Convolution and Noise Reduction
Linear Systems Lab
ECE 3151
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Introduction

The overall purpose of this lab was to learn how to use convolution to reduce noise in a signal that has noise, how to normalize an impulse response of a system, how effective a noise-reduction filter is depending on the level of noise, and how to solve a problem with limited guidelines. The main constraint of this project is not to use functions outside of the allowed syntax list. The general approach taken by this group was to work independently after the first lab day to allow both members of the group to improve their Matlab skills. After a few days had passed, the group consulted each other to compare results and approach. This plan worked out fairly well with the results and approach being similar for both members. Without the need to consult over issues, the robustness of this method is still not clear.

Results

Lab4_data.m

The **Lab4_data.m** script was used to determine the optimal impulse response with corresponding tau values. Of the indexes for the impulse response signals, index 1 was not chosen as initial trials showed a distinctly different pattern from the noiseless signal, meaning the root mean squared error (RMSE) would always be relatively high. Figure 1 shows the RMSE versus tau where the blue line is index 2 and the green line is index 3. The lowest value of tau is approximately 0.25 with impulse response 2.

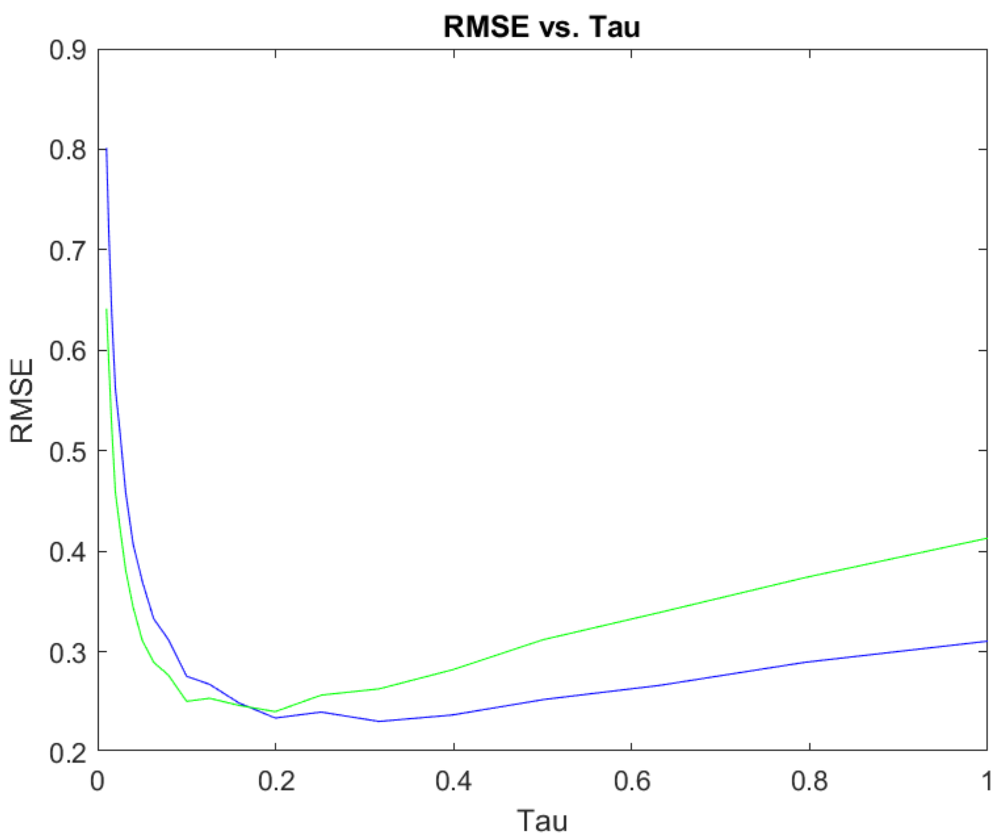

Figure 1: The root mean square error versus tau for two different impulse response signals. The signals are convolved with the noisy signal and the RMSE calculated compared to the noiseless signal provided.

Reduce_noise.m

The **reduce_noise.m** function has input variables ‘t’ and ‘z’, the time and noisy signal vectors respectively, and outputs the reduced noise signal ‘y’. The first part of the logic uses ‘if’ statements as precautions for the variables ‘t’ and ‘z’ making sure they are the same length and that they are vectors with more than one index. Next, the tau value found in **Lab4_data.m** is used as well as the index in the LTI function to generate the impulse response. The result is divided by the integral of the signal to normalize it. The normalized impulse function is then used to find the convolution of the signal and output as ‘y’.

Output

The output ’y’ of the **reduce_noise.m** function is the reduction in noise when compared to the original noisy signal ‘z’. Due to ‘y’ being normalized, the lower the level of noise, the closer it matches up to ‘x’. The overall shape can be clearly seen throughout any noise level, but when the noise level goes up any sharp angles become less clear and ’y’ becomes farther from the original. With no noise the function resulted in a close match, as shown in Figure 2. At noise level 5, shown in Figure 3, the function performed decently with the shape still being noticeable, but there is more deviation from the signal. At noise level 10, the function performed subpar with the overall shape still being noticeable but large variation away from the desired signal, as shown in Figure 4. Overall, the noise reduction function achieves the shape of the desired noiseless signal with varying degrees of integrity.

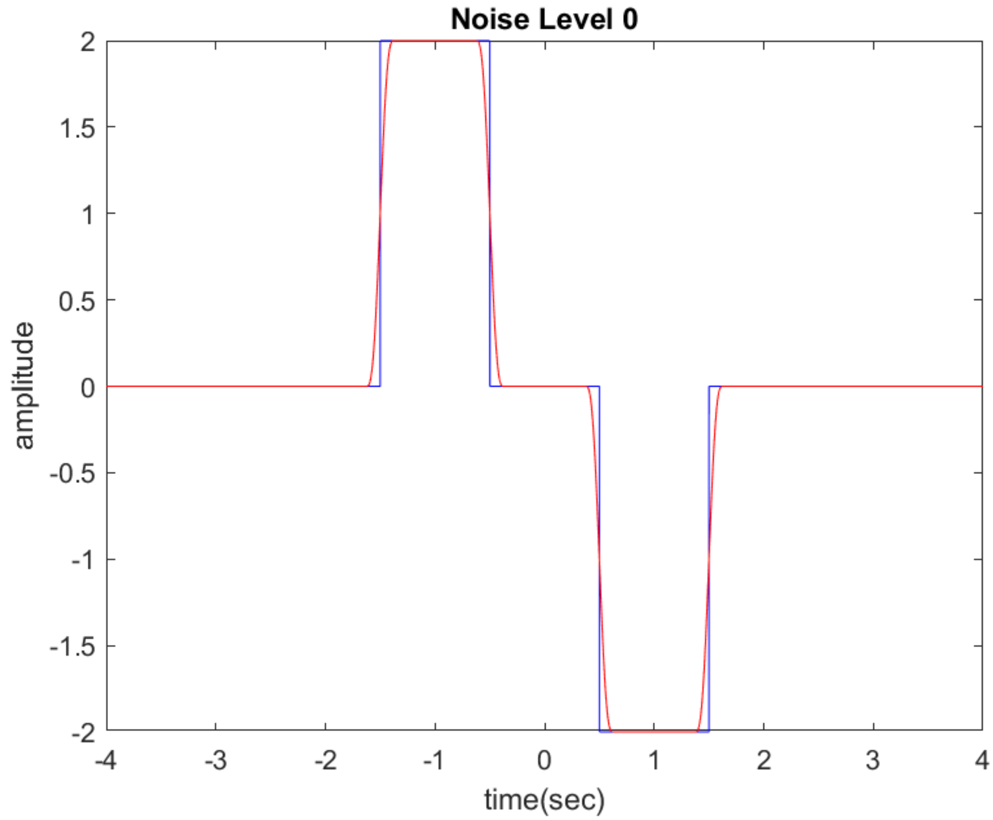

Figure 2: The resulting convolution using reduce_noise on a signal with level 0 noise. The blue is the noiseless signal while the red is the signal produced using the reduce_ noise function.

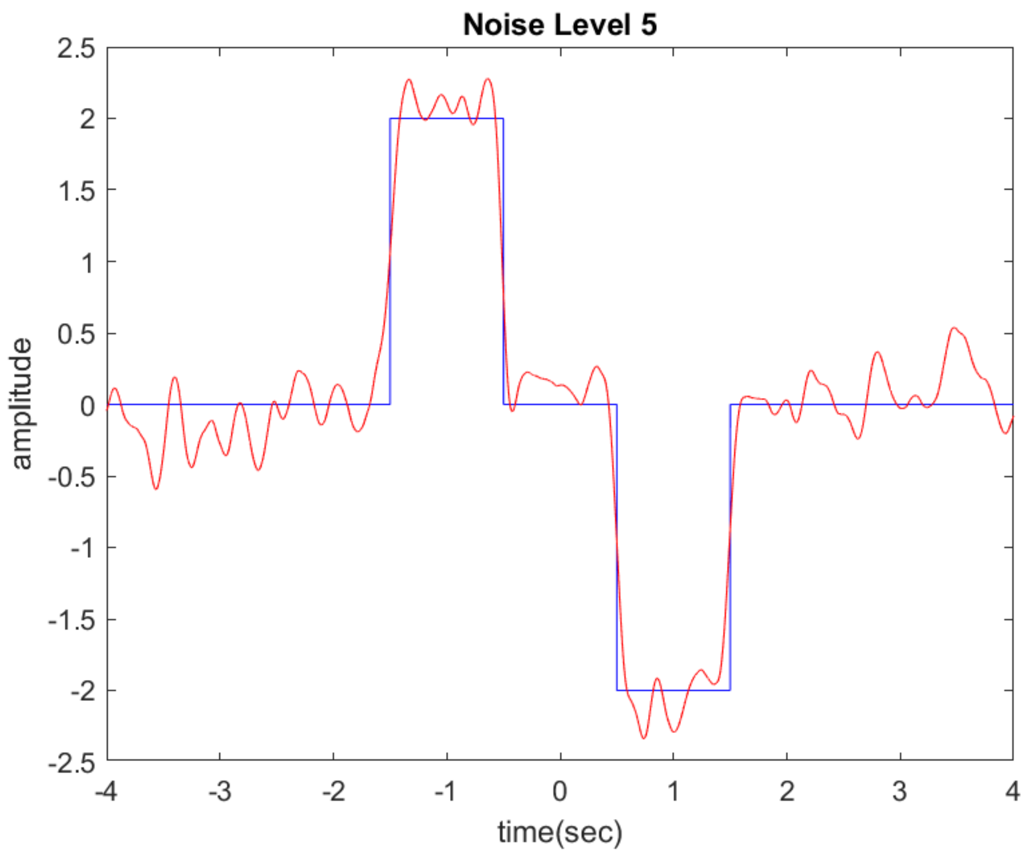

Figure 3: The resulting convolution using reduce_noise on a signal with level 5 noise. The blue is the noiseless signal while the red is the signal produced using the reduce_ noise function.

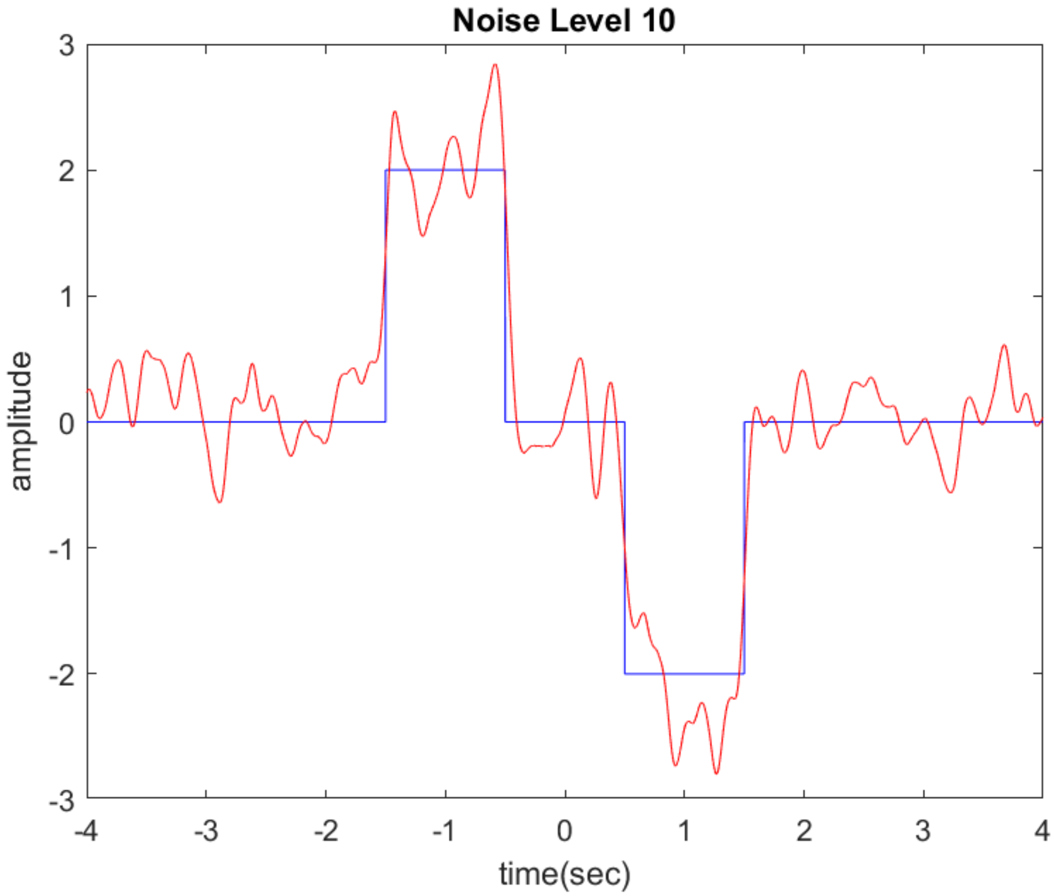

Figure 4: The resulting convolution using reduce_noise on a signal with level 10 noise. The blue is the noiseless signal while the red is the signal produced using the reduce_ noise function.

Conclusions

The overall purpose of this lab was learning how to use convolution to reduce noise in a signal that has noise, how to normalize an impulse response of a system, how both noise and signal change by a noise-reduction filter, and how to solve a problem with limited guidelines. All of this was achieved with very few setbacks. This led to a better understanding of how convolutions work regarding noisy signals and how to normalize an impulse response of a system. The lab also demonstrated the limitations of convolution when it comes to clarifying a noisy signal as the ideal noiseless signal was not achievable when given a noisy signal initially.