2018 Fall

CTP431: Music and Audio Computing

Sound Synthesis (Part 2)

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Category of Sound Synthesis

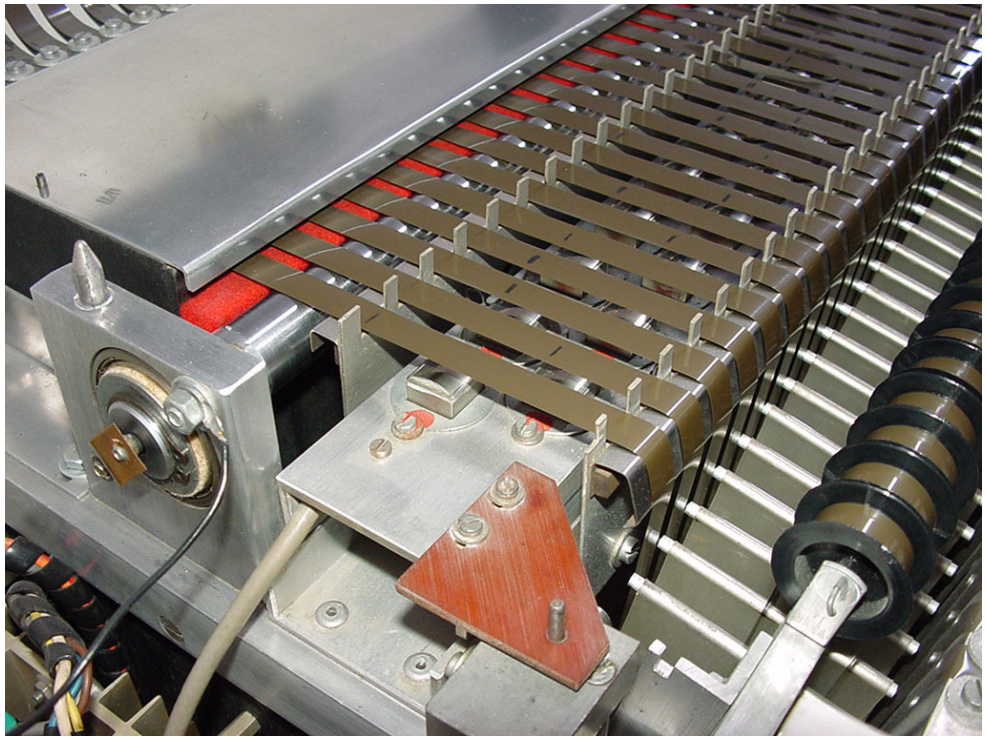
- Signal Models
  - Abstract sound synthesis
    - Additive Synthesis
    - Subtractive Synthesis
    - Modulation Synthesis
    - Distortion Synthesis
  - **Sample-based synthesis**
    - **Sampling Synthesis**
    - **Granular Synthesis**
    - **Concatenative Synthesis**
- **Physical models**
  - **Digital Waveguide Model**

Sample-based Synthesis

- Types of sample models
  - Sampling synthesis: reproduction of the original tone
  - Granular synthesis: sound textures by reorganizing a large set of sample grains
  - Concatenative synthesis: long-term sounds (e.g., speech or music phrase) by stitching short samples from a corpus

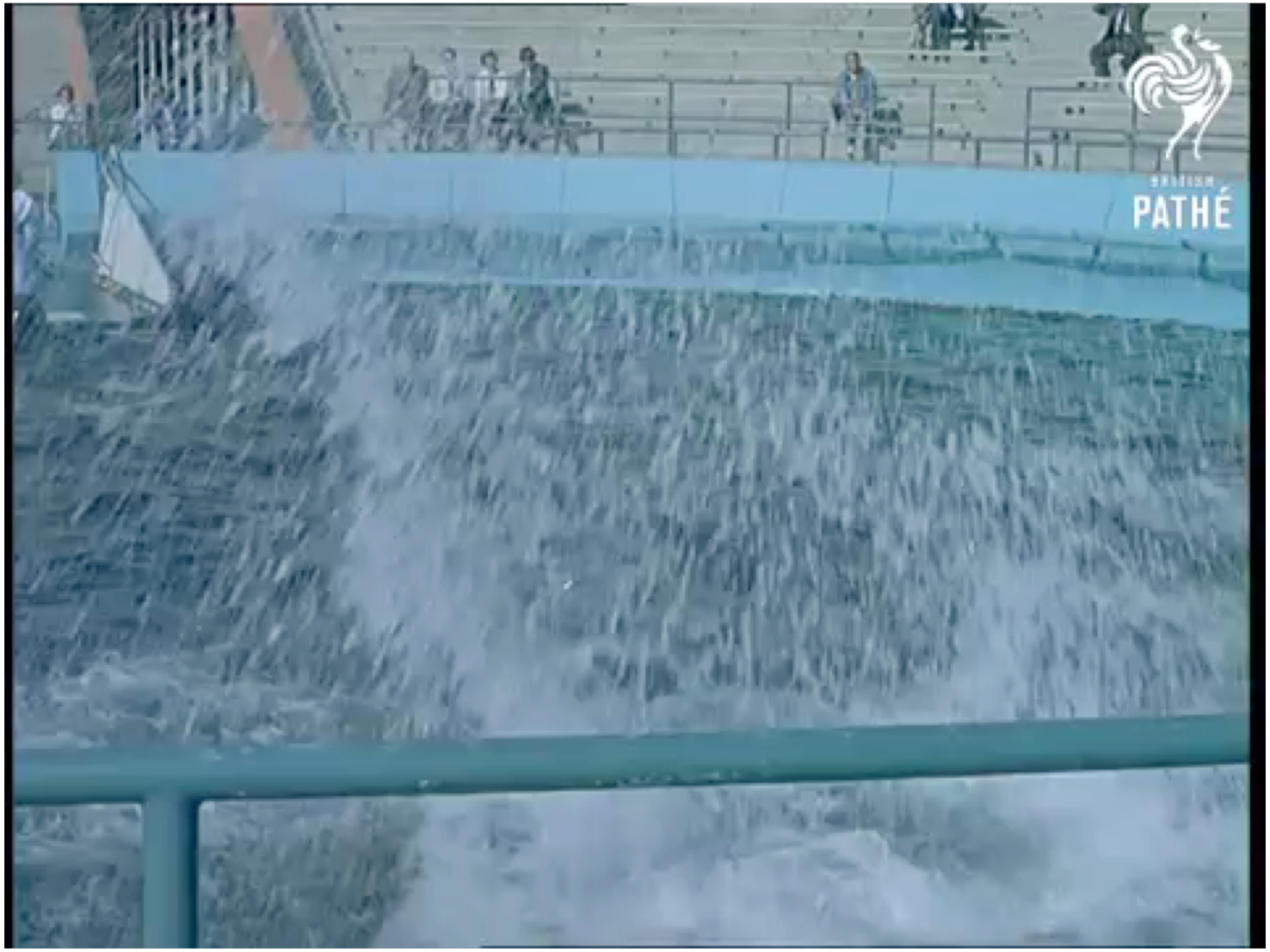
Early Sampling

- Record samples using magnetic tapes



Melotron (1963)

Melotron

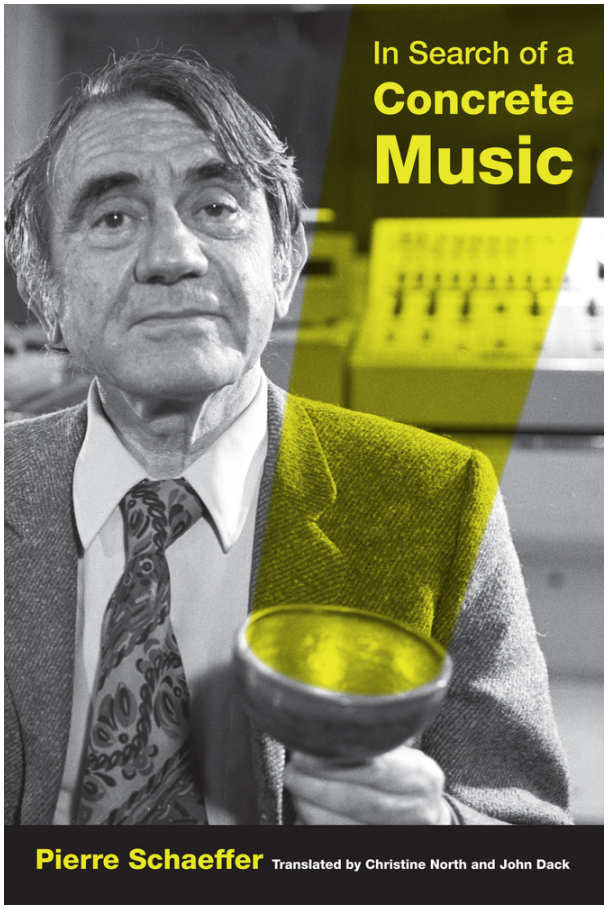


https://www.youtube.com/watch?v=HdkixaxjZCM

Music Concrete

- Music composition genre using recorded samples
  - Use “concrete” samples instead of “abstract” music symbols

- Sample modification by tape editing
  - Cut
  - Splice
  - Reverse
  - Speed up/down: pitch changes



Music Concrete

https://www.youtube.com/watch?v=c4ea0sBrw6M

Digital Sampling

Fairlight CMI (1979)

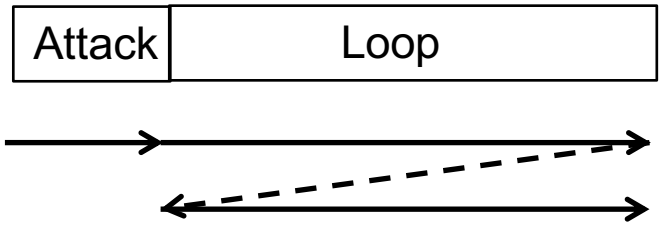
https://www.youtube.com/watch?v=iOlPCpSmhRM

Digital Sampling

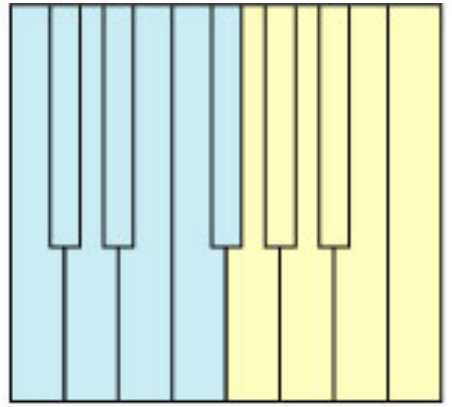
Synthogy Ivory II Piano (2011) : 77GB+, Steinway D Grand, …

Memory Saving Techniques

- Looping
  - Repeat a periodic segment seamlessly
  - The sustained part of a pitched musical note
  - Should consider amplitude decays and non-integer period



- Key mapping
  - Reuse a single sample for multiple notes
  - Pitch shifting by re-sampling



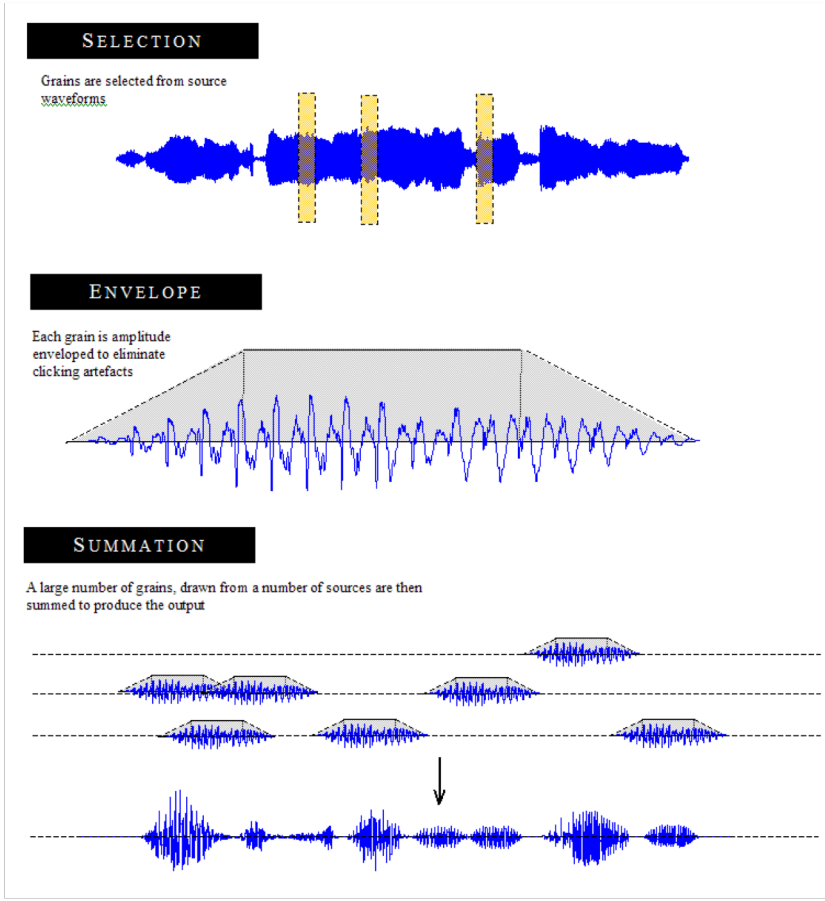
Synth: One sample for every five keys

- Velocity mapping
  - Reuse a single sample for different velocity
  - Use gain and low-pass filters for soft notes

Granular Synthesis

- Take small grains of samples from recorded audio and play them as “a cloud” to generate a sound texture
  - The grain is the quantum of sound

- Parameters
  - Grain size: 1 to 50ms
  - Grain envelope: attack and release time
  - Grain density: overlap



(Williams and Murray-Smith, 2003)

Granular Synthesis

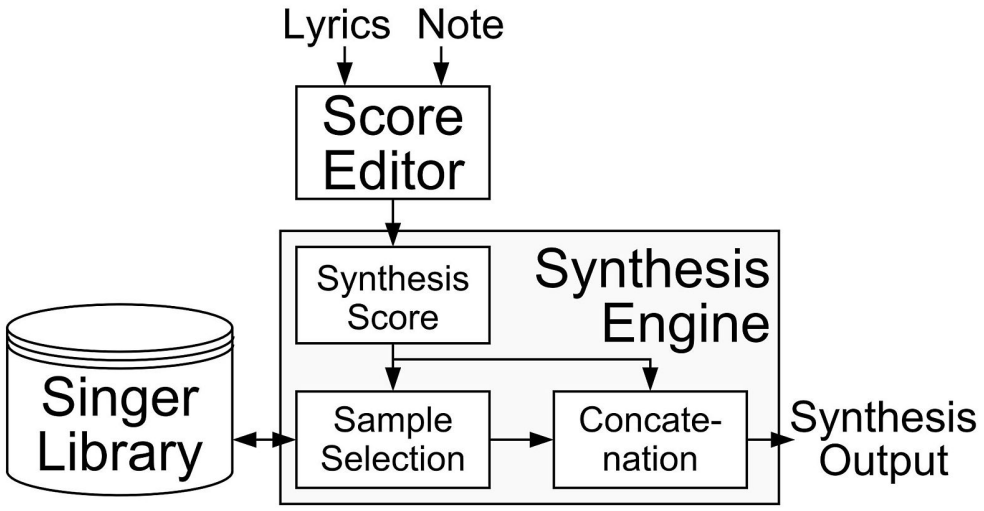
- Demos
  - https://www.youtube.com/watch?v=ywK9udx4Svc&t=50s
  - https://www.youtube.com/watch?v=Mb4EEWedQKM&t=2s

- Web audio
  - http://zya.github.io/granular/

Concatenative Synthesis

- Splicing short sample segments from a corpus
  - Unit selections: seamless stitching of samples using input information (e.g., score, lyrics)

- Typically in speech synthesis or singing voice synthesis
  - Speech: phoneme-level, word-level
  - Singing: note-level



Yamaha Vocaloid (Kenmochi and Ohshima, 2007)

Vocaloid

- Demos
  - https://www.youtube.com/watch?v=UAtVGHl1AFM
  - https://www.youtube.com/results?search_query=hatsune+miku
    (Vocaloid-based virtual singer)

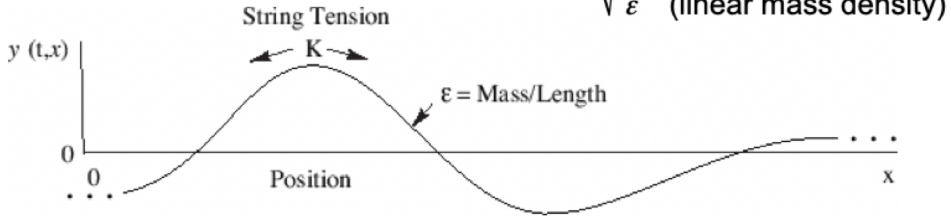
Physical Modeling

- Model the physical behavior of vibrating objects (i.e., musical instruments)
  - Numerical modeling of wave equations on strings, pipes, membranes
  - Parameters have direct physical interpretations
  - Finger positions on strings, body size

Wave Equation

$$K\frac{\partial^2 y}{\partial x^2} = \varepsilon\frac{\partial^2 y}{\partial t^2}$$

$c = \sqrt{\frac{K}{\varepsilon}}$ (string tension) (linear mass density)

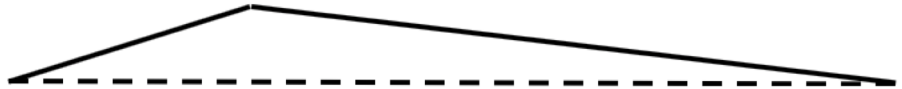


Boundary Conditions

Fixed or open ends

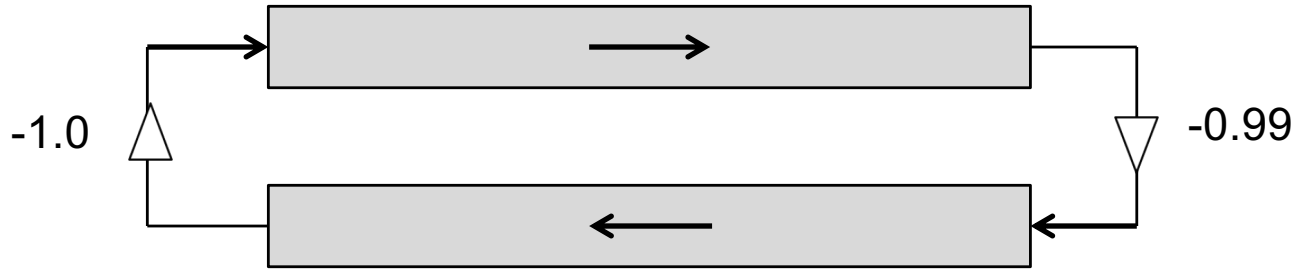
Initial Conditions

Action (plucking, striking)

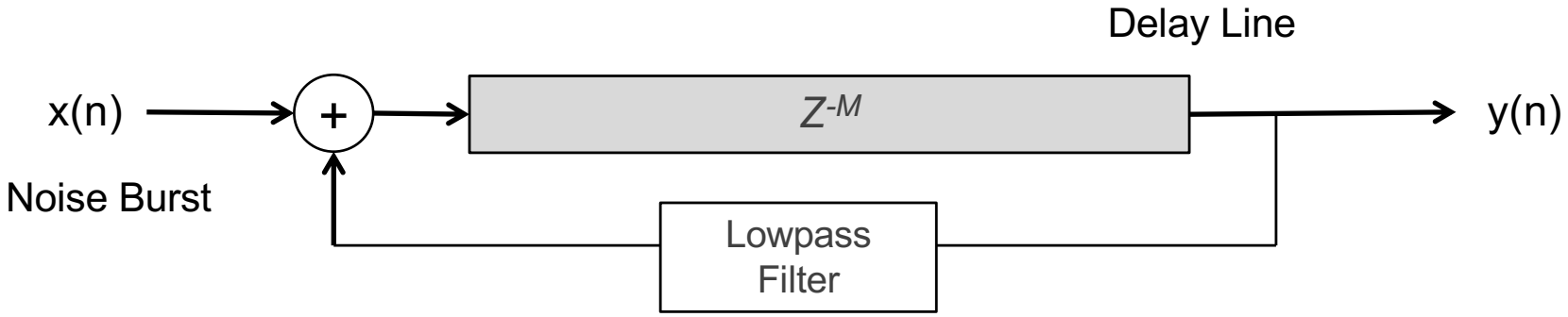


Physical Modeling

- Waveguide Model
  - With boundary condition (fixed ends)

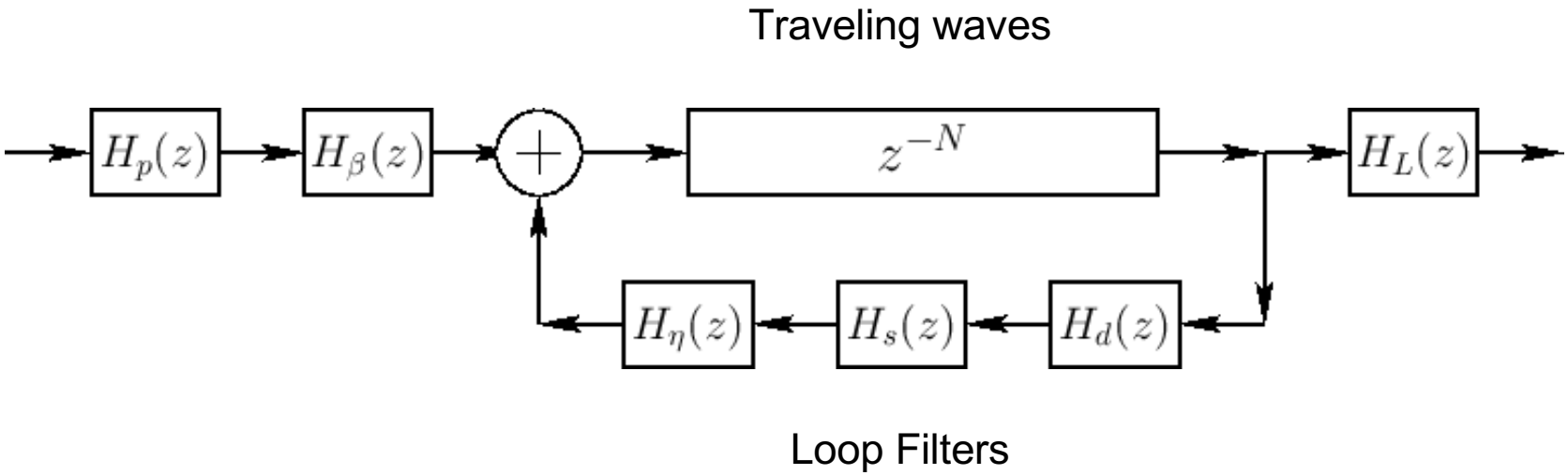


- The Karplus-Strong model



Physical Modeling

- The Extended Karplus-Strong model



https://ccrma.stanford.edu/~jos/pasp/Extended_Karplus_Strong_Algorithm.html

- Audio Examples
  - https://ccrma.stanford.edu/~jos/pasp/Sound_Examples.html

Comparison of Synthesis Techniques

	Memory (Storage)	Programmability (by # of parameters)	Reproducibility of natural sounds	Interpretability of parameters	Computation power
Additive	**	*****	****	****	****
Subtractive	*	***	**	***	**
Modulation / Non-linear	*	***	**	**	**
Physical model	***	**	****	*****	*** ~ *****
Sample-based	*****	*	*****	N/A	* ~ ***