**The Cooper Union**
**Department of Electrical Engineering**
**ECE416 Adaptive Filters**
**Course Description**
September 4, 2012

# Outline

## Preliminary Concepts

1. Overview of adaptive filters and their applications:

   (a) Formulation and configuration of adaptive algorithms for applications including: system identification, equalization, noise cancellation, array processing (e.g., beamforming). Students will implement and analyze adaptive algorithms in MATLAB for each of these applications during the course.

   (b) Filter structures: transversal and lattice filters; systolic arrays.

   (c) Performance parameters.

2. Discrete-time stochastic processes:

   (a) correlation and power spectral density for WSS processes;

   (b) ARMA models;

   (c) special processes including sinewaves plus noise, complex Gaussian processes.

3. Linear algebra:

   (a) review of the orthogonality principle;

   (b) special matrices: Hermitian, Toeplitz, positive-definite, unitary;

   (c) eigenanalysis, SVD and pseudo-inverse; matrix factorizations (Cholesky, QR, LU); efficient computations;

   (d) complex generalization of gradients and Lagrange multipliers; principle of steepest descent.

4. Optimum filters and stochastic realization:

   (a) discrete-time Wiener filter;

   (b) linear prediction;

   (c) Levinson-Durbin recursion and lattice filters.

### LMS Algorithm

1. Standard LMS algorithm: formulation and performance analysis.
2. NLMS and other variations of LMS. Comparative study of algorithms, and techniques for analysis.

### RLS Algorithm

1. Least-squares versus least mean-square problems.
2. Derivation of RLS algorithm and techniques for analysis.
3. Kalman filters and relation to RLS.

### Variations of RLS

1. Square-root formulation of Kalman filters and RLS algorithms. Connections with QR decomposition.
2. Order-recursive algorithms.
3. Adaptive algorithms implemented on lattice filters and systolic arrays.

### Array Processing Applications

Discussions of the application of adaptive algorithms and numerical linear algebra to array processing will be presented throughout the course. The summary of topics that will be covered is as follows:

1. Linear uniformly spaced arrays viewed as FIR filters. Generalized array geometries. Steering vectors, subspace concepts. Narrowband versus wideband environments.
2. Optimal beamformers: MVDR, general sidelobe cancellers. AOA estimation via MUSIC algorithm.
3. Constrained adaptive beamforming.

### Additional Topics

Additional topics may be covered as time permits.

## Course Information

The primary text is S. Haykin, *Adaptive Filter Theory,* Prentice-Hall, 4th ed., 2002. The plan is to cover most of chapters 1 through 12 (skipping 7), and parts of 13 and 14. We will also cover the Background chapter and a significant number of the Appendices in the text. I will also give some handouts on additional topics.

There will be a number of problems assigned on the underlying theory, and computer problems where you will implement adaptive algorithms in MATLAB and test them on simulated signals. Most of these problems will be assigned from the textbook. The MATLAB work must be done **individually** unless I specify otherwise.
There will be two one-hour exams.
Towards the end of the semester, each student is required to read a technical article on a topic related to the course, either from IEEE Transactions or another source at a similar technical level, and a summary of the article will be presented formally to the class. Your article choice must be approved by me in advance. More details on this assignment will be given in class.
The grade will be computed as follows: 30% exams, 50% homework (1/3 "theory", 2/3 MATLAB), 20% technical presentation.

**Schedule:**

We will normally meet Tuesday 11-12 and Thursday 9-11. There will be no class on the following Tuesdays: 9/18, 10/2, 10/9. I may also have to cancel class Tuesday 12/4 (that is during the ABET visit). Note that on Tuesday 11/20 the school follows a THURSDAY schedule. The last day of regular class is Tuesday 12/11. We will have presentations during the finals week, schedule to be announced later.

**Contact:**

Everyone is REQUIRED to join the email group *cuece416f12@googlegroups.com.* Instructions to join are:

- if you are going to use a gmail address, go to *http://groups.google.com/groups/cuece416f12* and ask to join;
- if you are going to use another address, send email to *fredf88cooper@gmail.com* and I will send you an invite.

Contact me via email *(fredf88cooper@gmail.com)* if you have questions outside of class time, or if you want to set up an appointment to meet in person.