EEL 6504 – Machine Learning for Time Series

Project I: Noise Reduction

Due March 21, 2023

The purpose of this project is to design and evaluate the performance of a noise reduction system that will clean, on line, the desired input (speech plus noise) from the machine noise (input). The machine learning algorithm must belong to the APA family. This is an example of the interference canceling problem explained as follows:
Speech data is collected by two microphones in a noisy room with a loud vacuum cleaner: one placed on a table that captures speech with the vacuum cleaner noise (used as d(n)) and the other very close to the vacuum cleaner (used as input n(n)) that basically captures no speech. Even if you listen to d(n) the speech is barely audible, and the speech message is not understandable. The goal is to denoise d(n) and be able to understand the speech. I suggest that you use the signal n(n) as the input to the LMS algorithm and use d(n) as the desired response, but you can reverse them and evaluate the differences.

The simplest algorithm of the APA family is the normalized LMS (NLMS), and please start with it.

You will find the data set project1.mat in the course website. This file contains a .mat file with two channel data labeled desired (d) and input (n). The sampling frequency is 21 KHz.

The project requires a report explaining the experimental procedures you followed and you must include data to support your conclusions. Your report will be like a paper. Please use the format of the IEEE Transactions on Signal Processing template (limited to 7 double column pages). This means you must write a brief intro to the theory, explain well the methods and present carefully the results (see below) and conclude. Remember that any scientific paper should, by definition, contain sufficient information such others can replicate your results. A scientific paper must also contain ORIGINAL material only. If you happen to use text or equations from other sources you must reference the material that you cut and paste from (this is not allowed in a normal publication, but here it is OK as long as you provide the reference). Of course, I expect the results to be done by the student, without outside help. I would like to see in the report (at least) the following:

Start with a 2-tap filter
1- Plot the performance surface contours for the two weights filter case.
2- Plot the weight tracks
3- Plot the learning curve and interpret it.
4- Estimate the frequency response from the desired signal to the error when the filter is adapted.
5- Estimate the SNR improvement in dB by the ERLE=$10\log(E\{d^2\}/(E[e^2])$.

Increase the filter order based on an analysis of performance. Explain your choice for the filter order.

1- Estimate again the frequency response from the desired signal to the error.
2- Compute the SNR improvement in dB. Is ERLE a good figure of merit for this task?
3- Evaluate the filter performance as a function of the stepsize.
4- Estimate the misadjustment and see if you can understand the message.
5- Comment on the results obtained and address issues related to the convergence of the algorithm in non-stationary environments.

Repeat the procedure with another APA algorithm with the same filter order. My suggestion is to use a member of the APA 2 class, but you can also try a APA1, which is an enhancement for the NLMS. Explain what you expect to improve in performance with your selection and then verify your hypothesis by comparing the performance/computation tradeoff against the NLMS and see if your goal was fulfilled.