EE 628 - Spring 2019
Project 2, Due Date: April 2, 2019

1. In what follows, you will be given the steps to generate a desired signal from an LTI system, and then design adaptive systems to estimate the parameters of the "black-box" that generated the desired signal.

   (a) **Desired signal**: Implement an LTI system whose impulse response is given by $h(n) = \delta(n) + 0.2\delta(n-1) - 0.8\delta(n-3)$. Excite this system with white Gaussian noise of zero mean and unit variance. The output of this system will be our desired signal, $d(n)$.

   (b) **Performance bounds**: Assuming zero mean, unit variance, white noise input, and no order mismatch on the adaptive filter, determine, for the scalar LMS:

      i. The minimum MSE
      ii. Stability bounds on the step size
      iii. The time constants
      iv. Misadjustment

   (c) **LMS**: Implement the LMS algorithm. You can initialize the algorithm with an all-zero vector for $\boldsymbol{b}$. Assume you know that $\boldsymbol{b}$ should have 4 elements (no order mismatch). As the algorithm runs, record the values of the error, and plot the error for each iteration of the algorithm. Do this for two values of step-size, μ:

      i. Use a small value of the step size μ.
      ii. Use a large value of μ.

   (d) For each of the step-size values above, run the LMS algorithm 50 times, independent of each other. Average the error evolution curves, and plot the average versus iterations.

   (e) **Newton algorithm**: Implement the Newton algorithm. Assume you have the $\mathbf{R}_{xx}$ matrix estimated perfectly. Discuss the impact on convergence.

   (f) **NLMS**: Implement the normalized LMS.

   (g) **BLMS**: Implement the block LMS with different values of block-size, N, and

      i. No overlap between blocks
      ii. 50% overlap between blocks
      iii. What effect does overlap have?
      iv. What effect does block-size have?

   (h) **FDAF**: Implement the frequency domain adaptive filter with no overlap between blocks.

   (i) Compare all the results. What do you observe?

2. In this example, you will be asked to adapt to an all-pole system.

   (a) **Desired signal**: Implement an LTI system whose impulse response is given by $h(n) = 0.8^n u(n)$. Excite this system with white Gaussian noise of zero mean and unit variance. The output of this system will be our desired signal, $d(n)$.

   (b) **Performance bounds**: Assuming zero mean, unit variance, white noise input, and no order mismatch on the adaptive filter, determine, for the scalar LMS:

i. The minimum MSE
ii. Stability bounds on the step size
iii. The time constants
iv. Misadjustment

(c) **LMS**: Use an all-zero system for $\boldsymbol{b}$. Implement the LMS algorithm. You can initialize the algorithm with an all-zero vector for $\boldsymbol{b}$. As the algorithm runs, record the values of the error, and plot the error for each iteration of the algorithm. Select one value of the step-size, μ, which works well. Run the algorithm for different values of L, i.e., change the number of elements in $\boldsymbol{b}$. Try:

i. $L = 2$
ii. $L = 4$
iii. $L = 10$

(d) In each case, plot the frequency response, and compare with the frequency response of the desired system. What do you observe?

(e) In each case, plot the impulse response, and compare with the impulse response of the desired system. What do you observe?

(f) **Output-Error**: Use the output-error model to solve the adaptive filter problem. Assume no order mismatch.

(g) **SHARF**: Implement the SHARF algorithm. Compare the results with the output error model.

(h) **Levinson Durbin**: Use the Levinson Durbin algorithm to estimate the IIR filter. Assume no order mismatch. What are your conclusions from the result?

(i) Compare all the results. What do you observe?