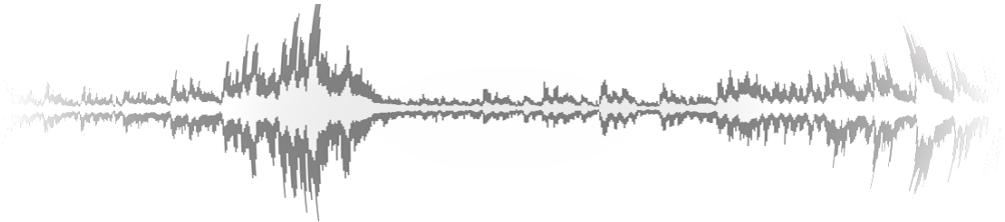
Digital Signal Processing for Music

Part 20: Reverb

alexander lerch



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artificial reverberation

introduction

- **idea**:
  - artificially generate the impression of envelopment and reverberation
  - possibly allow to modify specific characteristics of the “modeled” room

- **approaches**
  - (digital) parametric reverberation (predecessors: spring, plate, room, . . .)
  - fast convolution

artificial reverberation

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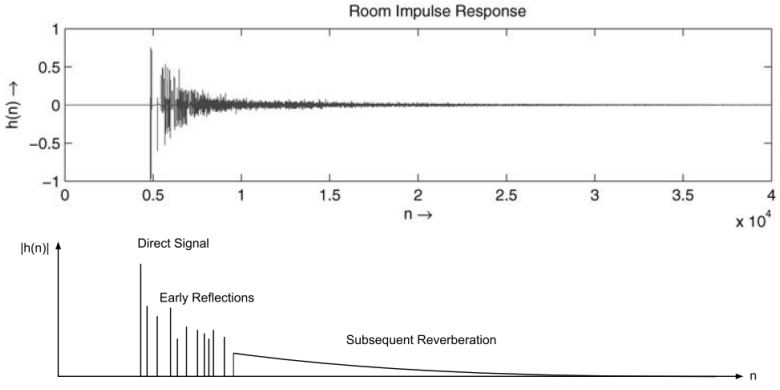
artificial reverberation

room impulse response



artificial reverberation

room impulse response: properties

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room impulse response is sum of (filtered and delayed) reflections

- **properties**
  - level decrease is app. linear
  - density of reflections increases
- **description**
  - reverberation time: time in seconds for a level decrease of 60 dB
  - depends mainly on
    - room *volume*
    - surface *area*
    - surface *absorption*
  - Sabine:

$$T_{\mathrm{RT}} = 0.163\mathrm{m}^{-1}\frac{V}{\sum \alpha_n \cdot S_n}$$

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room simulation

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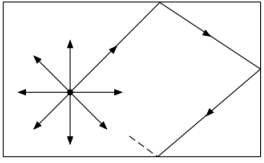
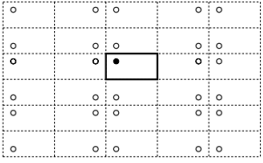
a) Ray Tracing

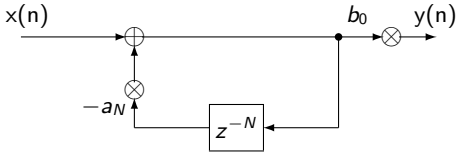


b) Virtual Image Sources



artificial reverberation

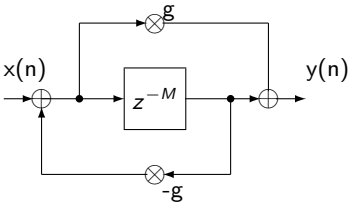
traditionally used filters: comb filter



$$
\begin{aligned}
y(n) &= b_0 \cdot x(n) - a_N \cdot y(n-N) \\
H(z) &= \frac{b_0}{1 - a_N \cdot z^{-N}}
\end{aligned}
$$

artificial reverberation

traditionally used filters: all pass filter

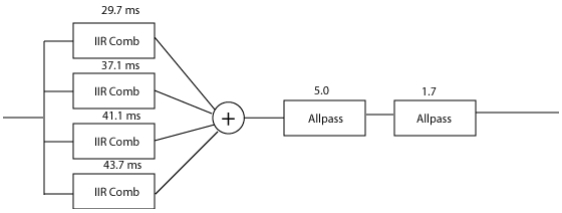


$$y(n) = g \cdot x(n) + x(n-M) - g \cdot y(n-M)$$

$$H(z) = \frac{z^{-M} + g}{1 + g \cdot z^{-M}}$$

artificial reverberation

reverberation: Schroeder 1/2

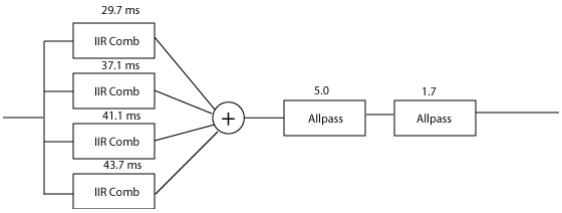


questions:

- how to change the reverberation time?
- how to change the density?

artificial reverberation

reverberation: Schroeder 1/2



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artificial reverberation

reverberation: Schroeder 2/2

- **problems**
  - sound coloring ($\rightarrow$ prime numbers)
  - periodicity

- **audio**
  - original
  - wet

artificial reverberation

reverberation: Schroeder 2/2

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artificial reverberation

reverberation: Moorer

- similar to Schroeder's model
- more comb filters
- low pass in feedback paths
- simple FIR model for early reflections

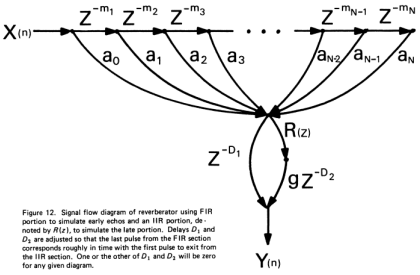
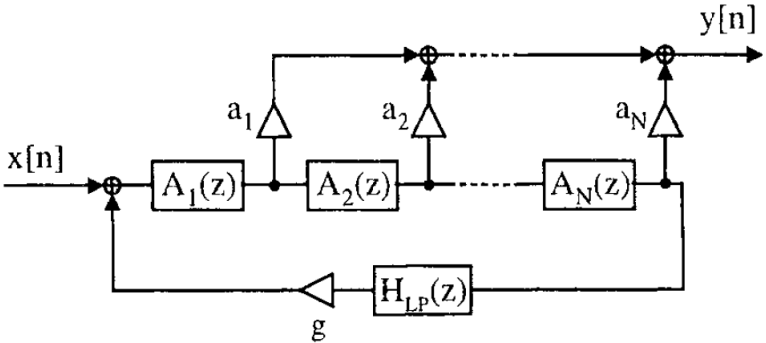


Figure 12. Signal flow diagram of reverberator using FIR portion to simulate early echos and an IIR portion, denoted by $R(z)$, to simulate the late portion. Delays D_1 and D_2 are adjusted so that the last pulse from the FIR section corresponds roughly in time with the first pulse to exit from the IIR section. One or the other of D_1 and D_2 will be zero for any given diagram.

- original
- wet

artificial reverberation

other reverberation approaches: Gardner



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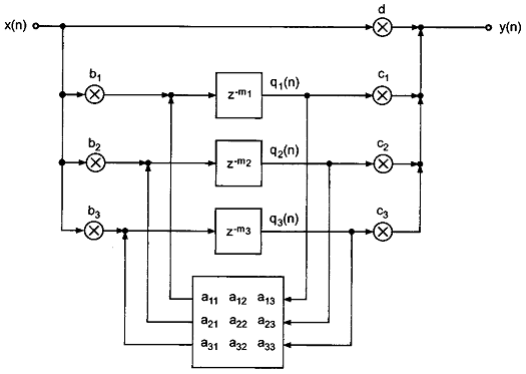
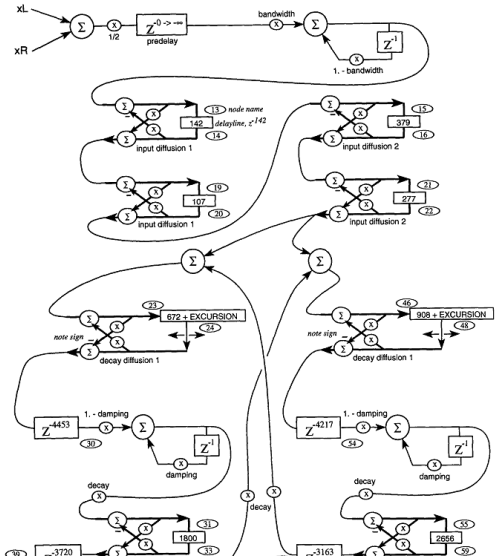
other reverberation approaches: Jot (feedback delay network)



artificial reverberation

reverberation: Dattorro 1/2



artificial reverberation

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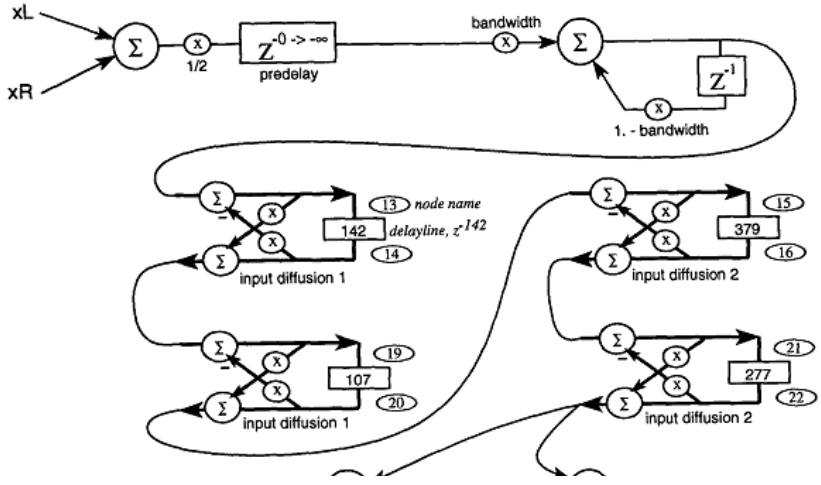

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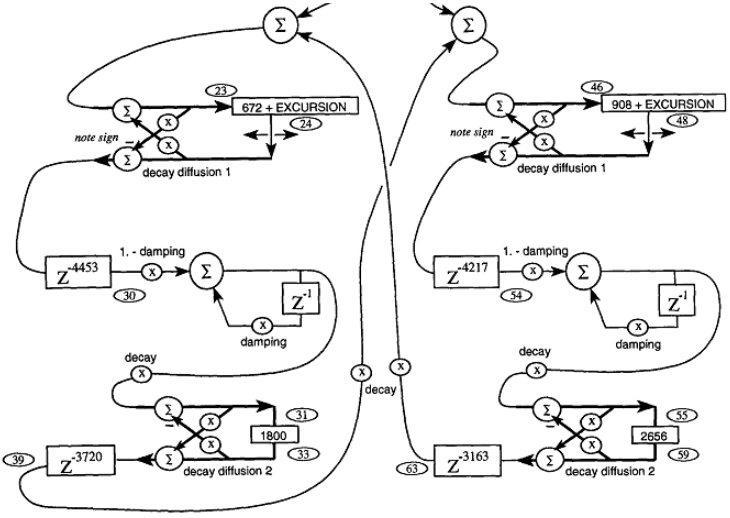

artificial reverberation

reverberation: Dattorro 2/2

intention: plate reverb model (dense, bright, fast build-up time)

- original
- wet (Plate)
- wet (Medium Hall)
- wet (Cathedral)

artificial reverberation

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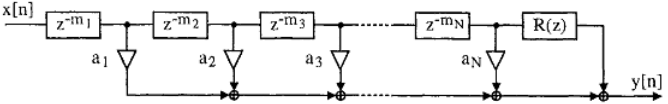
artificial reverberation

early reflections: models 1/2



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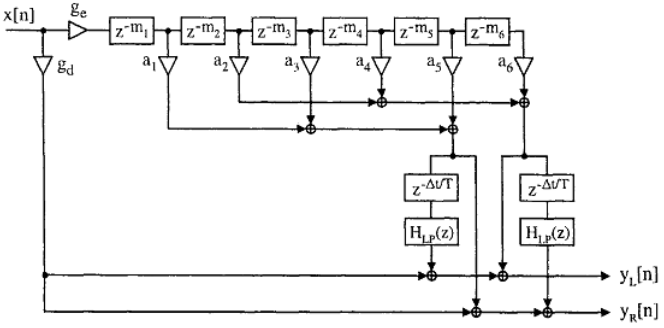
early reflections: models 2/2



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quality enhancements

- **multi-channel processing**
  - mono in $\rightarrow$ mono out
  - mono in $\rightarrow$ stereo out
  - stereo in $\rightarrow$ stereo out
- **delay modulation**
  - increase "diffusity" and "liveliness"

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common parameters

- wetness
- reverberation time
- pre-delay
- low pass cutoff
- low pass slope
- bass boost
- ratio of early reflection/late reverberation
- diffusion, liveliness, etc.

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parametric reverb

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  - works well with already somewhat reverberated recordings
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