Homework 1

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1 Design

We chose $\rho = 0.01$ because of the noise. Since a small ρ will make the RLS algorithm less sensitive to noise. The downside with this is that the convergence rate is slow and possibly that the end result of the estimation parameters may differ from the real values.

The same logic was applied to the choice of μ. Therefore μ was chosen to be equal to 0.001.

2 Results

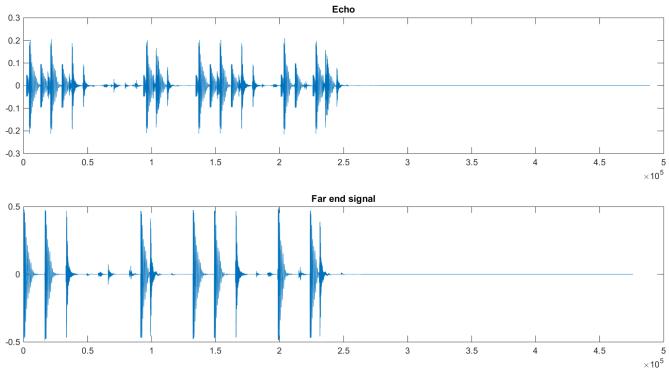

Figure 1: Far end signal compared to echo.

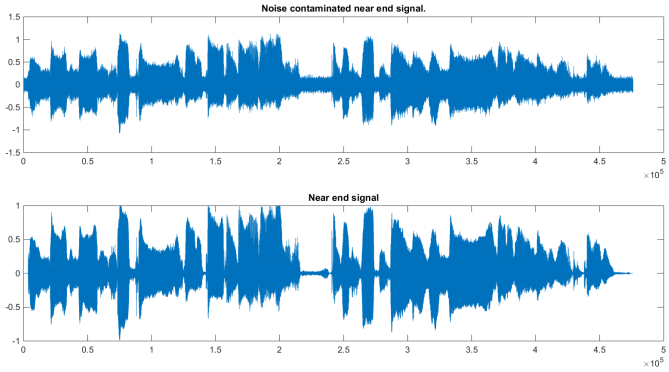

Figure 2: Near end signal compared to noise contaminated signal.

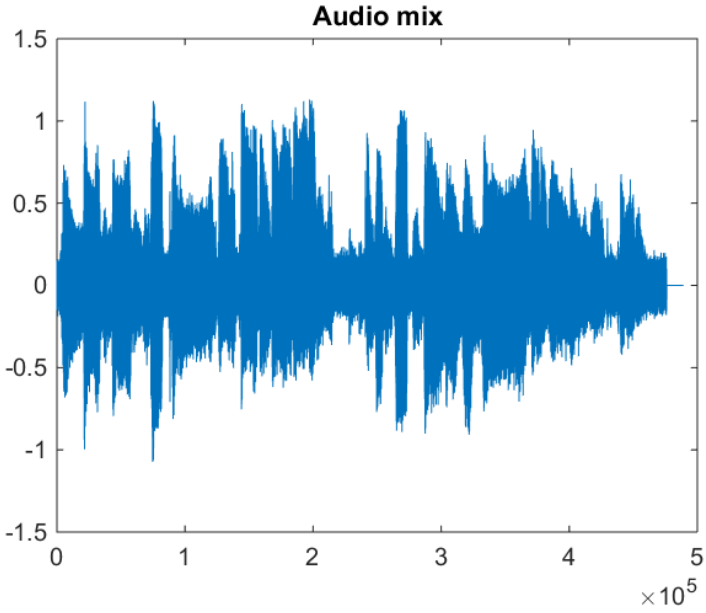

Figure 3: Audio mix, sum of noise contaminated near end signal and far end echo.

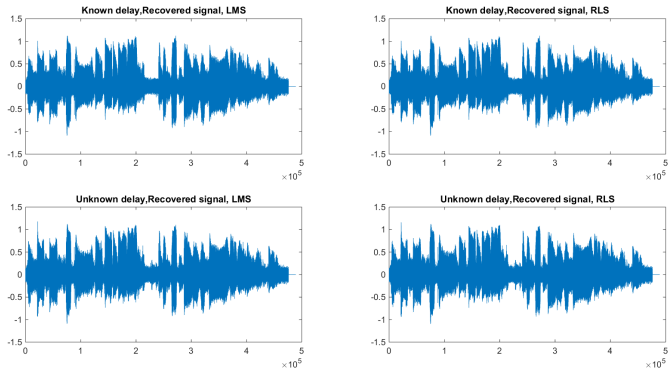

Figure 4: Recovered signal, echo removed from mixed audio.

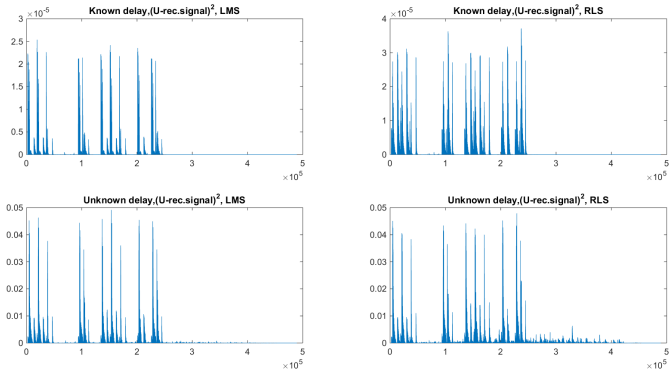

Figure 5: Squared error between noise contaminated near end signal and the recovered signal.

In figure 6 the squared error between y and$\hat{y}$ is shown for the different algorithms and delays. We also computed the time-average squared error between them.

When using LMS and known delays the time-average squared error was: $4.94 * 10^{-7}$.

When using RLS and known delays the time-average squared error was: $9.54 * 10^{-7}$.

When using LMS and unknown delays the time-average squared error was: $8.16 * 10^{-4}$.

When using RLS and unknown delays the time-average squared error was: $9.31 * 10^{-4}$.

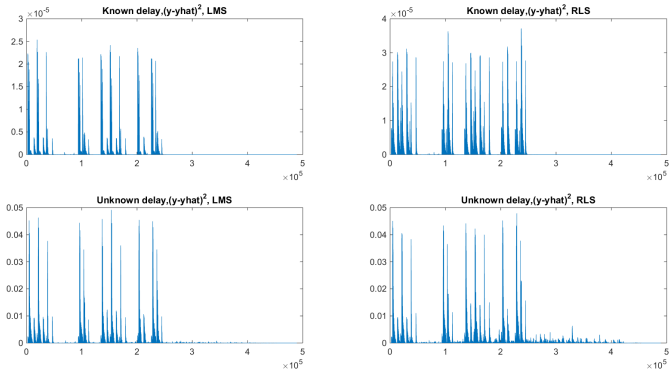

Figure 6: Squared error between y and $\hat{y}$.

In figure 7 we can see how the three estimated parameters change, when using LMS, with each iteration and how they converge to one value. The three other straight lines in this figure are the true values of the parameters.

The same thing can be seen in figure 8 but this time we are using RLS. Both of these figures are drawn using the known delays.

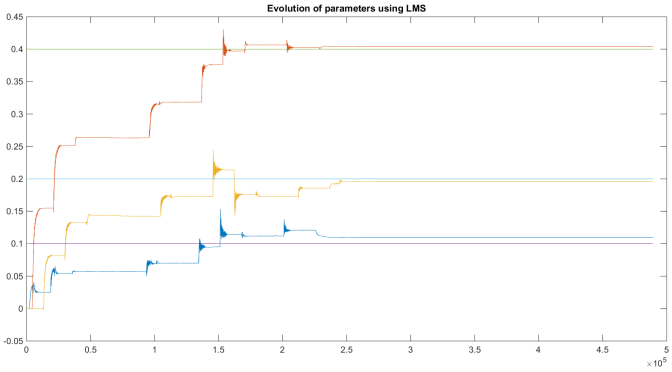

Figure 7: Evolution of estimation parameters compared to real parameters over all iterations using LMS.

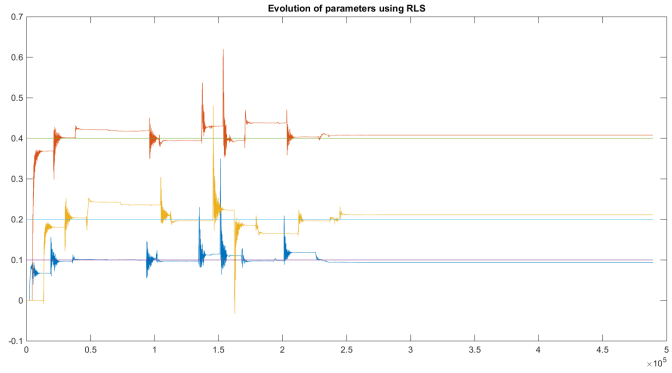

Figure 8: Evolution of estimation parameters compared to real parameters over all iterations using RLS.

The average squared error in the parameter estimation was calculated to $4.38 * 10^{-5}$ when using LMS and $7.65 * 10^{-5}$.

The CPU-time for the different methods and delays was calculated to:

$t = 3.1s$, with LMS and the known delays.

$t = 6.34s$, with RLS and the known delays.

$t = 4.09s$, with LMS and the unknown delays.

$t = 8.49s$, with RLS and the unknown delays.

3 Observations and comments

It is difficult to make out a difference in the recovered signal when using LMS and RLS. Though a difference can be heard when using the known delays and the unknown delays.

The average squared error of RLS was a bit better than the one for LMS and that is because RLS tends to converge faster than LMS.

Running the RLS algorithm with known delays took twice as long as for the LMS algorithm and the same result for the unknown delays and that is because RLS have heavier functions in each iteration.