# EEE6504, Spring 2020 Homework 1
# Wiener Filter and LMS

January 23, 2020

## Due: January 30, 2020

## Instructions

Please submit your solutions as a **single PDF file** to the course website on e-Learning at `http://elearning.ufl.edu/`. If you solve any problems by hand, you should scan it as PDF and submit it online.

If your report includes graphics (figures, tables) make sure you have addressed them properly and everything is visible in the final PDF file. Remember commenting your results is very important.

Your homework submission must cite any references used (including articles, books, code, websites, and personal communications). All solutions must be written in your own words, and you must program the algorithms yourself. If you do work with others, you must list the people you worked with.

Regarding the second problem of this homework, you are encouraged to read the paper " Speech Analysis and Synthesisby LinearPredictionof SpeechWave," by Atal,1971. For thisproblem,use the data in the supplied datafile

- 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 the TA:

## 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 with $\alpha = 1.5$. To generate this noise use the characteristic function $\phi(t) = exp(-\gamma|t|^{\alpha})$ with $\alpha = 1.8$ 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 Wiener filter 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, at least, filters of order 5, 15, and 30, and windows of size 100, 500, and 1000 samples to estimate the auto-correlation function and cross-correlation vector. 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.** Apply the Wiener filter in different windows of the input (you have 10,000 samples), and conclude if you need this procedure or not (i.e., only one window suffices?)

**iii.** Show the effect of increasing the noise $N (N = 0.3, 1.5)$ in your results. Comment on the Wiener filter parameters. Explain what you observe.

**iv.** Repeat with the LMS algorithm and compare performance with the Wiener solution.

## 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 also to compare the quality of Wiener predictors in this time series. The difficulty is that speech is non-stationary!

Study the effect of the window size and of the filter length in the quality of the prediction. Normalize the error power by the input signal power and use this measure to compute the different predictors and windows.

**i.** It is suggested that you use filters of order 6 and 15, and windows of size 100, 200, and 500 samples.

**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.

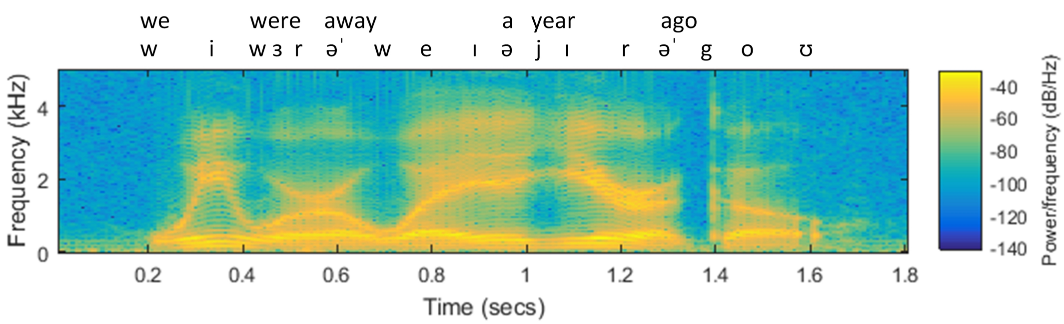


Figure 1: Wide-band sound spectrogram for the utterance "we were away a year ago," spoken by a male speaker. The IPA phonetic transcription is also presented synchronized with the spectrogram.

**iv.** Repeat with the LMS and compare with the Wiener solution.