ECE–595, Section 011, Fall 2011
Adaptive Filtering
Instructor: Balu Santhanam
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Goal

The goal of this course is to introduce the theoretical foundations of adaptive filtering algorithms and to explore the design, implementation and convergence issues associated with them. We will specifically look at the application of these algorithms in interference cancellation, target tracking, and biomedical signal processing related problems.

Instructor

My contact coordinates are:

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Textbooks and References

The two textbooks that will be used extensively in the class are:

1. Simon Haykin, "Adaptive Filter Theory," Fourth edition, Prentice Hall Inc, Upper Saddle River, New Jersey, 2002.

2. B. Widrow and S.D. Stearns, "Adaptive Signal Processing," Prentice Hall Inc, Upper Saddle River New Jersey, 1985.

Some other references that will be helpful in the class are:

- Athanasios Papoulis, "Probability, Random Variables, and Stochastic Processes," Second edition, McGraw-Hill Book Company, 1984.

- Gilbert Strang, "Linear Algebra and its Applications," Third Edition, Harcourt Brace Jovanovich Inc, 1988.

- "Applied Optimal Estimation," edited by Arthur Gelb, Analytical Sciences Corporation, 1974.

- B.D.O. Anderson and J.B. Moore, "Optimal Filtering," Prentice Hall Inc, Englewood Cliffs, New Jersey, 1979.
- M.H. Hayes, "Statistical Digital Signal Processing and Modeling," John Wiley and Sons, Inc., 1996.

These references will be further augmented with web-based lecture notes and review papers in the area of adaptive filtering.

Grading Scheme

Problem Sets/Computer Exercises: 40 %
Theoretical component: Exam : 30 %
Applications component: Final Project: 30 %

Library and Computing Resources

If you do not have an EECE account, you are urged to do so by filling in the online form. This will provide you access to MATLAB that is installed on the EECE network. A folder containing solutions to problem sets and exercises and class notes will be placed in the reserve desk at the CSEL library. Copies of the reference books will also be placed in the CSEL library for 1 hour check-out.

Prerequisites

You are expected to have taken the courses EECE–541 (random signal processing), EECE–539 (digital signal processing) or the equivalent. You will also be expected to program in MATLAB. I can provide you with references to help you in some of these areas. Needless to say that it is your responsibility to ensure that you have the requisite knowledge from these courses.

Outline

1. **Review of random processes**: stationary random processes, WSS processes, ergodicity, correlation matrix, AR/MA processes, power spectral factorization, Wold's decomposition, modes of convergence of random sequences, optimal filtering, linear prediction of AR random processes.

2. **LMS algorithm**: steepest descent algorithm, convergence and properties of the steepest descent algorithm, LMS algorithm, small step-size theory, error analysis and learning curves, transient behavior and convergence considerations, applications of the LMS algorithm to channel equalization, normalized LMS (NLMS) algorithm, stability analysis of the NLMS algorithm, Affine projection adaptive filters, block-adaptive LMS, frequency domain LMS (XLMS), self orthogonalizing XLMS algorithm, subband–LMS algorithm.

3. **Least-squares algorithm**: principle of least-squares estimation, properties of least-squares estimates, singular-value decomposition (SVD) and pseudo-inverse, recursive least-squares (RLS) algorithm, properties and convergence analysis of the RLS algorithm, application to channel equalization and adaptive prediction.

4. **Other adaptive filtering algorithms**: derivatives of the LMS/RLS algorithms, adaptive correlation enhancement (ACE) algorithm, constant modulus algorithm (CMA).

5. **Kalman filtering**: innovations process, state estimation using the innovations process, initialization, extended Kalman filter, square-root Kalman filter, applications to the multiple target tracking problem.

6. **Order recursive adaptive filters**: gradient adaptive lattice predictors, recursive least-squares lattice filters.

7. **IIR adaptive filtering**: output-error method, equation, error method, adaptive Laguerre filters.