EEE6504, Spring 2022 Homework 2

RLS and APA

February 3, 2022

Due: February 24, 2022

- The audio file *speech.WAV* contains an utterance of a sentence "we were away a year ago" sampled at 10 kHz, 12 bits A/D.

If you have any questions address them to:

Problem 1 – 10 points

An "unknown" plant has transfer function $H(z) = (1 - z^{-10})/(1 - z^{-1})$ and its output is added with white Gaussian noise of power $N = 0.1$. The input to the plant is alpha stable noise. To generate this noise use the characteristic function $\phi(t) = exp(-\gamma|t|^{\alpha})$ with $\alpha = 1.5$ and choose $\gamma = 1$. Generate 10,000 samples of the alpha stable noise as well as the white Gaussian noise. Take the auto-correlation and power-spectrum density (PSD) to confirm input and output.

The user has only access to the noisy output of the plant and to its input. The goal of this problem is to design a linear filter **updated with the RLS algorithm** to identify the unknown plant transfer function. You can NOT use the fact that you know the plant to design the adaptive filter, but you can use this knowledge to evaluate and interpret the solution obtained. Use the normalized MSE as the quality of the identification (normalize by the power of the input).

- **i.** It is suggested that you use filters of order 5, 15, and 30. Compare the accuracy of the system identification by computing the weighted error power. $WSNR = 10\log(\frac{W^{*T}W^{*}}{(W^{*}-W(n))^{T}(W^{*}-W(n))})$. Here W^{*} is the optimal weight vector that you know because I supplied the unknown system (you have to think how to size W^{*})
- **ii.** Show the effect of increasing the noise $N (N = 0.3, 1.5)$ in your results. Explain what you observe.
- **iii.** Compare performance with both the Wiener solution and the LMS you employed in HW1.

Problem 2 – 10 points

In the course website you will find a time series called *speech.WAV*. This file contains an utterance of the sentence "we were away a year ago" sampled at 10 kHz, 12 bits A/D. **The purpose here is to design predictors using RLS algorithm and also an appropriate adaptive filter from APAs Family.** The difficulty is that speech is non-stationary!

i. Study the effect of the **filter length** and the **forgetting factor** in the quality of the prediction. Report the best forgetting factor to track the non-stationary time series at hand. Normalize the error power by the input signal power and use this measure to compute the different predictors. It is suggested that you use filters of order 6 and 15.

ii. Examine also the filter parameters and how they change over time. Can you find any similarity on the parameters versus the similarity in the sounds? (Listen to pieces of the sound and correlate with the parameter values)

iii. Figure.1 shows a diagram of changes in speech spectrum over time a.k.a spectrogram. Compare the prediction error, with major changes in the spectrogram. Discuss how this information may help you improve prediction and why convergence rate is important in this problem.

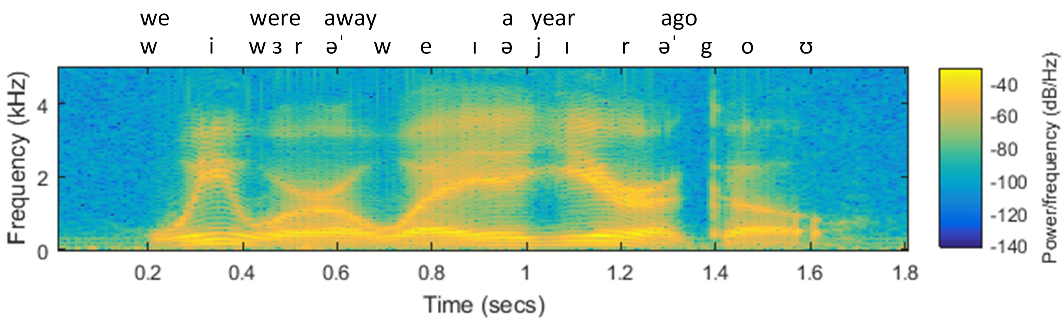

Figure 1: Wide-band sound spectrogram for the utterance "we were away a year ago," spoken by a male speaker. The IPA phonetic transcription is also presented synchronized with the spectrogram.

iv. Repeat with the APA and compare with the RLS solution. Explain why you choose this APA and if it could improve the prediction.

v. With a goal to achieve the best prediction performance, modify the number of samples you use in the APA model to estimate the data statistics, and show how complexity is affected when changing the number of samples.