Commuted Synthesis of Strings

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Outline

• Basic Idea

• Body Resonator Factoring
  – Shortened Body Impulse Response
  – Corresponding Amplitude Response
  – Localized Second-Order Mode Elimination Filter

• Commuted Piano Synthesis
  – String Interface
  – Excitation Factoring

• Linear Commuted Violin Synthesis

*Work supported by the Wallenberg Global Learning Network
Commutated 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

- Assumes *ideal Helmholtz motion*
- Sound examples:

Multiple-Excitation Commuted Synthesis

![Diagram of Multiple-Excitation Commuted Synthesis]

- **Attack Signal**
- **Trigger**
- **Excitation 1**
- **Excitation M**
- **Length N Delay Line**
- **Nonlinearity**
- **Loop Filter**

Symbols and Equations:
- $g_0(n)$
- $g_1(n)$
- $g_M(n)$

Equations:
- $\ldots$
- Nonlinearity
- Loop Filter
- Output
Filtered-Noise Excitation Synthesis

\[ \gamma_1(n) \]

\[ \gamma_L(n) \]

FIR filter

Convoluted

Stochastic Excitation Component

Noise Generator
Commuted Synthesis of the Linearized Violin

a)
\[
\text{Amplitude}(n) \quad \text{Frequency}(n) \quad \text{Impulse Train} \quad e(n) \quad s(n) \quad \text{String} \quad \text{Resonator} \quad x(n) \quad \text{Output}
\]

b)
\[
\text{Amplitude}(n) \quad \text{Frequency}(n) \quad \text{Impulse Train} \quad e(n) \quad a(n) \quad \text{Resonator} \quad \text{String} \quad x(n) \quad \text{Output}
\]

c)
\[
\text{Amplitude}(n) \quad \text{Frequency}(n) \quad \text{Impulse-Response Train} \quad a(n) \quad \text{String} \quad x(n) \quad \text{Output}
\]