least-mean-squares (LMS) algorithm.
- Recursive least-squares (RLS) algorithm.

IV. Spectral and Frequency Estimation

- Nonparametric methods: periodograms and windowing methods, minimum-variance spectral estimation (Capon), amplitude and phase estimator (APES), iterative adaptive approach (IAA).
- Parametric methods: AR, MA, and ARMA spectral estimation; maximum entropy method.
- High-resolution subspace approaches: Pisarenko, MUSIC, ESPRIT.

V. Analysis of Variance (ANOVA)

- Estimable functions, Gauss-Markoff theorem.
- Confidence ellipsoids/intervals, t-test, F-test.
- ANOVA.

Workload & Grading: There will be 2–3 projects and 6 homework assignments (60%), one midterm exam (20%), and one final exam (20%). Projects are recommended to be done in Matlab, alternatively in R, Python, or C++.