Aalto University

ELEC-C5340
Applied Signal Processing
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Reverb

Reverb is one of the most used sound effects. The objective is to give a perception of an added room or large space response to the original signal. There are several digital filter solutions for computationally efficient room response modeling and simulation.

Your goal is to implement a real time reverb application or a VST plug-in based on the following classic algorithms.

Realization

I Multiple delays with feedback

One of the simplest versions is to have a few delay lines with individual feedback paths. A delayline with a feedback path is analogous to a digital waveguide (see the guitar synthesizer assignment). The transfer function of a delayline with a feedback path is

$$H(z) = \frac{1}{1 - gG(z)z^{-L}}, \tag{1}$$

where g is the feedback gain, L is the length of the delayline, and $G(z)$ is a simple lowpass filter given as $G(z) = 1/(1 - az^{-1})$. The lowpass filter controls the amount of the attenuation of the high-frequencies. Use MATLAB to see how the a effects the high-frequencies. Use values $0 < a < 1$ for the attenuation of the high-frequencies.

In addition, useable values for the feedback gain are $0.7(1+a) < g < 0.99(1+a)$. The filter $H(z)$ should remain stable at all times. The frequencies of the resonances of the $H(z)$ are controlled through the length of the delayline $L = round(f_s/f_0)$, where the f_s is the sampling frequency and f_0 is the frequency of the lowest resonance.

II Schroeder reverb

A classic Schroeder reverb [1] was invented already in the early sixties. The base building blocks of this design are comb filters as they add a weighted delay to the signal and allpass filters to create dispersion to the echoes (reducing the metallic ringing sound).

Figure 1 shows the overall block diagram of the Schroeder Reverb. It uses four parallel comb filters with different delay times and two allpass filters in series.

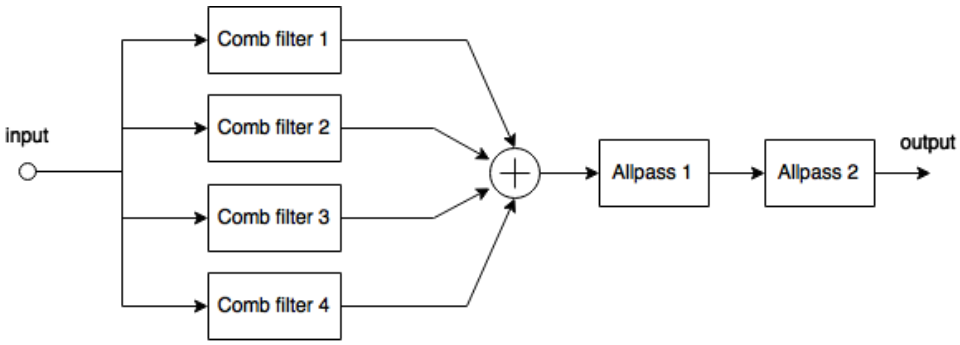

Figure 1: High level block diagram of a Schroeder reverb.

A popular public domain C++ program Freeverb [2] by "Jezar" is based on Schroeder design and still widely used in software e.g. Csound. You can check it out for reference but don't just straight up copy it into your work.

III Moorer reverb

Moorer's design extends the Schroeder reverb by including an additional FIR tap-delay path to simulate early reflections [3]. He also added a first order lowpass filter inside the comb filters feedback loop. This simulates the absorption characteristics of air, as the energy of higher frequencies attenuate faster than lower frequencies when sound travels through air and reflects from surfaces.

IV Feedback delay networks

Multiple feedback delay network (MFDN) enables to get an improved amount of reflections and resonances and hence resulting in a smoother response and better sounding reverb. In a way the MFDN is an extension and generalization of the algorithms mentioned above. You can implement a modified version of

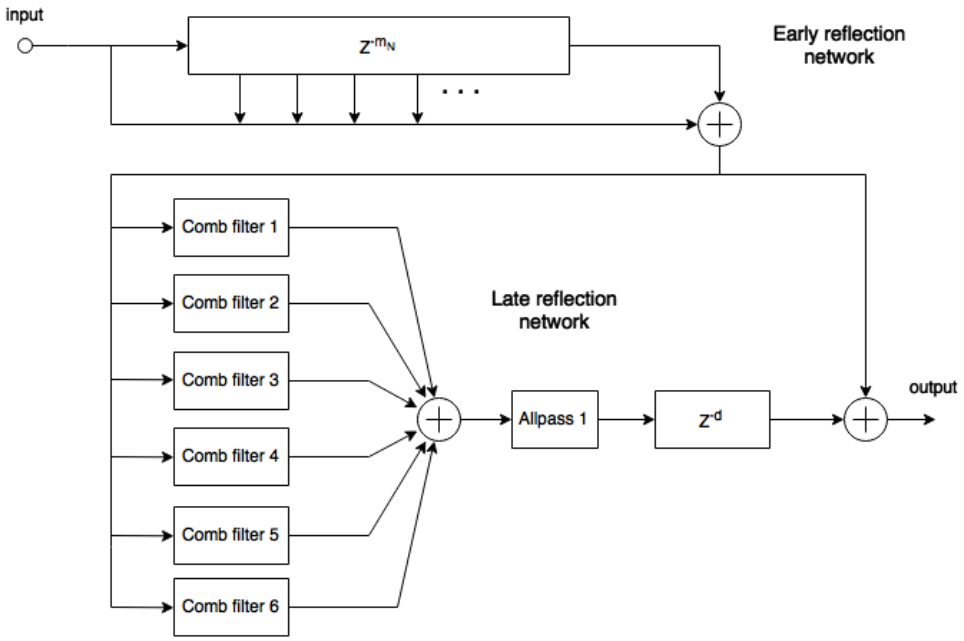

Figure 2: High level block diagram of a Moorer reverb.

the MFDN which results in a good response with less computations due to the allpass filters used in the feedback paths [4].

There are good blogs on designing Audio Units and VSTs online, for example Christian Floisands Float Audio Programming [5] which covers Schroeder and Moorer reverbs in a very practical tone.

References

[1] Manfred R. Schroeder. Natural sounding artificial reverberation. Journal of the Audio Engineering Society, 10(3):219–223, July 1962.

[2] Julius O. Smith, Physical Audio Signal Processing, 2010, chapter on Freeverb available online at https://ccrma.stanford.edu/~jos/pasp/Freeverb.html

[3] F. Richard Moore. Elements of Computer Music, chapter 4.4–4.5, pages 380–388. Prentice-Hall, Englewood Cliffs, NJ, 1990.

[4] Riitta Väänänen, Vesa Välimäki, Jyri Huopaniemi, and Matti Karjalainen. Efficient and parametric reverberator for room acoustics modeling. In Proceedings of International Computer Music Conference, pages 200–203, Thessaloniki, Greece, September 1997.

[5] Christian Floisand, Float Audio Programming, Blog available online at
https://christianfloisand.wordpress.com/2012/09/04/digital-reverberation/