E9 211: Adaptive Signal Processing

Lecture 1: Introduction
Course information

➤ Instructor:
  – Sundeep Prabhakar Chepuri.
    Email: spchepuri@iisc.ac.in

➤ Exercise sessions:
  – Amaralingam Madapu.
    Office: ECE MP building 121

➤ Class schedule:
  – Tuesdays and Thursdays 1.30-3.00pm MP 30, ECE dept.
  – Office hours: Tuesdays 3.10-3.30pm, MP 128

➤ Course webpage:
  https://ece.iisc.ac.in/~spchepuri/classes/e9211.html
Other resources:

Grading and course requirements

► Three homeworks (programming): 10% each, i.e., 30% in total
  – Mandatory to participate in the final exam and to pass the course.
  – Prepare reports using LaTeX.
  – Submit only pdf files. Include Matlab scripts as appendices. Word documents will not be graded.
  – Late submissions are allowed, but will not be graded.

► Midterm exam on October 3, 2019: 20%
  – Written exam. A4 cheat sheet will be allowed.

► Final exam on TBD: 50%
  – Written exam. A4 cheat sheet will be allowed.
  – Needless to say, includes the entire syllabus.
Review of linear algebra and random processes.
Optimal estimation.
Linear estimation.
Steepest-descent algorithms.
Stochastic-gradient algorithms.
Least squares and recursive least squares.
Kalman filtering (and Particle filtering).
Blind deconvolution and beamforming.
Subspace tracking.
Robust adaptive filters.
Selected emerging topics
- Graph signal processing.
- Iterative solvers of large-scale linear systems.
- Ill-posed inverse problems.
Open-loop adaptation
Closed-loop adaptation
Applications

- Signal modeling and identification
- Inverse modeling, equalization, and deconvolution
- Prediction
- Interference cancellation
Signal modeling and identification
Signal modeling and identification

Seismic impulse response for subsurface imaging ("layer identification").
Inverse modeling, equalization, and deconvolution

Example: channel equalization
Prediction

\[ x_k \rightarrow \text{Delay} \rightarrow z^{-M} \rightarrow x_{k-M} \rightarrow \text{Adaptive filter} \rightarrow H_k \rightarrow y_k \rightarrow \Sigma \rightarrow e_k \]

Graph showing the input \( x_k \), delay \( z^{-M} \), adaptive filter \( H_k \), and output \( y_k \) and error \( e_k \) over a range of sample numbers from 0 to 400.
Interference cancellation

![Diagram of interference cancellation system]

- Signal source
- Noise source
- Primary input: $s + n_0$
- Adaptive filter
- Reference input
- Filter output: $y$
- Error: $\epsilon$
- System output: $\epsilon$
- Adaptive noise canceler

**Diagram Explanation:**
- The signal source is combined with noise $n_0$ to form the primary input $s + n_0$.
- The adaptive filter produces a filter output $y$.
- The error $\epsilon$ is calculated as the difference between the primary input and the filter output.
- The adaptive noise canceler adjusts its parameters to minimize the error $\epsilon$.
Interference cancellation
Course objectives

▶ How to **mathematically formulate** such problems?

▶ We use **optimization** techniques to compute filter weights. Are the filter weights that we compute **unique**?

▶ How to analyze the **performance** of the adaptive algorithms? Are these adaptive filters **stable**? Do they **converge** or diverge?