

GeoShred, A Musical Instrument App based on Physical Modeling Synthesis A Fusion of Technology and Musical Art



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This Deck and our Full Deck on Physical Modeling Technology:

<http://www.moforte.com> go to the “News and Media” section

Or

This Deck

<http://www.moforte.com/geoshred-fusion-of-technology-and-musical-art/>

The Full Physical Modeling Deck:

<http://www.moforte.com/berklee-voltage-physical-modeling/>

GeoShred is a Fusion of Technology and Musical Art



GeoShred World Artists



Artists Performing GeoShred

The Story

- **Technology** - An abbreviated history of Physical Modeling Synthesis. Why in 1994, PM was poised to be the “Next Big Thing”.
And why it’s back!



- **Musical Art** - An artist’s perspective of interacting musically with a model.
- **Future** Directions



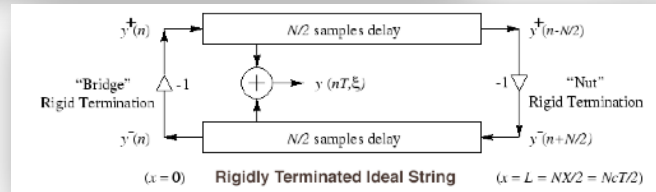
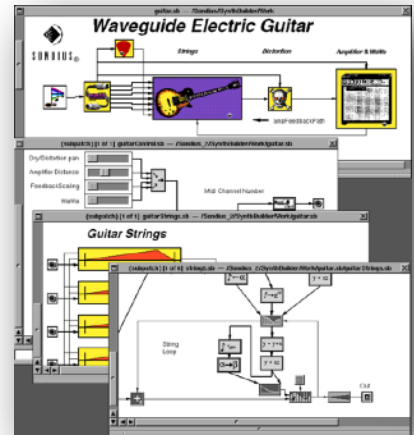
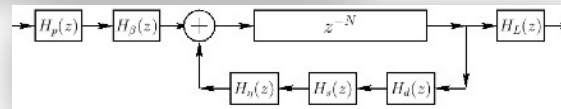
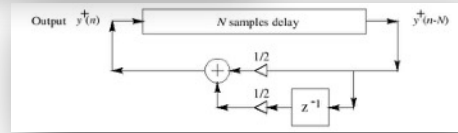
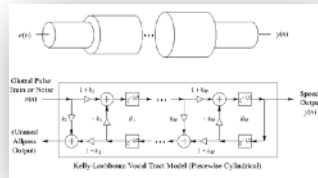
For Context, what is Physical Modeling Synthesis?

- Methods in which a sound is generated using a mathematical model of the physical source of sound.
- Any gestures that are used to interact with a real physical system can be mapped to parameters yielded an interactive and expressive performance experience.
- **Physical modeling is a collection of different techniques specific to each sound generation process.**

$$\frac{\partial^2 y}{\partial t^2} = \frac{1}{v_w^2} \frac{\partial^2 y}{dt^2}$$

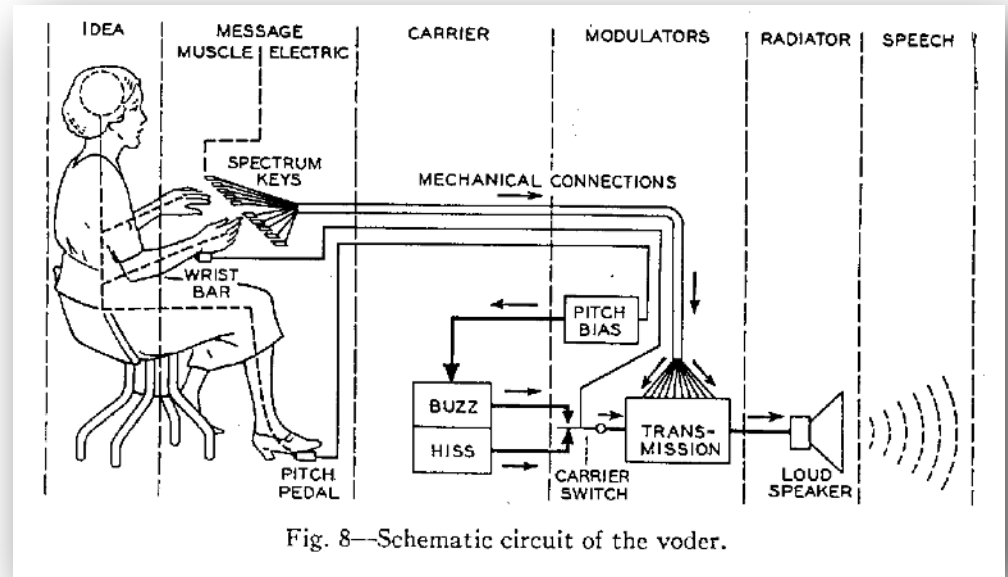
History:

A Few Key Topics to Draw an Arc for Why Physical Modeling is Back.

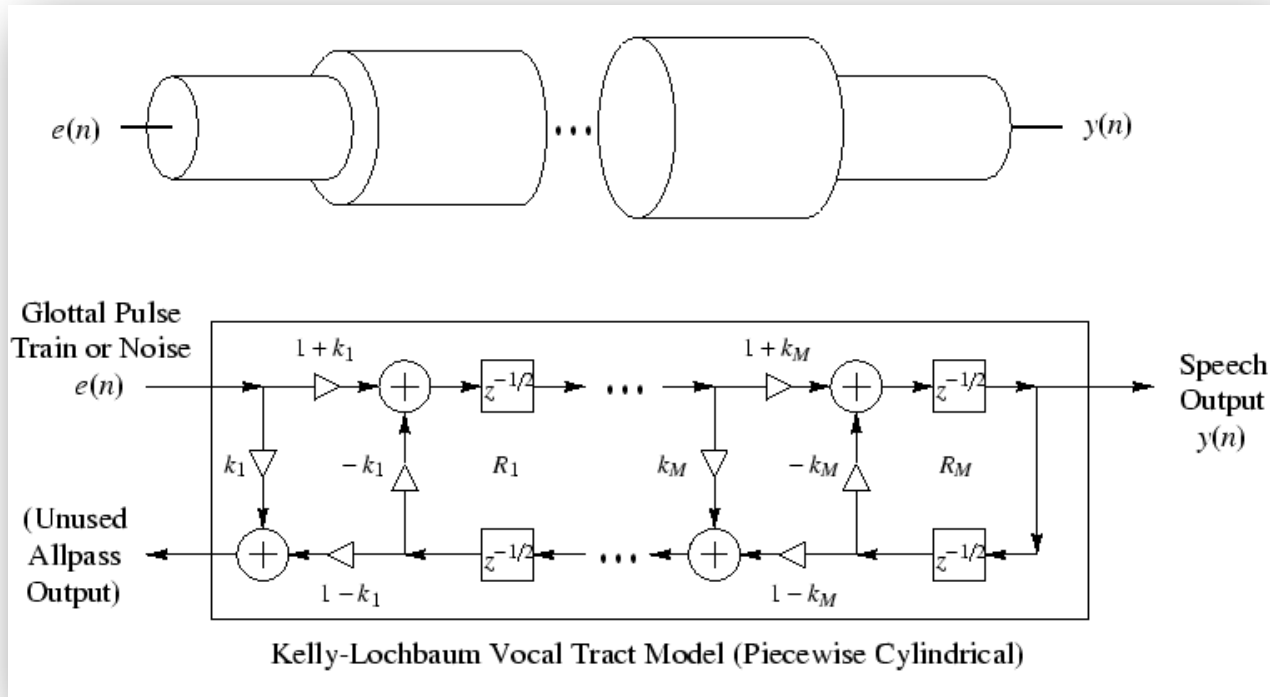


The Voder (1937-39) - Homer Dudley

- Analog Electronic Speech Synthesis
- Analog model of the vocal tract
- Develop from research on voice compression at Bell Labs.
- Featured at the 1939 Worlds fair
- [YouTube](#)



Kelly-Lochbaum Vocal Tract Model (1961)



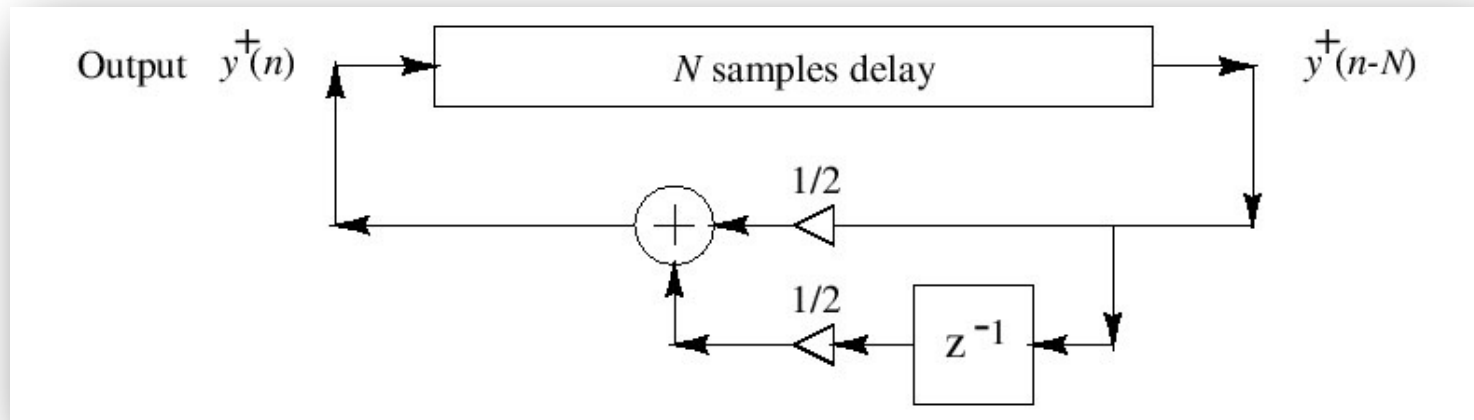
- Equivalent to d'Alembert's Solution to the Partial Differential Equation for a string (1747)

Daisy Bell (1961)

- Daisy Bell ([MP3](#))
- Vocal part by Kelly and Lochbaum (1961)
- Musical accompaniment by Max Mathews
- Computed on an IBM 704
- Based on Russian speech-vowel data from Gunnar Fant's book
- Probably the first digital physical-modeling synthesis sound example by any method
- Inspired Arthur C. Clarke to adapt it for "2001: A Space Odyssey" the Hal 9000's "first song"

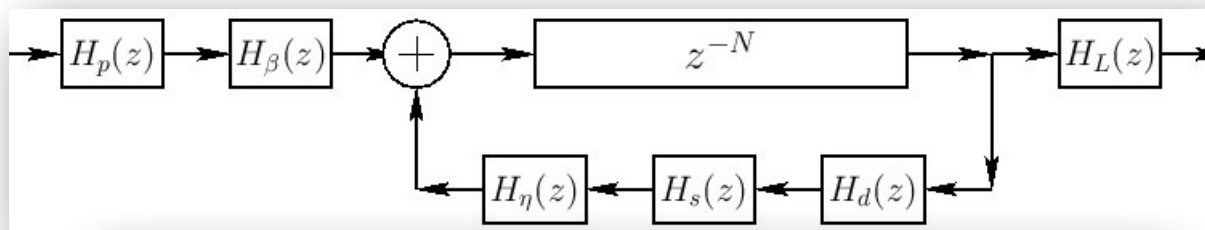


Karplus-Strong (KS) Algorithm (1983)



- Discovered (1978) as “self-modifying wavetable synthesis”
- Wavetable is preferably initialized with random numbers
- Licensed to Mattel

EKS Algorithm (Jaffe-Smith 1983)



$$H_p(z) = \frac{1-p}{1-pz^{-1}} = \text{pick-direction lowpass filter}$$

$$H_\beta(z) = 1 - z^{-\lfloor \beta N + 1/2 \rfloor} = \text{pick-position comb filter, } \beta \in (0, 1)$$

$$H_d(z) = \text{string-damping filter (one/two poles/zeros typical)}$$

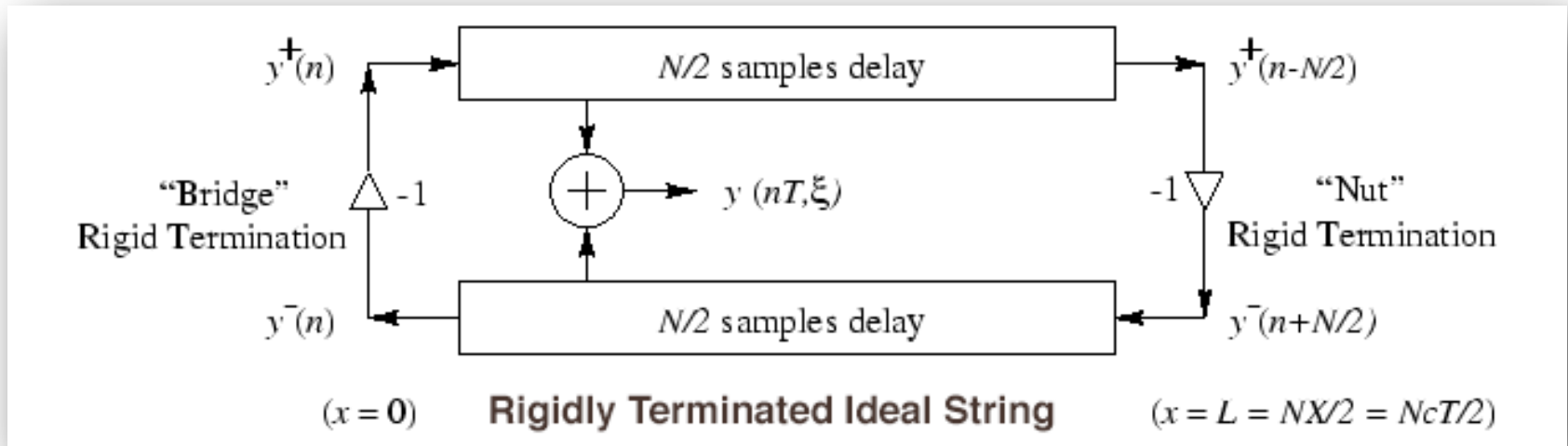
$$H_s(z) = \text{string-stiffness allpass filter (several poles and zeros)}$$

$$H_\eta(z) = -\frac{\eta(N) - z^{-1}}{1 - \eta(N)z^{-1}} = \text{first-order string-tuning allpass filter}$$

$$H_L(z) = \frac{1-R_L}{1-R_Lz^{-1}} = \text{dynamic-level lowpass filter}$$

- The first musical use of the algorithm was in the work “*May All Your Children Be Acrobats*” written in 1981 by David A. Jaffe. [\(MP3\)](#)
- Musical Example “*Silicon Valley Breakdown*” (Jaffe 1992) [\(MP3\)](#)
- Musical Example BWV-1041 (used to intro the NeXT machine 1988) [YouTube](#) 11

Digital Waveguide Models (Smith 1985)

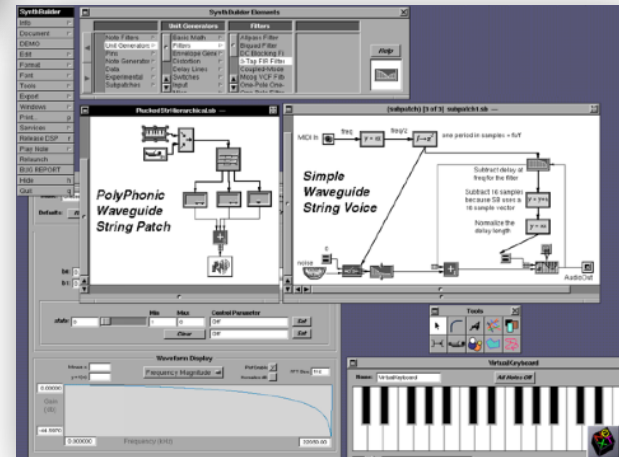


- Equivalent to the Kelly-Lockbaum vocal tract model with all but two scattering junctions removed, and the remaining two made into pure reflections or filters.
- Useful for efficient models of
 - Strings
 - Bores
 - plane waves
 - conical waves

Stanford Sondius Project (1994-1997)

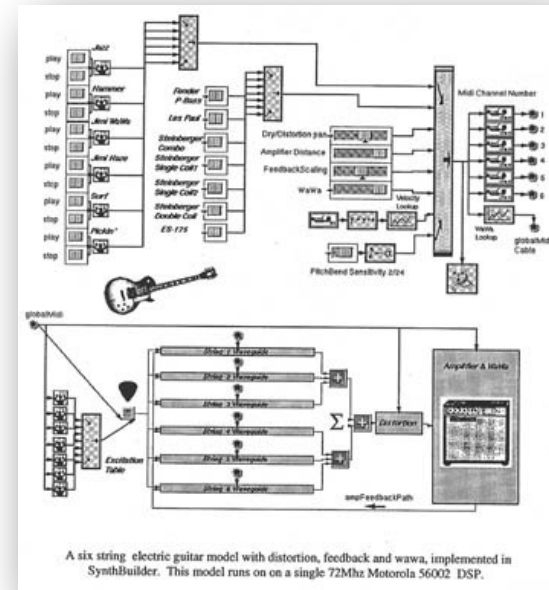
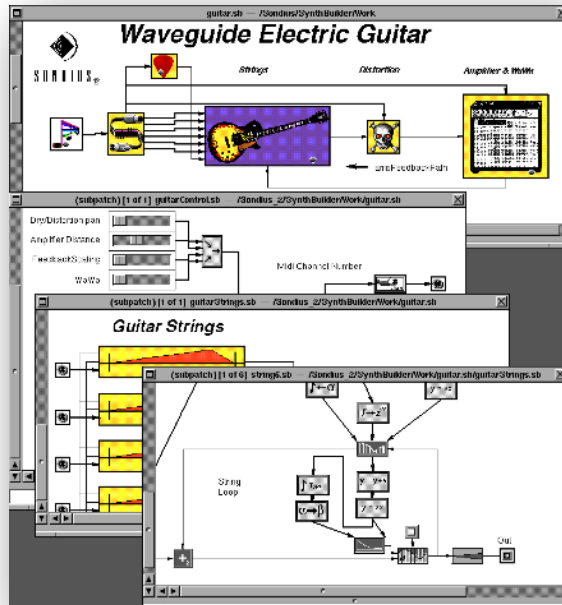


- Stanford OTL/CCRMA created the Sondius project to assist with commercializing physical modeling technologies.
- The result was a modeling tool known as SynthBuilder (Porcaro, et al.) , and a set of models covering about two thirds of the General MIDI set.
- Many modeling techniques were used including EKS, Waveguide, Commuted Synthesis, Coupled Mode Synthesis, Virtual Analog.



- Wind Chime Model ([MP3](#))
- Tubular Bells Model ([MP3](#))
- Percussion Ensemble ([MP3](#))
- Taiko Ensemble ([MP3](#))
- Piano ([MP3](#))
- Harpsichord ([MP3](#))
- Virtual Analog ([MP3](#))

The Sondius Electric Guitar (1996)



- Pick model for different guitars/pickups (commuted synthesis, Scandalis)
- Feedback and distortion with amp distance (Sullivan)
- Wah-wah based on cry baby measurements (Putnam, Stilson)
- Reverb and flanger (Dattorro)
- Hybrid allpass delay line for pitchBend (Van Duyne, Jaffe, Scandalis)
- Performed using a 6-channel MIDI guitar controller.
- With no effects, 6 strings ran at 22k on a 72 Mhz Motorola 56002 DSP.
- Waveguide Guitar Distortion, Amplifier Feedback ([MP3](#))

First Generation PM Products

- Yamaha VL-1 + Chipsets (1994-2000)
- Korg SynthKit ... Kronos (1994-present)
- Seer Systems Reality (1997)
- Aural ASP 301 Chip (1995-1997)
- Staccato SynthCore Sondius Models (1997-2001)



In 1994 Physical Modeling Was Poised to be the “Next Big Thing”. So What Happened?

- By 1994, FM was the standard for PC Game Music. In part due to it's small memory footprint.
- PM was seen by Yamaha as the successor to FM (John Chowning's pioneer FM patent was expiring).
- The cost of memory starting plummeting in 1996. Sampling became common.
- Some expressivity could be achieved with extensively interpolated samples.
- Voicing PM is difficult (like FM), voicing samples is more direct.
- Controllers that could express multiple dimensions were not common.



Why is PM Back?

- **“The Glass”** - Multi-touch, lots of sensors, mobile devices are everywhere; great for parametrically controlled, physically modeled musical instruments
- **MPE** - There is a new generation of polyphonic expressive controllers based on the new MIDI MPE spec.





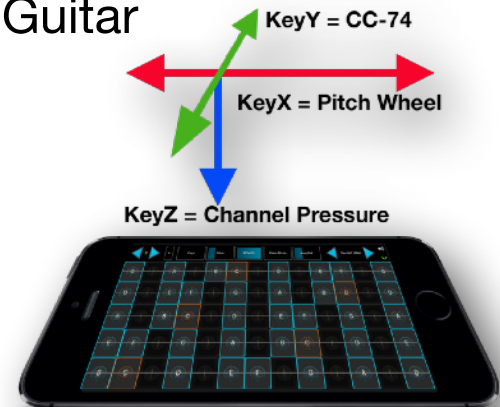
MIDI Polyphonic Expression

- MPE spec was adopted January 2018
- A set of **conventions built on MIDI 1.0** to communicate multidimensional control data.
- Until recently, the options for expressing musical parameters typically affected all notes the same way. **MPE is a standard for expressive control on a per-note or per-string basis.**
- Already adopted by over 50 hardware and software products.
- MPE combined with PM, the sum is greater than the parts.

MPE in a Nutshell

- Derivative of Multi Mode (MIDI Mode 5), enabled with RPN-6.
- Can be Channel-Per-Note (for Keyboards, like the Seaboard) or Channel-Per-Row (String) (GeoShred, LinnStrument, Guitar Controller).

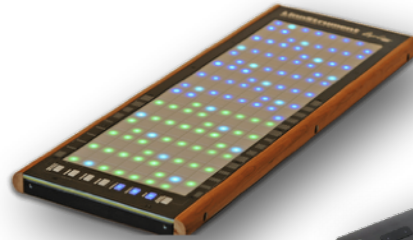
- Expression Control Conventions.
 - KeyX – Pitch Bend (Roli calls this *Glide*)
 - KeyY – CC-74 (Roli calls this *Slide*)
 - KeyZ – Channel Pressure (Roli calls this *Press*)



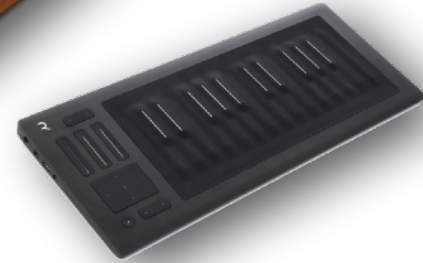
- Provides for master channels (typically 1 or 16) that globally control the MPE voice channels. (ie modWheel to all voice channels)
- Provides for a low/high split, and each split can have it's own master channel.

MPE Controllers

- LinnStrument



- Seaboard



- GeoShred



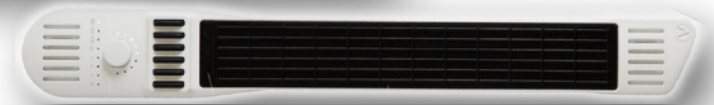
- KMI K-Board Pro 4



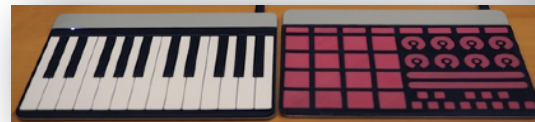
- Haken Continuum



- Artiphon INSTRUMENT 1



- Sensel Morph



- Joué



MPE Modeled Synths

- GeoShred



- SWAM

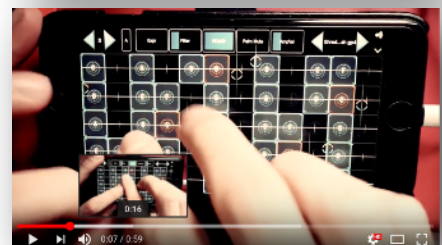
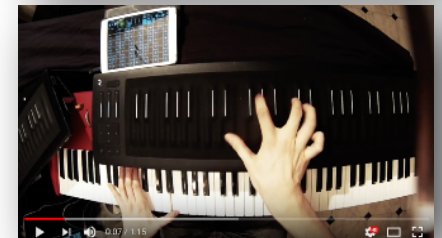
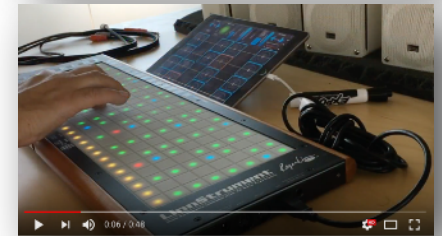


- Animoog/Model 15



MPE/Model Demos

- [GeoShred Controlling SWAM Sax \(Jordan Rudess\)](#)
- [Seaboard and LinnStrument controlling GeoShred](#)
- [Seaboard Controlling GeoShred \(Gerald Peter\)](#)
- [GeoShred with MPE KeyZ using 3D Touch \(Gerald Peter\)](#)



An Artist's Perspective

- “Almost Magic” Pitch Rounding Algorithms
- MPE
- Diatonic Keyboard
- GeoShred in India



What Comes Next?

- Plugins (Au3)
- Desktops
- More algorithms from the back room
 - Virtual Analog
 - Percussion
 - Woodwinds.
 - FM
 - Other
- Maybe, Alien Orchestras
- Oh Yeah... We're working on a thing



Questions?