MUS420 Lecture
Commuted Synthesis of Strings

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Outline

• Basic Idea

• Commuted Piano Synthesis
  – String Interface
  – Excitation Factoring

• Linear Commuted Violin Synthesis
Commuted Synthesis of Strings

Schematic diagram of a stringed musical instrument.

Equivalent diagram in the linear, time-invariant case.

Use of an aggregate excitation given by the convolution of original excitation with the resonator impulse response.

Possible components of a guitar resonator.
Features of Commuted Synthesis

- Enormous resonators can be implemented inexpensively (three orders of magnitude less computation for typical stringed instruments)
- Good qualitative excitation signals are easy to measure (just tap on the bridge)
- Apparent “resonator size” can be modulated by changing the *playback rate* of the excitation table

Drawbacks:

- Requires *linearity* and *time invariance*
Linear Commuted Violin Synthesis

a) Amplitude(n) Frequency(n) \( \rightarrow \) Impulse Train \( \rightarrow \) e(n) \( \rightarrow \) String \( \rightarrow \) Resonator \( \rightarrow \) s(n) \( \rightarrow \) Output x(n)

b) Amplitude(n) Frequency(n) \( \rightarrow \) Impulse Train \( \rightarrow \) e(n) \( \rightarrow \) Resonator \( \rightarrow \) a(n) \( \rightarrow \) String \( \rightarrow \) Output x(n)

c) Amplitude(n) Frequency(n) \( \rightarrow \) Impulse-Response Train \( \rightarrow \) a(n) \( \rightarrow \) String \( \rightarrow \) Output x(n)

- Assumes \textit{ideal Helmholtz motion}
- Sound examples:

Multiple-Excitation Commuted Synthesis

- For pianos, harpsichords, etc.,
  - Excitation point moves with key number
  - Wavetable interpolation can be used as in \textit{sampling synthesis}
- For guitars, violins, cellos, etc.
  - Each string has a slightly different excitation point
  - Vertical and horizontal excitations different
- “Attack Signal” = sound going “around” the strings (or only once through the string)
Energy Decay Relief (EDR) of a Violin Body
Impulse Response

- Energy summed over frequency within each “critical band of hearing” (Bark band)
- Low-frequency modes “resolved”
- High-frequency modes merge together perceptually into a
Filtered-Noise Excitation Synthesis

\[
\gamma_i(n) \quad \ldots \quad \gamma_L(n)
\]

FIR 1 \quad \rightarrow \quad \cdots \quad \rightarrow \quad \text{FIR filter}

\text{Convolution} \quad \rightarrow \quad \text{Stochastic Excitation Component}

\text{Noise Generator}