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EEE 606 – Final Take Home Exam Part B
Due 12/8/2024 by midnight

1. A simulation diagram for IIR system identification (SID) is shown below. The SID relies on the equation error model.

Equation Error IIR Adaptive Filtering

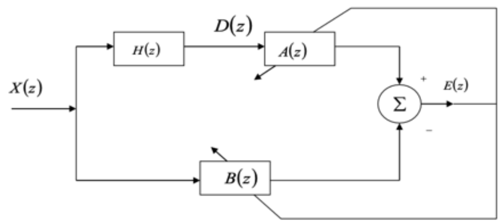

Fig. 1. IIR System ID Concept using the Equation Error Model.

You need to show the following:

a) Show the IIR Equation Error Model (IIR EEM) LMS update equations.

b) Give the optimal solution, derive in detail convergence, and state the condition on the step size for convergence.

c) Simulate the IIR EEM with "unknown" system H(z) and white noise input as follows.

i. Use first $H(z) = (1+1.62\, z^{-1} + 0.74\, z^{-2}) / (1 - 0.96 z^{-1} + 0.614\, z^{-2})$ and L=2 and M=2 (L order of B(z) and M order of A(z)). Compute the NEE (stated in Test 1) and show the NEE vs iterations convergence curve. Give the final coefficients in a table. The input X(z) is a white noise of zero mean and unit variance.

ii. Now use $h(n)=0.9^n u(n)$ where h(n)<-> H(z) and L=2, M=2. Compute the NEE and show the NEE vs iterations convergence curve. Give the final coefficients of B(z) and A(z) in a table. The input X(z) again is the white noise of zero mean and unit variance.

iii. Repeat the above parts i and ii with colored noise inputs. Use the color noise model that we had in Test 1, namely. Give again the pertinent convergence curves.

Comment on the results. Give 2-3 lines of comments for each part.

Give the MATLAB program in an appendix for these simulations.

$$NEE = \frac{\int_{-\pi}^{\pi} |H(e^{j\Omega}) - \hat{H}(e^{j\Omega})|^2 \, d\Omega}{\int_{-\pi}^{\pi} |H(e^{j\Omega})|^2 \, d\Omega}, \quad NEE_{dB} = 10 \log(NEE)$$

The colored noise model is given by its spectral density:

$$R_{xx}(\Omega) = |1 + 2e^{-j\Omega} - e^{-j2\Omega}|^2$$

2. System Identification only from output observations using Linear Prediction.

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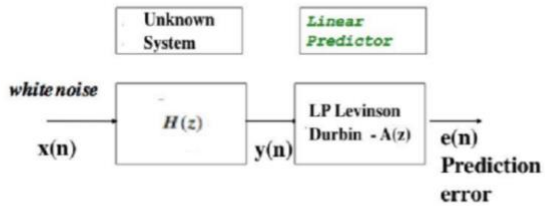

Fig. 2. LPC Concept and Inverse Filtering.

The linear prediction concept is shown in Fig. 2. The input here, w(n), is white Gaussian noise of zero mean and unit variance. The system H(z) is unknown in practice. The idea here is to use linear prediction and obtain the inverse system A(z). Of course, A(z) would be a true inverse only if H(z) = 1/A(z), in which case A(z) is also a "whitening" filter. The idea here is to use the Levinson-Durbin algorithm to obtain A(z). The following will have to be addressed.

i. State the Levinson-Durbin algorithm. Give a complete set of equations. Explain clearly what A(z), x(n), and e(n) represent in a system ID simulation that uses only output samples.

ii. Program the Levinson-Durbin algorithm in MATLAB by using the built-in function in MATLAB. Develop the simulation shown in the block diagram in MATLAB. Give the MATLAB program for this simulation. Please make sure that in the following simulations, you give all the plots in a decent size so that we can clearly observe the signals/functions as needed.

iii. Generate 100 samples of w(n) and use $H(z)= 1 / (1 - 0.96z^{-1} + 0.614 z^{-2})$. Use Levinson Durbin on *x(n)*. Compute the coefficients of A(z) where the order of A(z) is 2. Increase to 1000 samples of x(n). Use NEE and compare H(z) to 1/A(z) in both cases. Compare the frequency response magnitude (dB) of H(z) against 1/A(z) (superimpose the plots)

iv. After estimating the coefficients of A(z), compute e(n) (the prediction residual) and plot it against w(n)(superimpose).

v. Repeat part 3-iii (only for 1000 i/p samples) and give all plots for
$H(z)= (1+1.62 z^{-1} +0.74 z^{-2}) / (1 - 0.96z^{-1} + 0.614 z^{-2})$

Comment on the results. Give 2-3 lines of comments for each part.

- **For the entire project, give half a page on what you learned.**
- **Organize your report. Start each problem on a separate page, Label all figures. Use dB values on NEE as needed. For each part, provide one paragraph explaining the results.**
- **Part B will cover 75% of the overall final grades.**
- **Part B is due on December 08, 2024, by 11:59 PM Midnight AZ time. Late submissions can be accepted up to December 10, 2024, with a 25% penalty.**