Signal Processing Homework Assignment 1: Acoustic Echo Cancellation

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1. Introduction

This report describes an echo cancellation algorithm for acoustic signals using MATLAB. The algorithm uses Least Mean Square (LMS) and Recursive Least Square (RLS), both for known and unknown delays.

2. Design and Implementation

Table 1 shows used values for parameters.

Parameter	Value
Known delays d_i	0.04, 0.08, 0.1
Coefficients c_i	0.5, 0.3, 0.1
Variance of noise sigma σ^2	0.01
Step size LMS, μ	0.001
Initial value of a recursive matrix RLS, ρ	1
Number chosen for maximum unknown delay N_m	5

Table 1. Chosen values for relevant parameters.

The audio file provided with the task, "drumloop.wav", was chosen as near end signal, and the audio file "vocal.wav" as the far end signal.

3. Results

Figure 1 shows the original near end signal and the echo respectively.

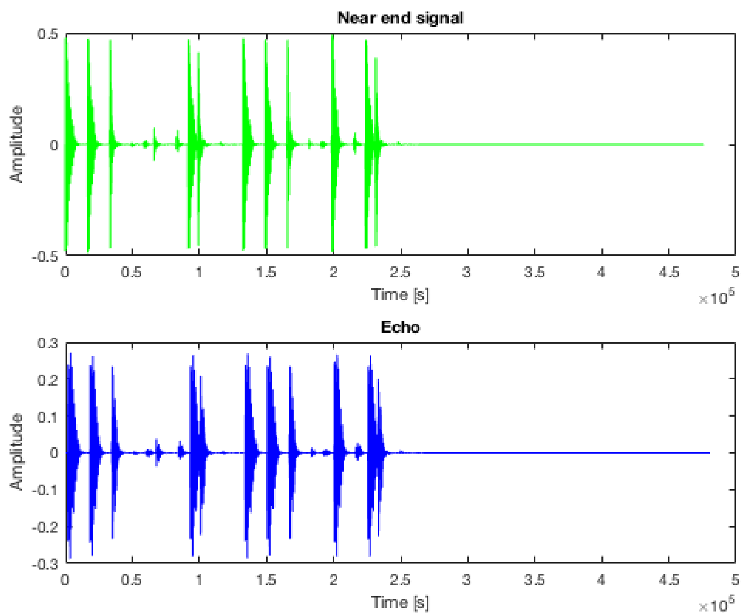

Figure 1. Original near end signal and echo signal.

Figure 2 shows the original far end signal and the noise respectively.

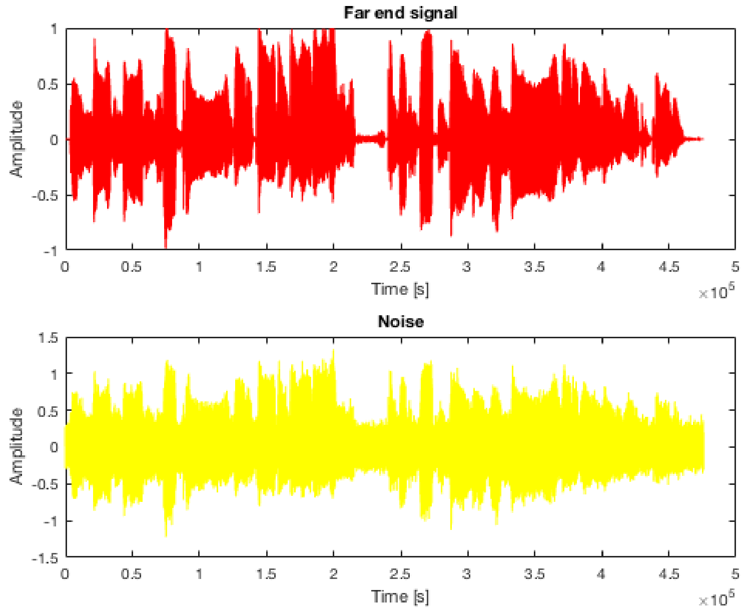

Figure 2. Original far end signal and noise contaminated signal.

Figure 3 shows the signal consisting of the noise contaminated far end signal and the near end signal echo.

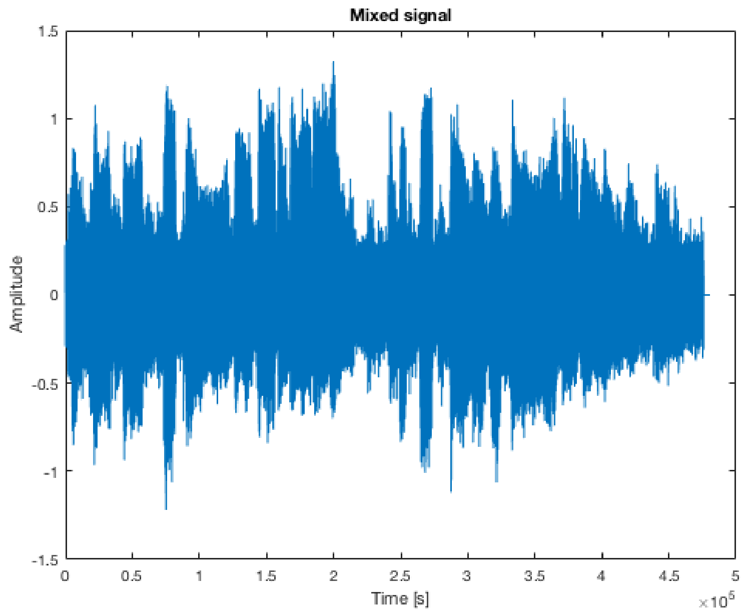

Figure 3. Mixed signal, consisting of the noise contaminated far end signal and the near end signal echo.

Figure 4 shows the signals recovered using LMS.

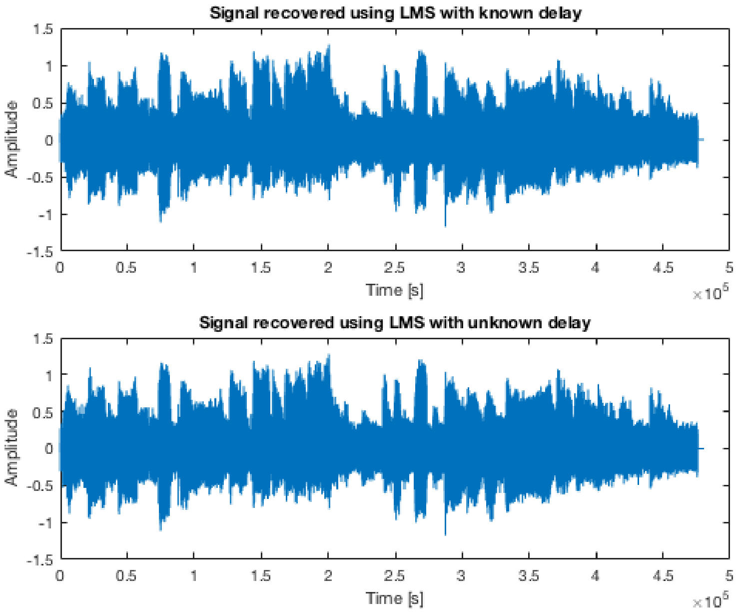

Figure 4. Recovered signals using LMS for known and unknown delays.

Figure 5 shows the signals recovered using RLS.

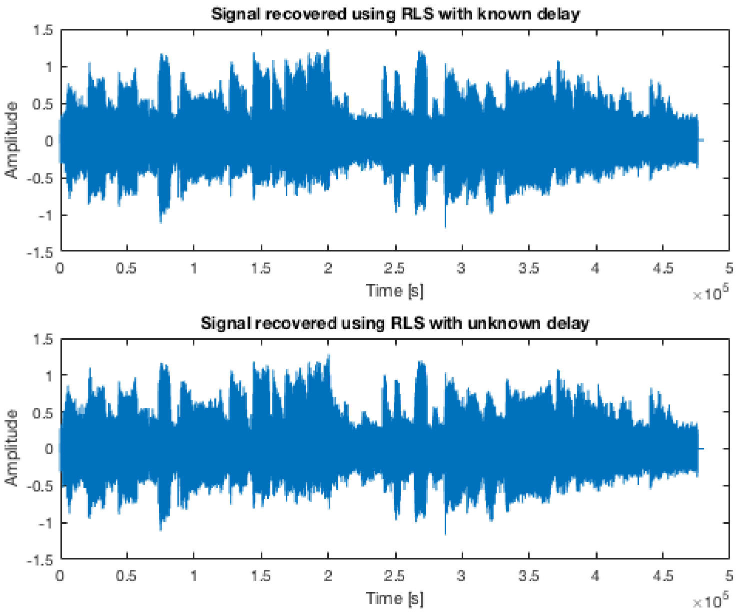

Figure 5. Recovered signals using RLS for known and unknown delays.

Figure 6 and 7 shows the squared error between the noise contaminated far end signal and the recovered signals using LMS and RLS respectively.

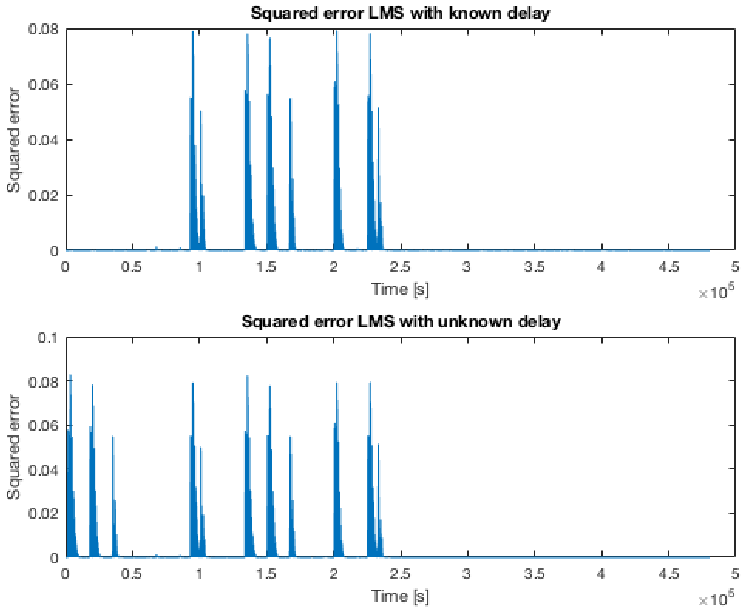

Figure 6. Squared errors between noise contaminated far end signal and the recovered signals using LMS.

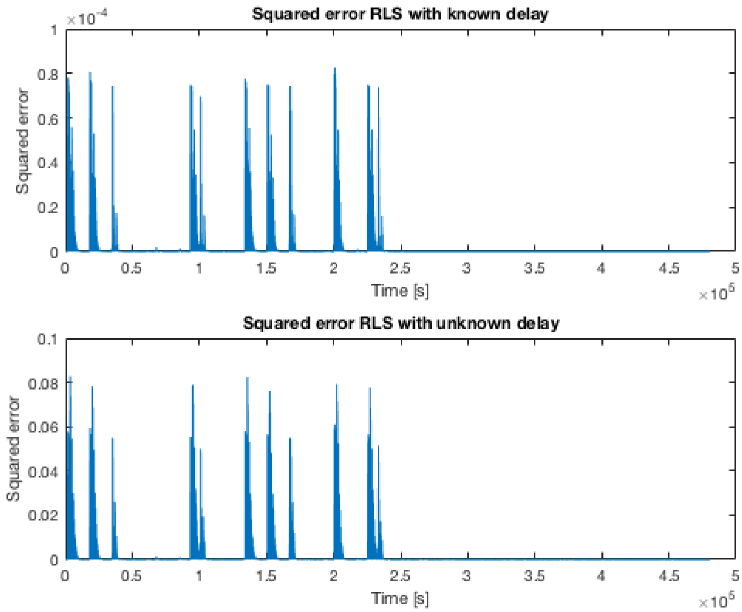

Figure 7. Squared errors between noise contaminated far end signal and the recovered signals using RLS.

Table 3 shows the average squared error over all samples.

Algorithm	**Value squared error**
LMS known delays	1.135e-2
LMS unknown delays	1.610e-2
RLS known delays	1.730e-5
RLS unknown delays	1.608e-2

Table 3. Average squared error between noise contaminated far end signal and the recovered signals, over all samples.

Figure 8 shows the squared error between the echo and the estimate of the echo using LMS.

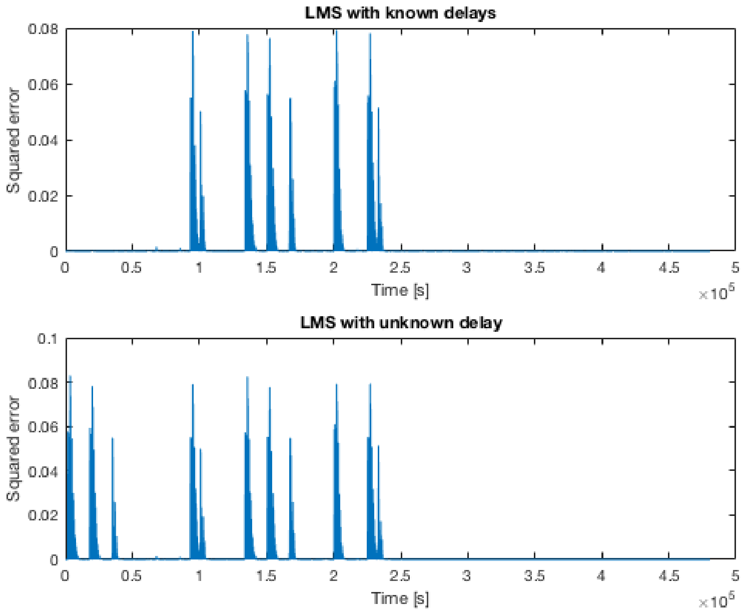

Figure 8. Squared error between echo and estimate of the echo made using LMS.

Figure 9 shows the squared error between the echo and the estimate of the echo using RLS.

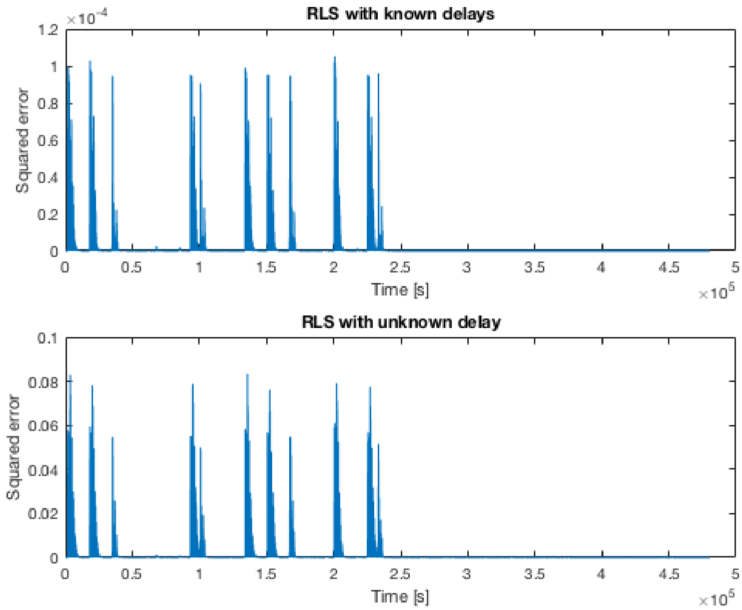

Figure 8. Squared error between echo and estimate of the echo made using LMS.

Table 4 shows the time-average squared error over all samples.

Algorithm	**Value squared error**
LMS known delays	1.135e-2
LMS unknown delays	1.610e-2
RLS known delays	1.730e-5
RLS unknown delays	1608e-2

Table 4. Time-average squared error between echo and estimate of the echo, over all samples.

Figure 9 shows the evolution of the 3 estimated echo path coefficients along with their set values for the known delay, using LMS and RLS.

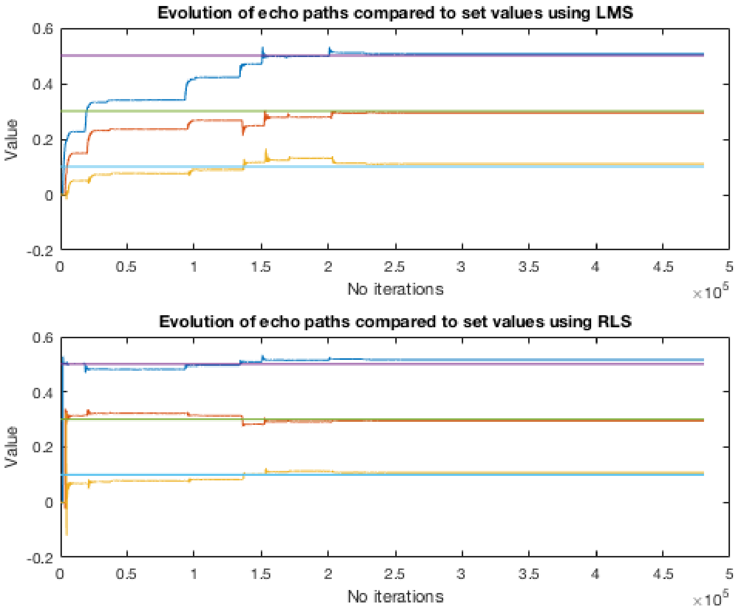

Figure 9. The evolution of the 3 estimated echo path coefficients and their set values for the known delay, both using LMS and RLS.

Table 5 shows the average squared error in parameter estimates using LMS and RLS.

Algorithm	**Value squared error**
LMS	0.01139
RLS	0.002366

Table 5. Average squared error in parameter estimates using LMS and RLS respectively.

Table 6 shows the CPU time needed to run the LMS and RLS algorithms, both with known and unknown delays.

Algorithm	**CPU time [s]**
LMS with known delays	1.558
RLS with known delays	9.787
LMS with unknown delays	1.612
RLS with unknown delays	11.41

Table 6. CPU time for LMS and RLS algorithms, both with known and unknown delays.

4. Discussion

The signals recovered using LMS and RLS where similar, but RLS has a smaller average error since it converges faster. Since RLS takes longer to run, it might still be suitable to use LMS for echo cancellation in cases where the time aspect is important even though the average error is bigger.