

Digital Signal Processing for Music

Part 20: Reverb

alexander lerch

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

introduction

■ idea:

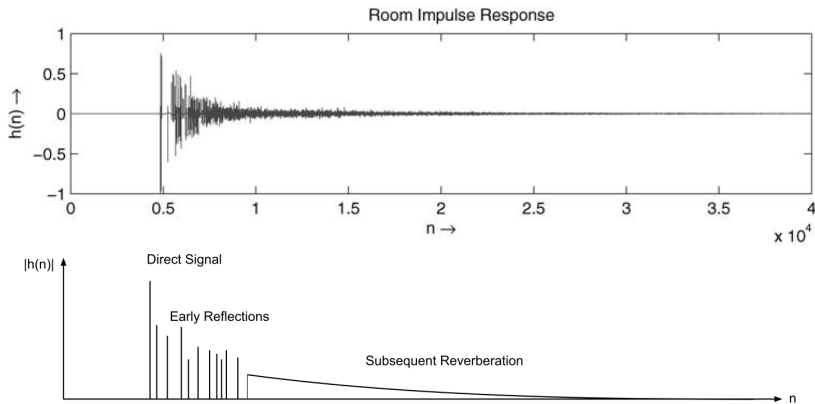
- artificially generate the impression of envelopment and reverberation
- possibly allow to modify specific characteristics of the “modeled” room

■ approaches

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

artificial reverberation

room impulse response



¹U. Zölzer, *Digital Audio Signal Processing*, 2nd Edition. Stuttgart: John Wiley & Sons Ltd, 2008, ISBN: 978-0-470-99785-7.

artificial reverberation

room impulse response: properties

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:

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

artificial reverberation

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artificial reverberation

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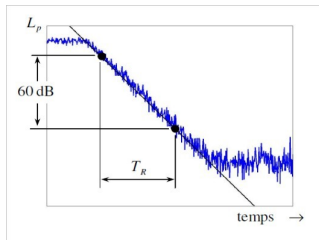
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artificial reverberation

room reverberation time

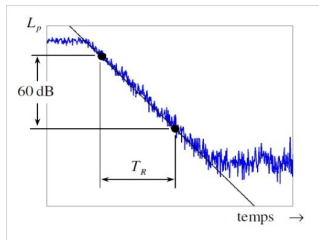


what are typical ranges for the room reverberation times



artificial reverberation

room reverberation time



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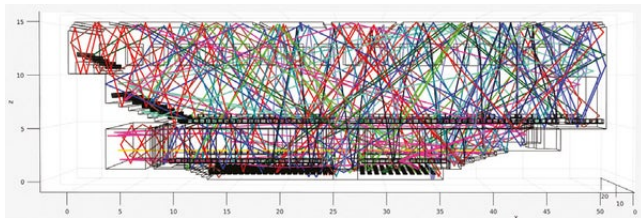
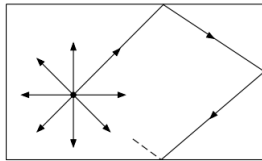
- 0.2-10s



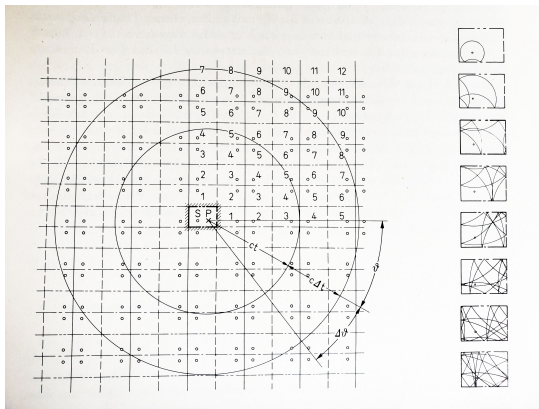
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room simulation: ray tracing

a) Ray Tracing



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convolution vs. parametric reverb

■ convolution reverb

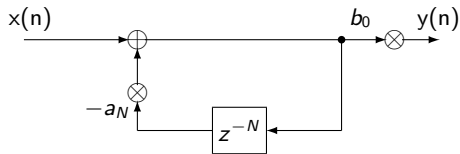
- + IR measured or generated by model
- + realistic
 - restriction to pre-generated IR libraries
 - high workload and memory requirements

■ parametric reverb

- + can be very efficient
- + can be parametrized
 - less realistic/no real-world IRs

artificial reverberation

traditionally used filters: comb filter

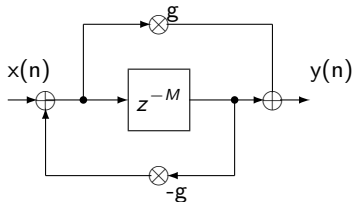


$$y(n) = b_0 \cdot x(n) - a_N \cdot y(n - N)$$

$$H(z) = \frac{b_0}{1 - a_N \cdot z^{-N}}$$

artificial reverberation

traditionally used filters: all pass filter

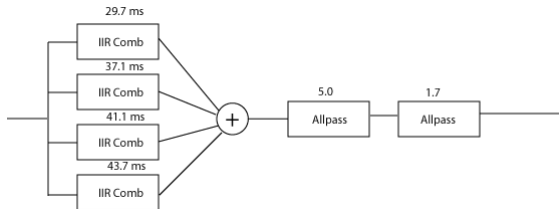


$$y(n) = g \cdot x(n) + x(n - M) - g \cdot y(n - M)$$

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

artificial reverberation

reverberation: Schroeder 1/2



questions:

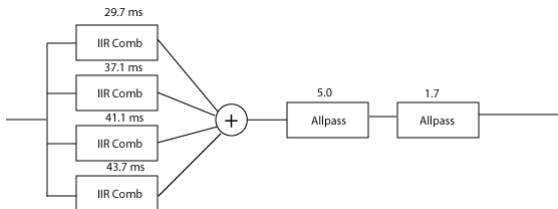
- how to change the reverberation time?
- how to change the density?

³M. Schroeder and B. Logan, "“Colorless” artificial reverberation," en, *IRE Transactions on Audio*, vol. AU-9, no. 6, pp. 209–214, Nov. 1961,

ISSN: 0096-1981, 2168-2984. DOI: [10.1109/TAU.1961.1166351](https://doi.org/10.1109/TAU.1961.1166351). (visited on 03/29/2023).

artificial reverberation

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artificial reverberation

reverberation: Schroeder 2/2

■ problems

- sound coloring (→ prime numbers)
- periodicity

■ audio

- original 
- wet 


artificial reverberation

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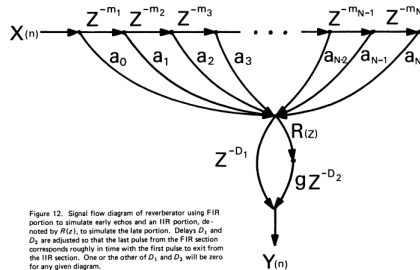
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artificial reverberation

reverberation: Moorer

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

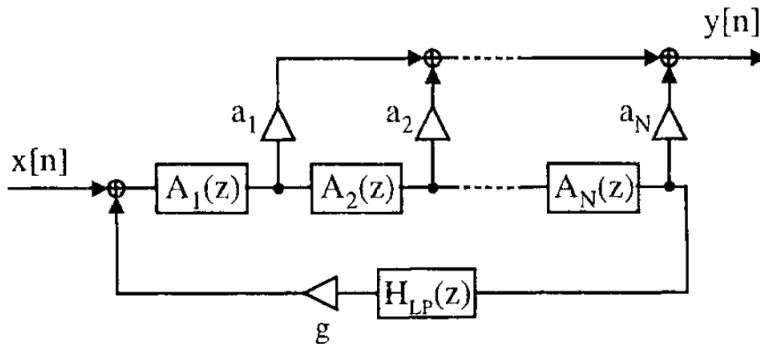
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⁴ J. A. Moorer, "About This Reverberation Business," *Computer Music Journal*, vol. 3, no. 2, p. 13, Jun. 1979, ISSN: 01489267. DOI:

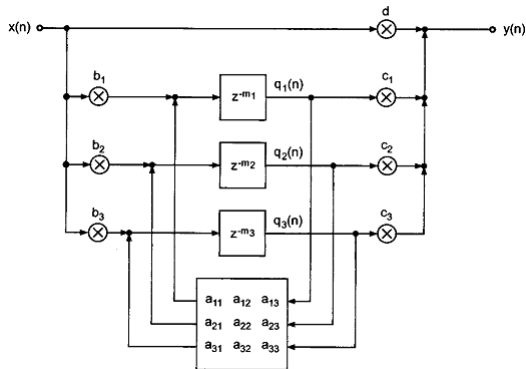
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other reverberation approaches: Gardner



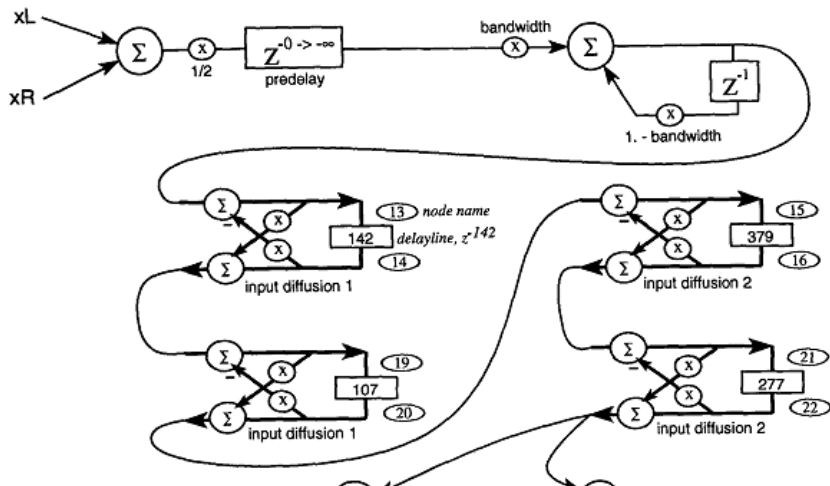
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other reverberation approaches: Jot (feedback delay network)



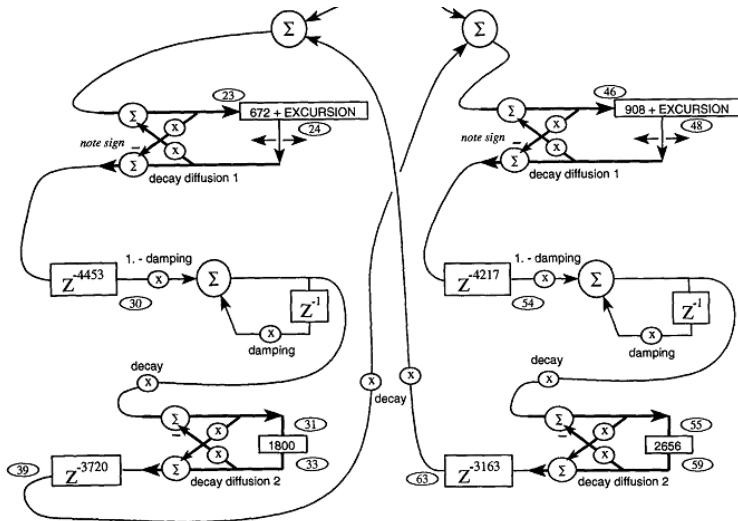
artificial reverberation

reverberation: Dattorro 1/2



artificial reverberation


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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

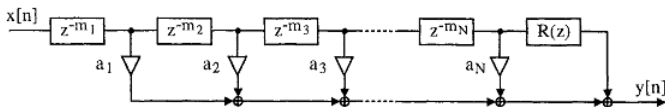
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artificial reverberation

early reflections: models 1/2



artificial reverberation

quality enhancements

■ multi-channel processing

- mono in → mono out
- mono in → stereo out
- stereo in → stereo out

■ delay modulation

- increase “diffusivity” and “liveliness”

artificial reverberation

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artificial reverberation

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

■ **advantages** over convolution reverbs

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- works well with already somewhat reverberated recordings
- lower workload (IIR vs. FIR)

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