Reverberation

- Reflections in a concert hall are many
- Number increases exponentially with time
- Typically modeled in two parts:
  - Early reflections – discrete delays
  - Late reflections – generated by a network of all-pass and feedback delay filters
  - Often add low-pass filter to network because high frequencies are absorbed by air and room surfaces

Artificial Reverberation

- RT60 – time to decay from peak amplitude to -60dB (1/1000 amplitude)
- Typical RT60 is 1.5 to 3 seconds
- Impulse response:
**Reverberator Building Blocks**

- Feedback delay (comb filter) provides decaying echo
- Allpass filter:

\[
g < 1
\]

\[
1 - g^2
\]

**Implementations**

- Schroeder
Improved Reverberators

• Add multitap delay for early reflections

Multitap delay line

• Low-pass in feedback loops
• More elaborate allpass filters
• Multichannel designs

Implementations in Nyquist

load “reverb.lsp”
reverb(sound, reverb-time)

• Mix “dry” sound with reverb:
  
  function reverb-mix(s, rt, wet)
  return s * (1 - wet) +
  reverb(s, rt) * wet

• Other reverb primitives in Nyquist:
  • nrev
  • jcrev
  • prcrev
Convolution-based Reverberators

- Reverberators can be seen as very big filters
- Long irregular impulse response
- Many modern reverb
  - Measure impulse response of real rooms and concert halls
  - Four impulse responses for stereo
  - Apply impulse responses using fast convolution (multiplication in the frequency domain)

Summary

- Many audio effects are available
- Audio effects are crucial in modern music production
- Reverberation
  - The effect of millions of “echoes”
  - becoming denser with greater delay, and
  - generally decaying exponentially with delay