Project 4 – EECS 152B

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Module 1 – Noise Signal Generator

The first part of the project concerns designing an input for the system that will be built. The input will be a random noise generator which yields a sequence of uniformly distributed numbers with a length of 3000 over the interval of -1 to 1.

Next, an IIR system is developed that we wish to approximate with an FIR filter. The IIR filter is specified by the following second-order difference equation:

This IIR filter is implemented with the filter function in MATLAB. The filter function produces both the impulse response of the filter and the output of the filter with the input of the random noise.

The MATLAB code for the above description is shown in figure 1.

A screenshot of a computer

Description automatically generated

Figure 1 – Code for IIR Filter and Random Noise Generator

Next comes the design of the adaptive filter. The adaptive filter will be an FIR filter of length N, whose coefficients are adjusted by the means of the LMS algorithm. The code for the filter is shown in figure 2 with filter length (N) = 5 and step size (delta1) = 0.01. These parameters can and will be adjusted as the project progresses.

A computer code with black text

Description automatically generated

Figure 2 – Code for FIR Adaptive Filter

Furthermore, the LMS algorithm can be unstable if the step size is too large; thus, we will monitor the convergence rate through computing a short-term average of the squared error. The formula for average square error (ASE) is as follows:

The variable m = n/K and e(k) is the error function. Utilizing K = 50, N = 5, delta = 0.01 and varying n in increments of 50, the average square error formula is plotted. The code for this is displayed in figure 3.

A screenshot of a computer program

Description automatically generated

A close-up of a math equation

Description automatically generated

Figure 3 – Code for Plotting ASE

The plot generated from the code in figure 3 is shown in figure 4.

A graph with a line drawn on it

Description automatically generated

Figure 4 – ASE vs n/K for K = 50, N = 5, delta = 0.01

The choice of step size is considered in the next section of the experiment. We begin with an FIR filter of length 5. Starting from 0.01 the step size is increased until 0.8. Here we see large deviations begin to develop. At 0.8 step size the ASE jumps at n/K values of 17 and 54 as shown in figure 5.

A graph with numbers and symbols

Description automatically generated

Figure 5 – ASE vs n/K for K = 50, N = 5, delta = 0.8

Then, as delta is increased further to 0.85, the instability further deteriorates and undoubtably diverges.

A graph with numbers and a line

Description automatically generated

Figure 6 - ASE vs n/K for K = 50, N = 5, delta = 0.85

This procedure is repeated for an FIR filter of length 10. Starting from 0.01 the step size is increased until 0.5. Here we see deviations begin to develop. At 0.5 step size the ASE jumps at the n/K value of 14 as shown in figure 7.

A graph with numbers and a line graph

Description automatically generated

Figure 7 - ASE vs n/K for K = 100, N = 10, delta = 0.5

Then, as the step size is increased to 0.55, the stability degrades further as shown in figure 8.

A graph with a line graph

Description automatically generated

Figure 8 - ASE vs n/K for K = 100, N = 10, delta = 0.55

Thus at delta = 0.55, a much lower amount than the 0.85 for the 5 length filter, the 10 length FIR filter is unstable. The code developed for the FIR filter of length 10 is displayed in figure 9.

A screenshot of a computer program

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A computer code with text

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Figure 9 – Code for FIR Adaptive Filter of Length 10

Notice that the sizes of the variables and step size for n has changed due to the change in length.

The impulse responses of the adaptive filter and the IIR filter are compared in this section for adaptive filter lengths of 5 and 10. A discrete impulse response is used to generate the impulse response of the IIR filter. Figure 10 shows this code for N = 5.

A screenshot of a computer

Description automatically generated

Figure 10 – Code for Impulse Response Comparison

The plot of the two impulse responses for N = 5 is displayed below in figure 11.

A graph with numbers and points

Description automatically generated

Figure 11 – Plot of Impulse Responses with FIR Filter of Length 5

As seen in figure 11 the FIR filter approximates the IIR filter exceedingly well, as the blue and red points are nearly on top of each other for the entire length of the FIR filter.

The plot of the two impulse responses for N = 10 is displayed below in figure 12.

A graph with numbers and points

Description automatically generated

Figure 12 – Plot of Impulse Responses with FIR Filter of Length 10

As seen in figure 12, the adaptive filter approximates the IIR filter so well that the two graphs completely overlap for the entire length of the FIR filter. The FIR filter is causal and thus will begin at the zero point. The code for this plot is displayed below in figure 13.

A screenshot of a computer program

Description automatically generated

Figure 13 – Code for Impulse Responses with FIR Filter of Length 10

Lastly, the ASE and impulse functions are compared for different initialization values. First, we initialize everything to ones in the LMS algorithm as shown in figure 14.

A screenshot of a computer

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Figure 14 – Code for Initialization of Ones

The ASE is repeated and plotted in figure 15.

A graph with a line

Description automatically generated

Figure 15 – ASE for Initialization of Ones

We see that when initialized as ones, the average square error begins at a lower value (hence better approximation as there is less error) and convergences down at about the same rate. If we refer back to figure 4, we see that the error starts higher but quickly decreases down to where both are below 0.1 error by m = 10. Furthermore, the impulse functions still roughly match up for the initialization of ones as seen in figures 16 and 17.

A graph with numbers and points

Description automatically generated

Figure 16 – Plot of Impulse Responses with FIR Filter of Length 5 w/ Initialization of Ones

A graph with numbers and points

Description automatically generated

Figure 17 – Plot of Impulse Responses with FIR Filter of Length 10 w/ Initialization of Ones

In figure 16 we see that the impulse functions are slightly less matching but still reasonably close to one other. For length 10 there is no difference in initializations as shown in figure 17. In conclusion we see that by changing the initialization from zeros to ones there is some slight differences but overall, the adaptive filter is not that sensitive to changes in initialization.