GeoShred,
A New Kind of Musical Instrument
新型樂器

Pat Scandalis — CTO, moForte

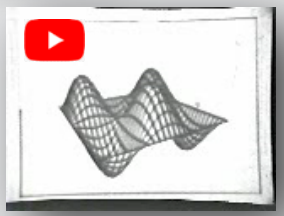
Jordan Rudess — Rock Star, President Wizdom Music

Dr. Julius O. Smith III — Professor Stanford/CCRMA

Nick Porcaro — Chief Scientist, moForte

About Pat

- 36 years in the Silicon Valley as an Engineer
- Built my first monophonic electronic instrument from a Radio Shack kit in 1970
- Gigged with an Arp Avatar guitar synth (1978)
- Computer modeling of vibrating strings and membranes for senior thesis in Physics (1982)
- Researcher in Physical Modeling at Stanford/CCRMA (1994)
- CEO/CTO of moForte



This Deck and our Full Deck on Physical Modeling Technology:

This Deck

www.moforte.com/musicacoustica2019

The Full Physical Modeling Deck:

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

Or

Go to the “News and Media” section at http://www.moforte.com

Imagine a new kind of musical instrument …

An instrument where a performer can fluidly express multiple independent voices … fingers. An instrument that is both pitch fluid, and helps the performer precisely reach desired musical pitches in any temperament.

This is GeoShred

GeoShred is an award winning, fluidly expressive musical instrument that runs on multi-touch devices. It has a unique **performance surface** with an "almost magic" pitch rounding algorithm, which is paired with a **physical model** of the physics of strings. Further, it's unique expressive control can be used to control other synthesizers.

Why?

As performing musicians, what we do, is translate emotional expression, feelings, into musical performance. We wanted to create a new kind of musical instrument that would help performers with musical expression.

Tens of Thousands of Artists in 48 Countries Perform GeoShred

Props

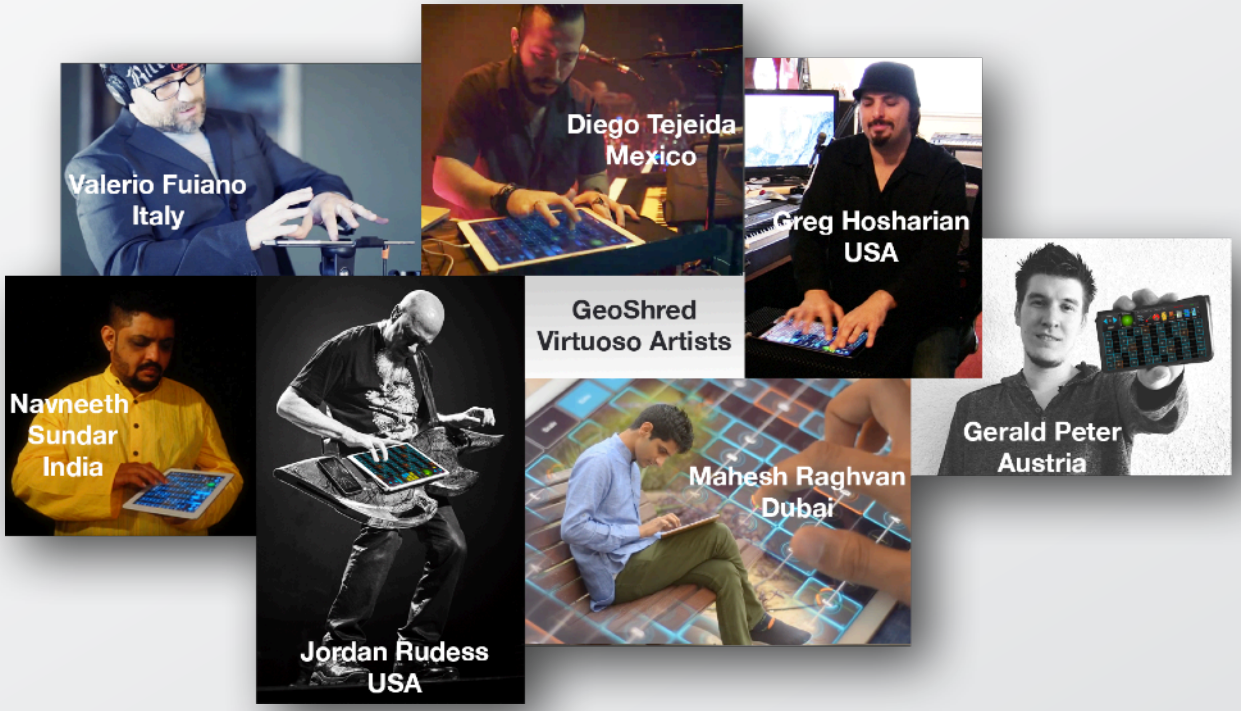
"GeoShred is brilliant- it's a real instrument."
– Eddie Jobson - Roxy Music, Jethro Tull, Frank Zappa, UK

"A fantastic new invention which is going to revolutionize the way music is played, expressed and learned! 'GeoShred' is one of the foremost best musical inventions I've had the pleasure to experience in recent years. Definitely 5 stars out of 5! GIGANTASTIVISSIMO.....R...A...Z !!!!!"
– Patrick Moraz, Yes, Moody Blues

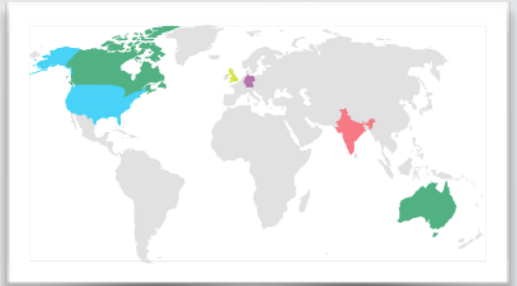
"That's just nuts. You're [Jordan] the best-guitarist-without-a-guitar of all time."
– Joe Satriani

"GeoShred is a breakthrough [musical instrument] for the iPad. Some might think it's the best evidence yet that there has indeed been reverse engineering of alien technology, but if that's the case, then aliens play guitar... and worship Jimi Hendrix."
– Craig Anderton, Harmony Central, Founding Editor Electronic Musician Magazine

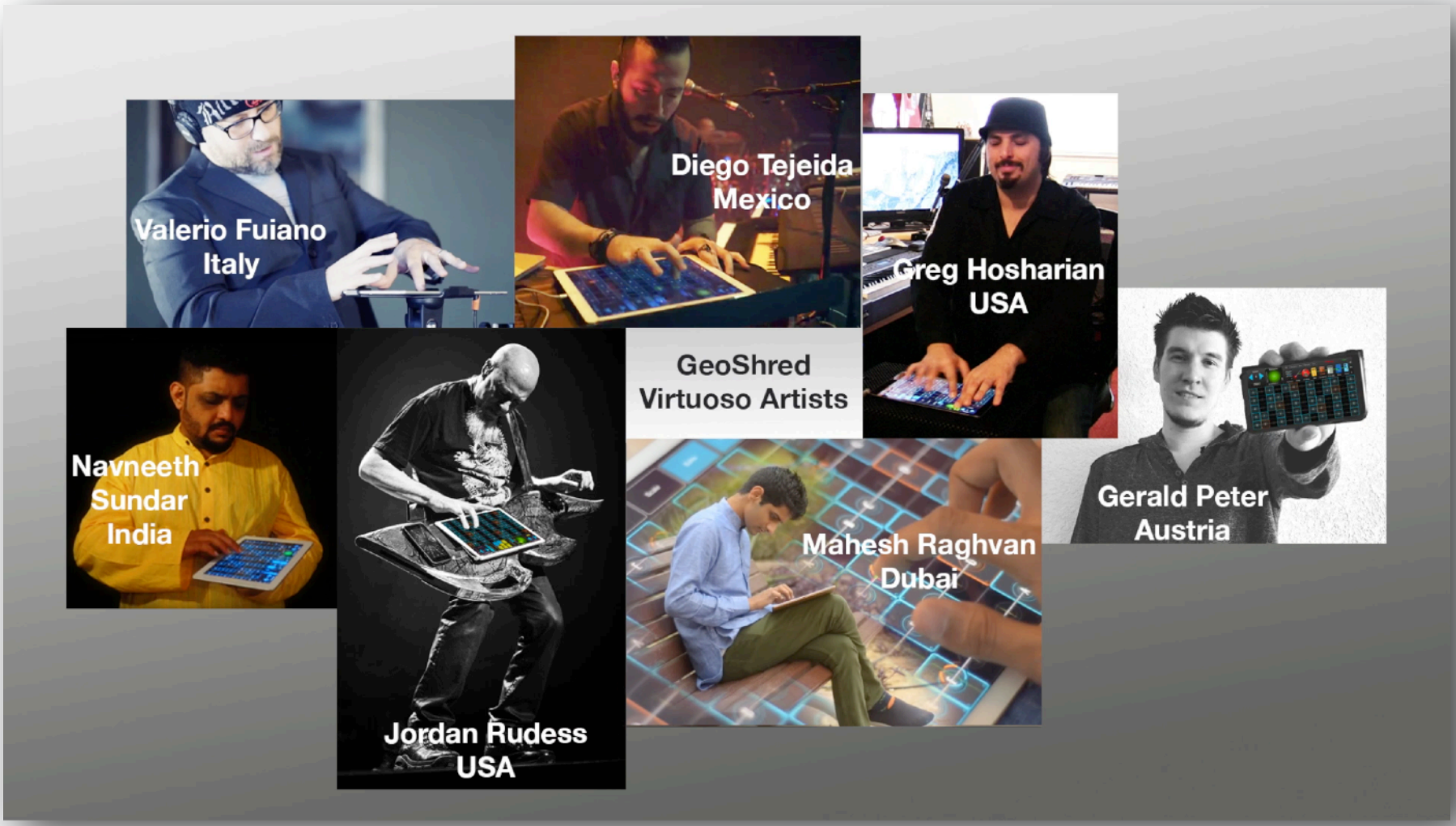
"...one of the most innovative, groundbreaking products to emerge in the past twelve months"
- Electronic Musician, 2017 Editor's Choice



27% of GeoShred Users are in India



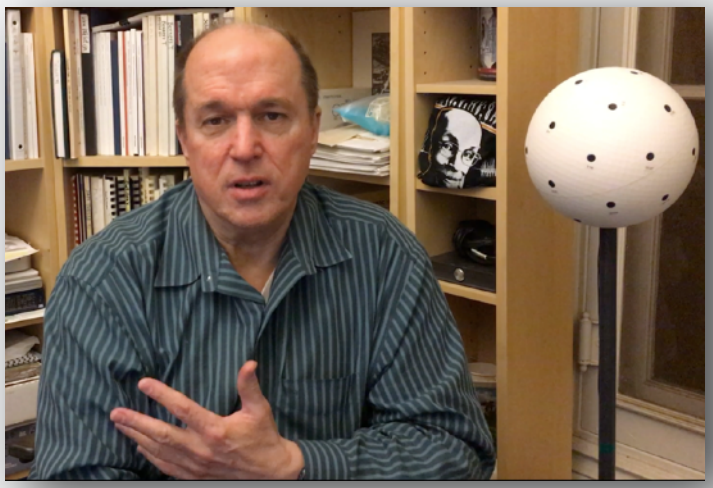
Artists


Valerio Fuiano
Italy
Diego Tejeida
Mexico
Greg Hosharian
USA
Navneeth
Sundar
India
Jordan Rudess
USA
GeoShred
Virtuoso Artists
Mahesh Raghvan
Dubai
Gerald Peter
Austria

The GeoShred Story

- **History**
  Performance Surface + Physical Model
- **GeoShred Performance Surface**
  Musical Expression
- **Controllable Physical Models**
  History, GeoShred Model
- **Pro Features**
  Bringing GeoShred's expression to other synths

History



GeoShred is a collaboration between Rock Star and mobile music innovator Jordan Rudess, Stanford/CCRMA Professor Dr. Julius O. Smith III, Nick Porcaro and Pat Scandalis

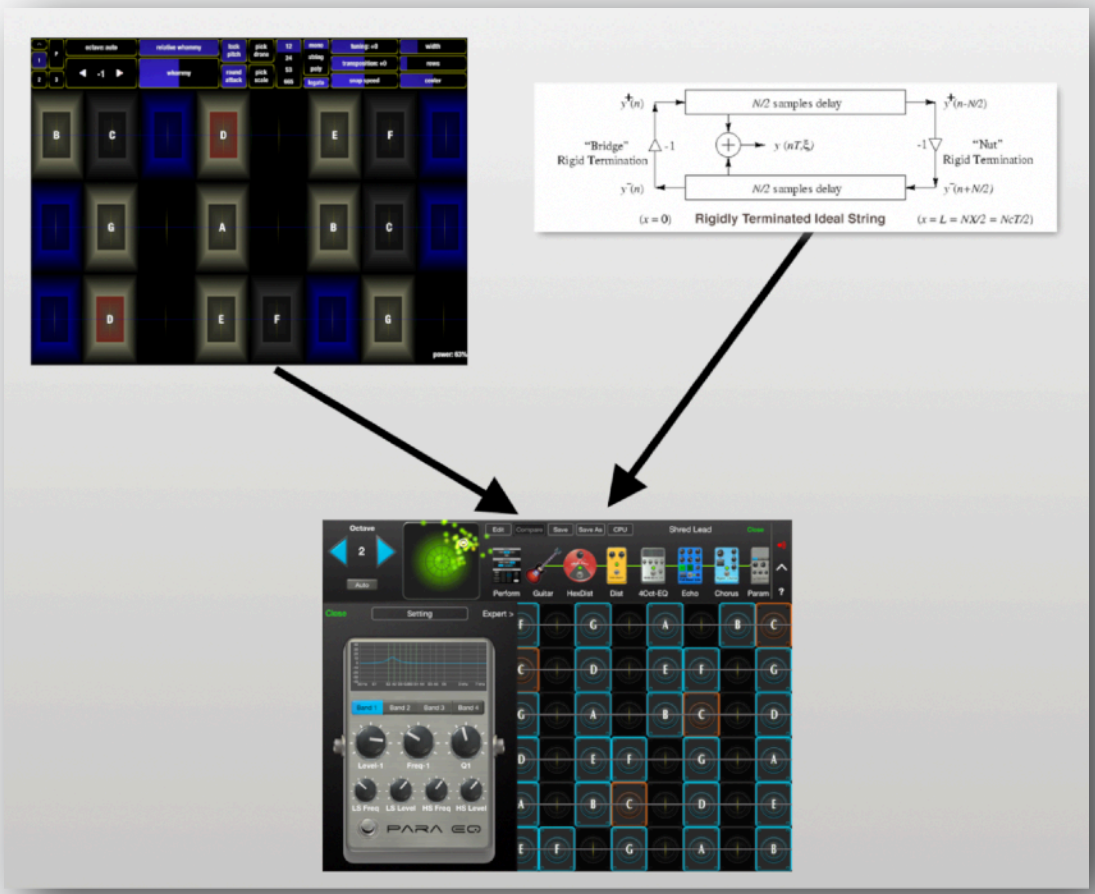
Performance Surface + Physical Model

GeoShred is a fusion of Jordan's musical performance ideas from an earlier instrument (Geo Synthesizer)

And advanced DSP models of the physics of strings that Julius, Nick and Pat have been working on for the past 35 years

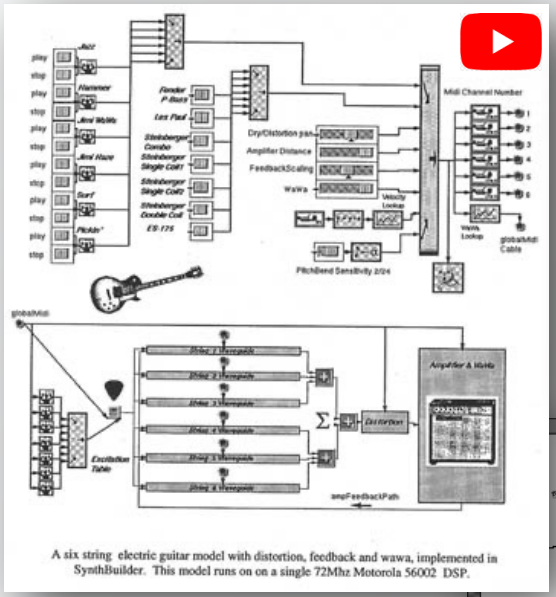
Physical Models have been around for years, unique performance surfaces have been around for years.

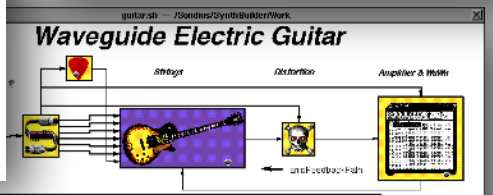
What we did is combine a unique performance surface with a physical model.

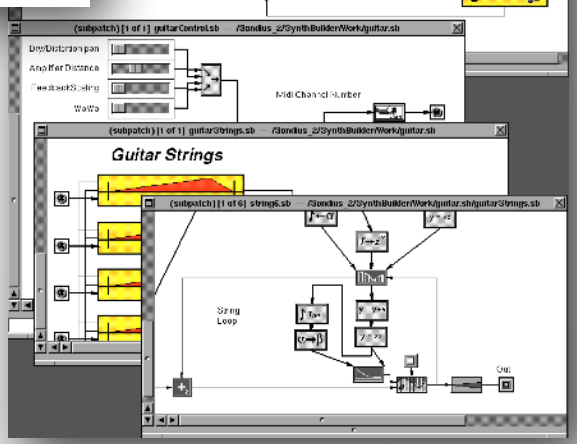


Early Guitar Model (1996)

- Versions of the model have been around since 1996 (Sondius)
- Mobile devices with sensors and multi-touch screens created a new opportunity to create a performable, expressible version of the model.







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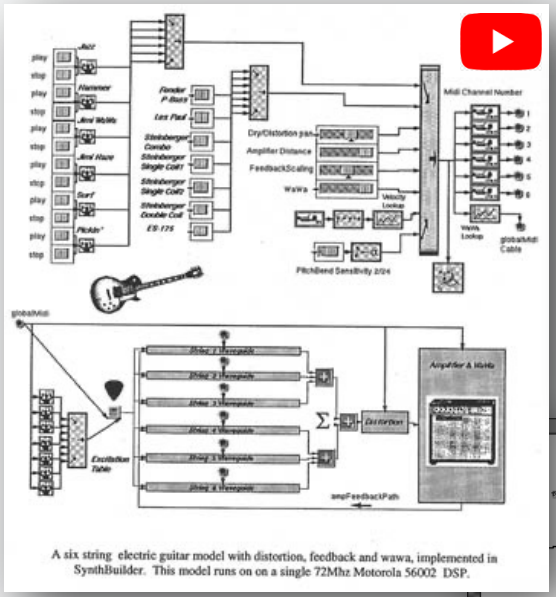
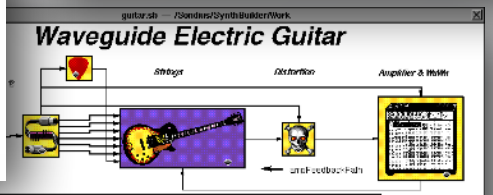
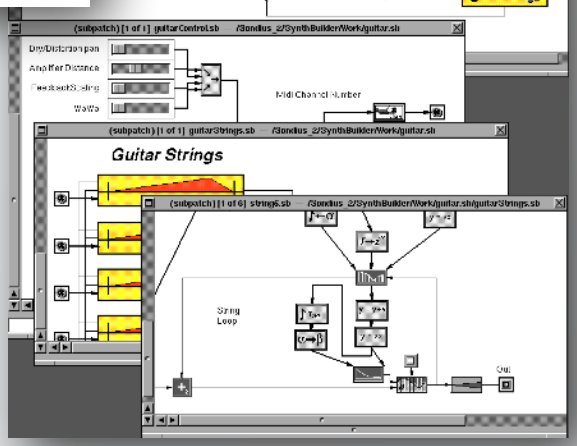


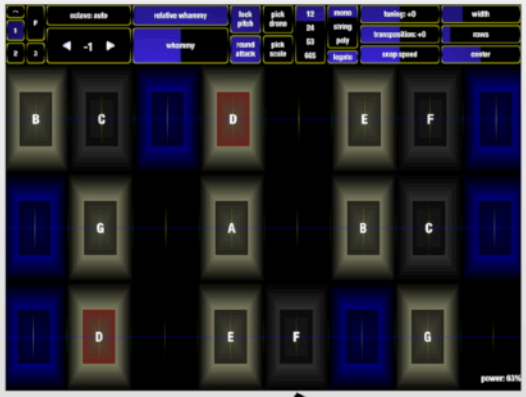


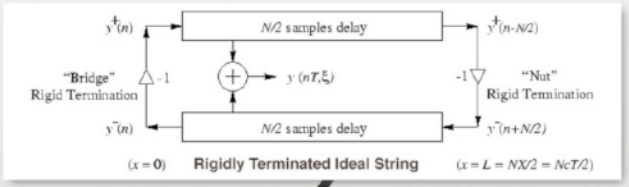


Geo Synthesizer (2011)

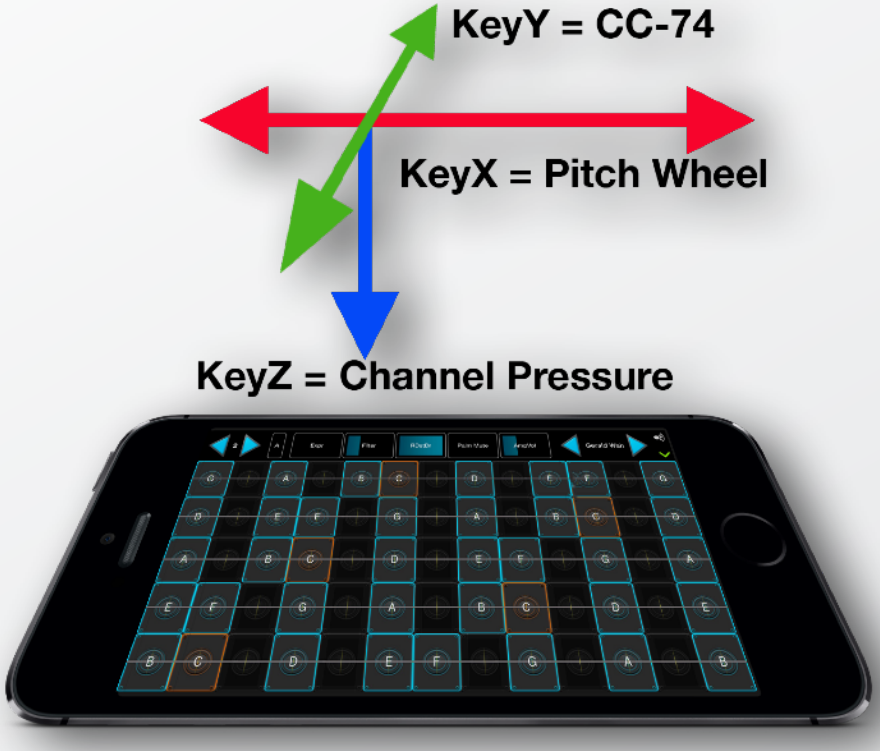
Jordan's ideas about a fluid multi-touch instrument, with pitch rounding were realized in 2011 with Geo Synthesizer, based on sampling.

The Rock Star and the Professor



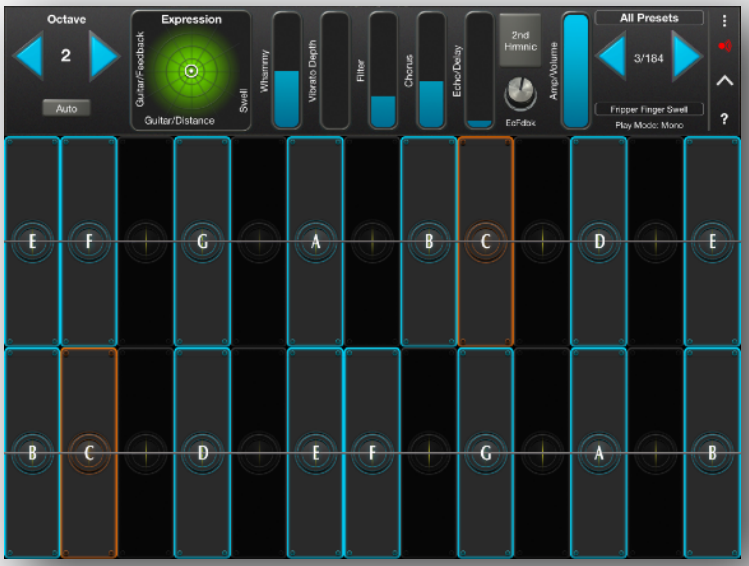


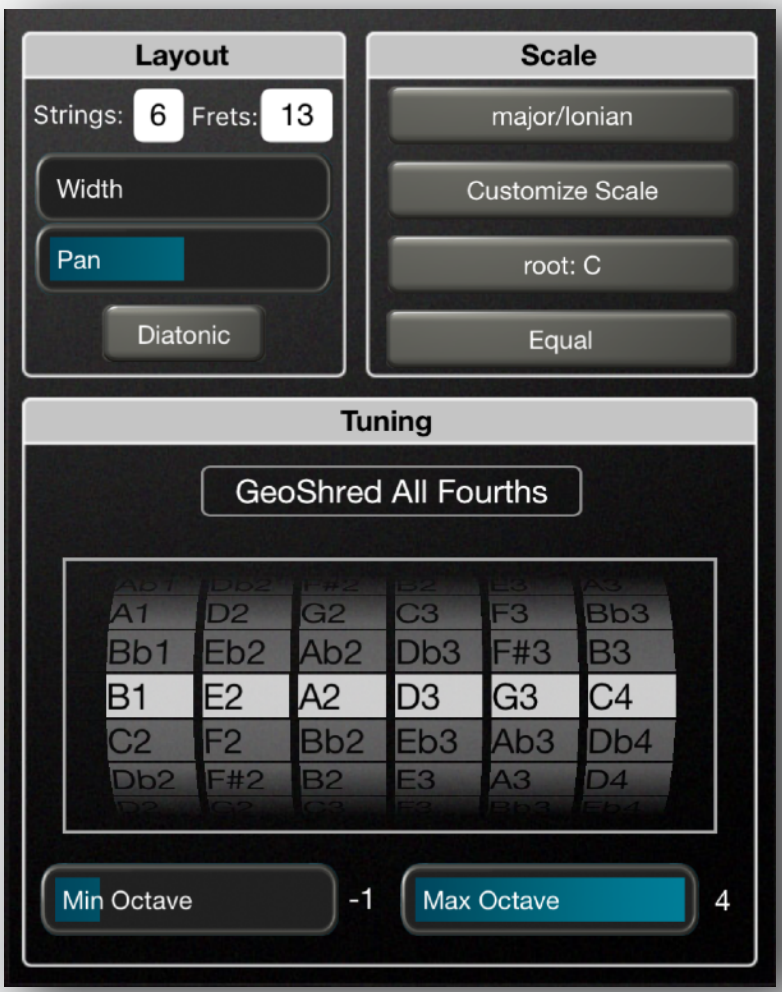
Performance Surface and Musical Expression



Keyboard

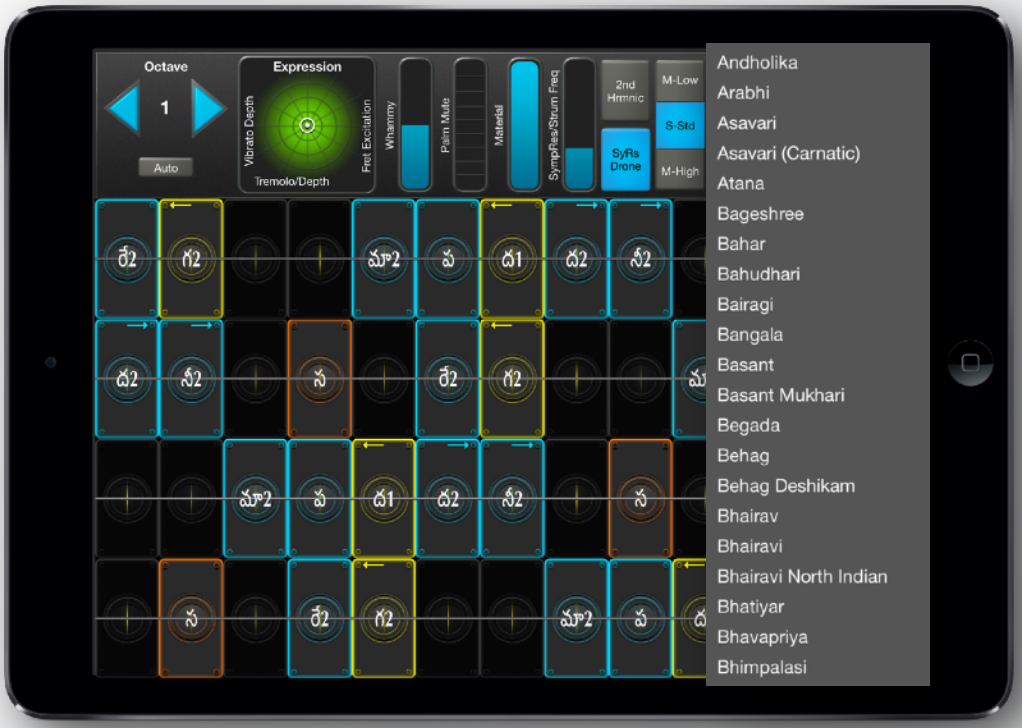
- Tuned in 4ths, but can be any tuning
- Variable number of strings and frets

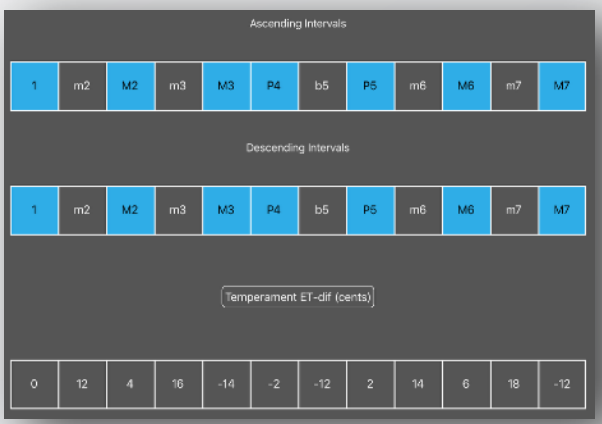




Keyboard

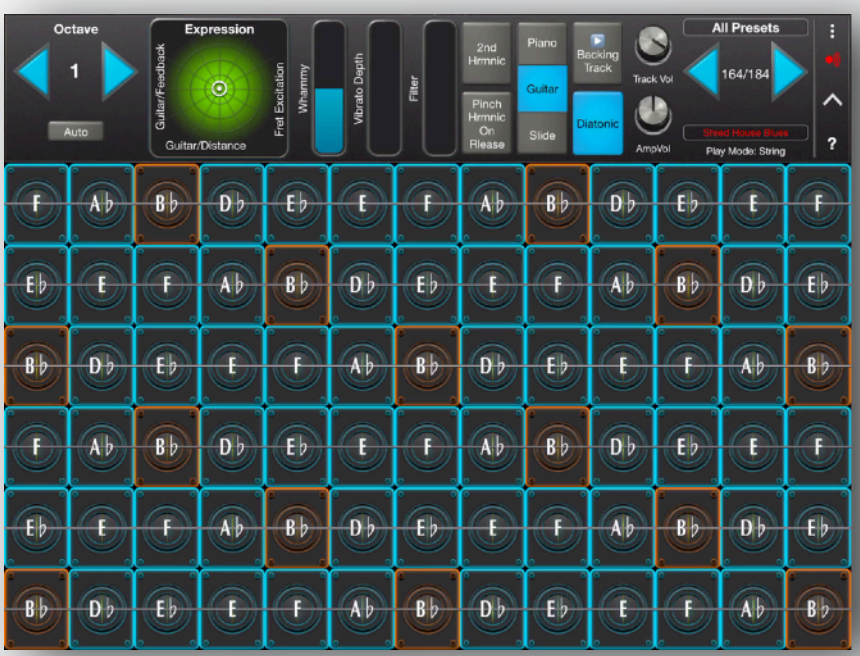
- Alternate Note Names
- Any scale, including over 200 ragas
- Any Temperament





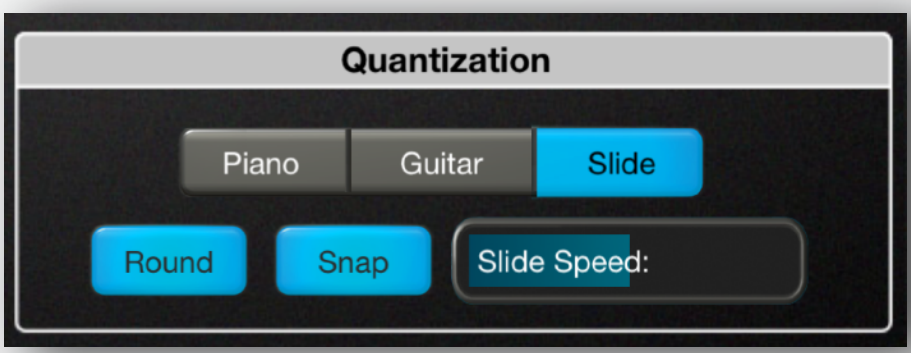
Diatonic Keyboard

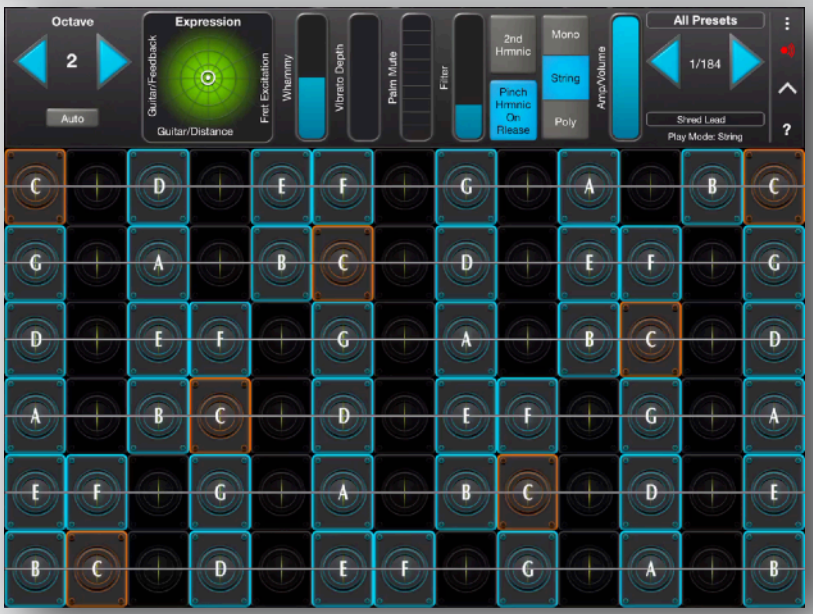
- Only notes in the scale
- Pitch rounding works with non-uniform intervals.
- Makes it possible for more people to play GeoShred



Pitch Expression (KeyX)

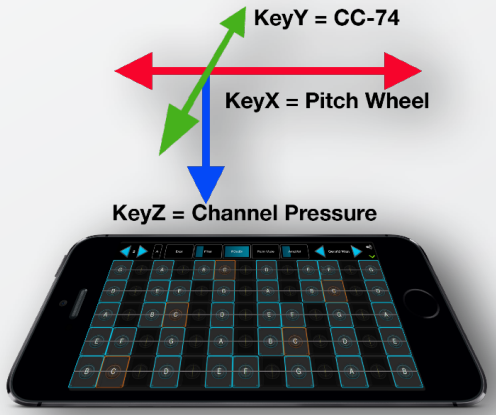
- The GeoShred Keyboard has a pitch rounding feature that makes it possible play in tune while sliding fluidly on the glass.
  - Initial touches are always in-tune.
  - Sliding will seek toward being in-tune.
  - Pitch Rounding can be turned off to enable full microtonal performances.

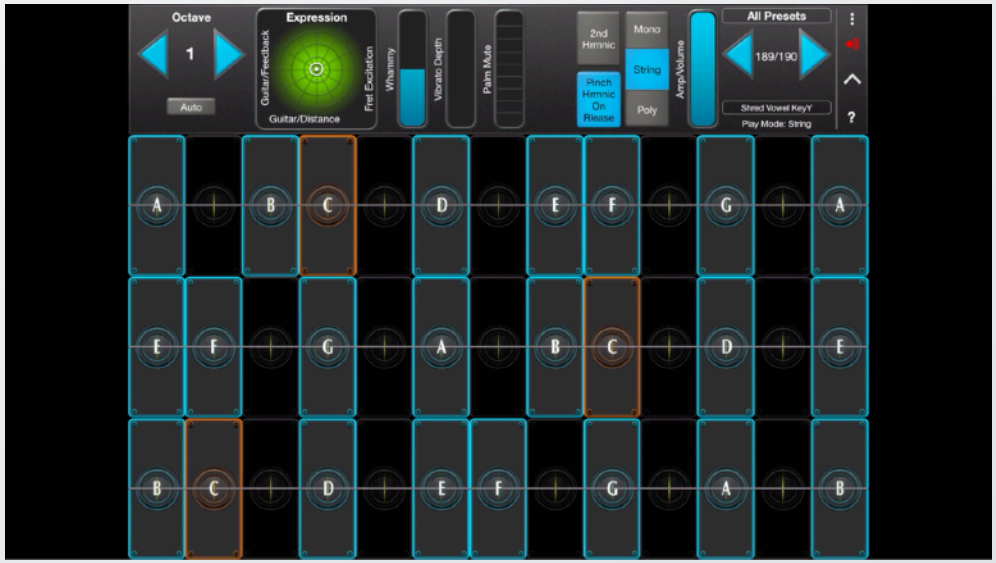




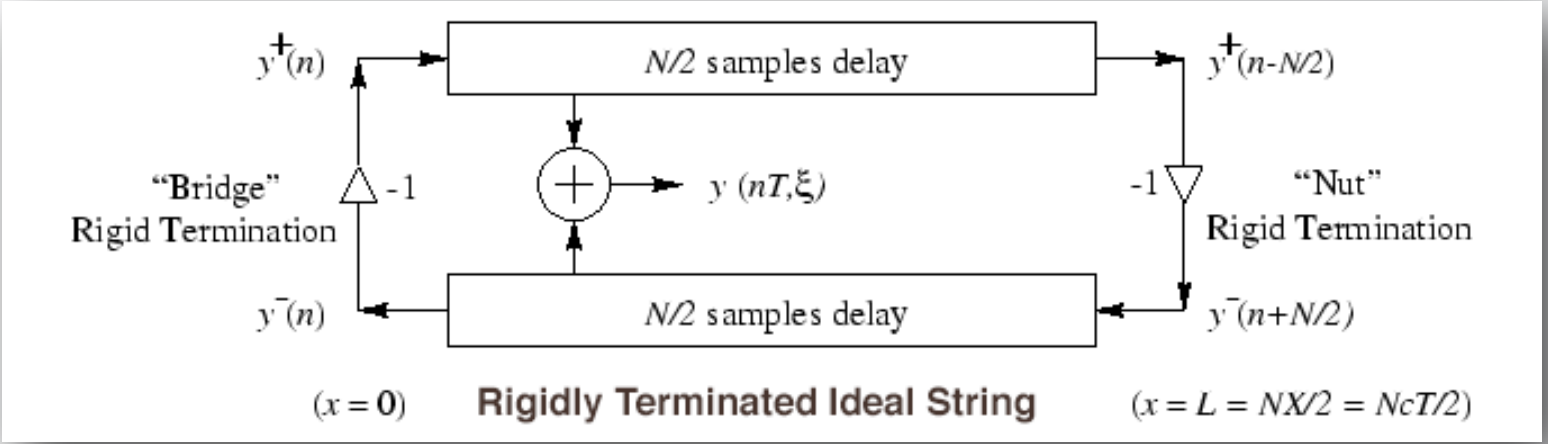
KeyY and KeyZ Expression

- KeyY and KeyZ are often assigned to a swell or filter sweep.
- However, they can be assigned to any of ~170 expressive controls in the model





The Physical Model of Strings (and Effects)



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.**

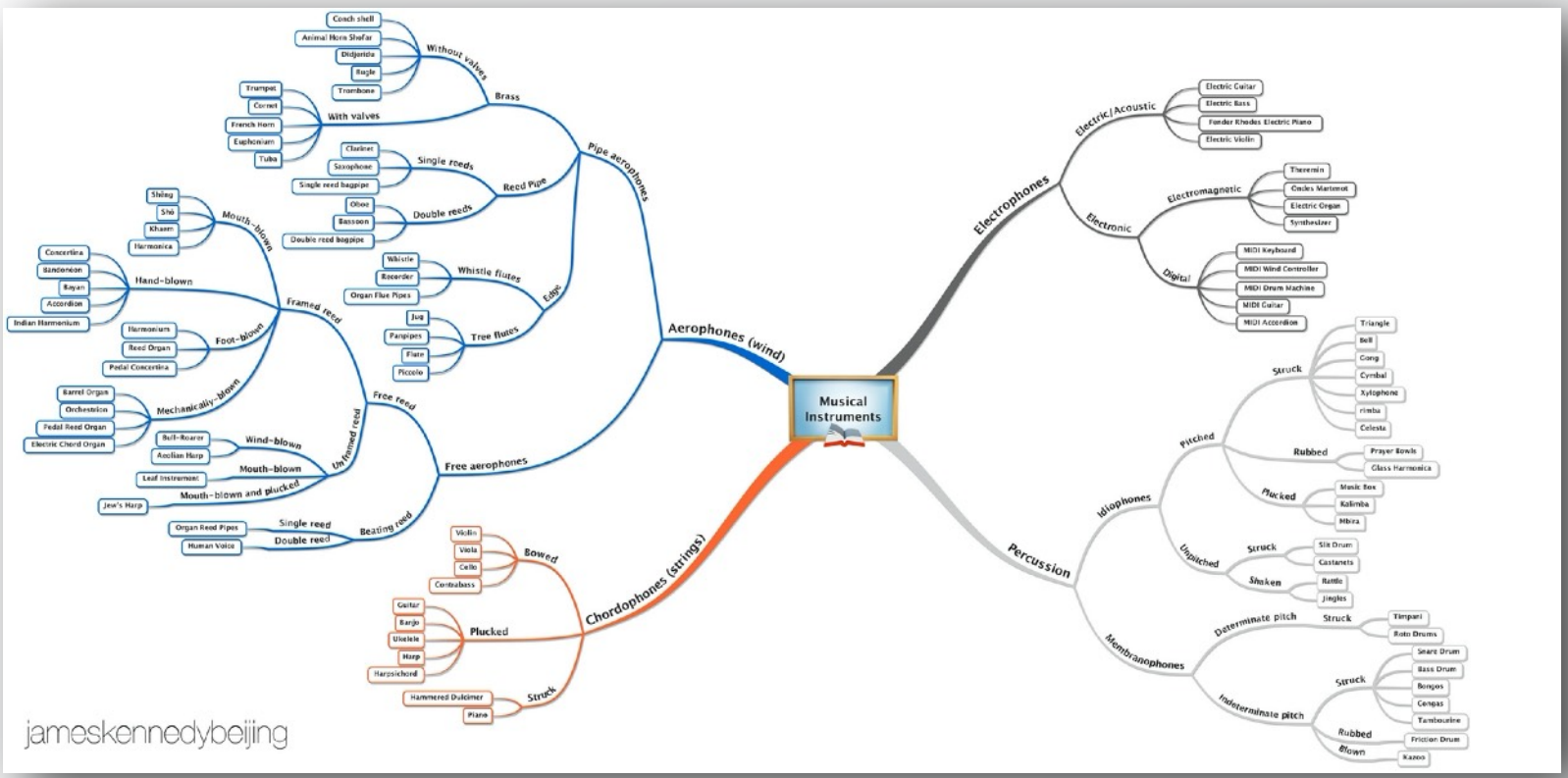
$$\frac{\partial^2 y}{\partial t^2} = \frac{1}{v_w^2}\frac{\partial^2 y}{dt^2}$$

Physics + Math

物理 + 數學

Taxonomy of Modeling Areas

Hornbostel–Sachs Classification



- Chordaphones - Guitars
- Aerophones - Woodwinds
- Membranophones - Drums
- Idiophones - Mallet Instruments
- Electrophones - Virtual Analog
- Game Sounds
- Voice

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

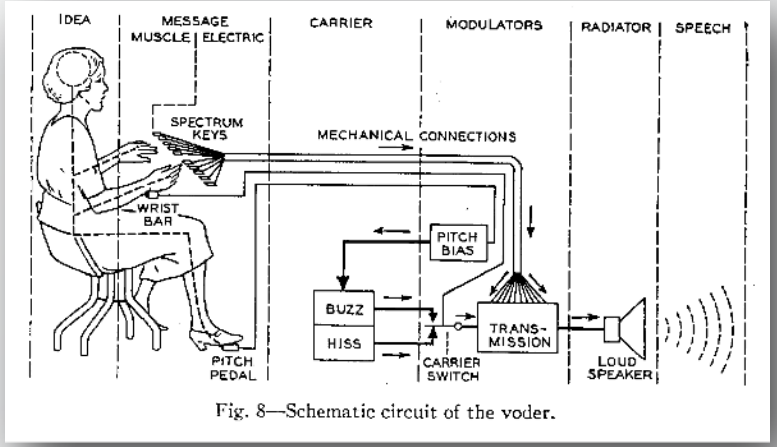
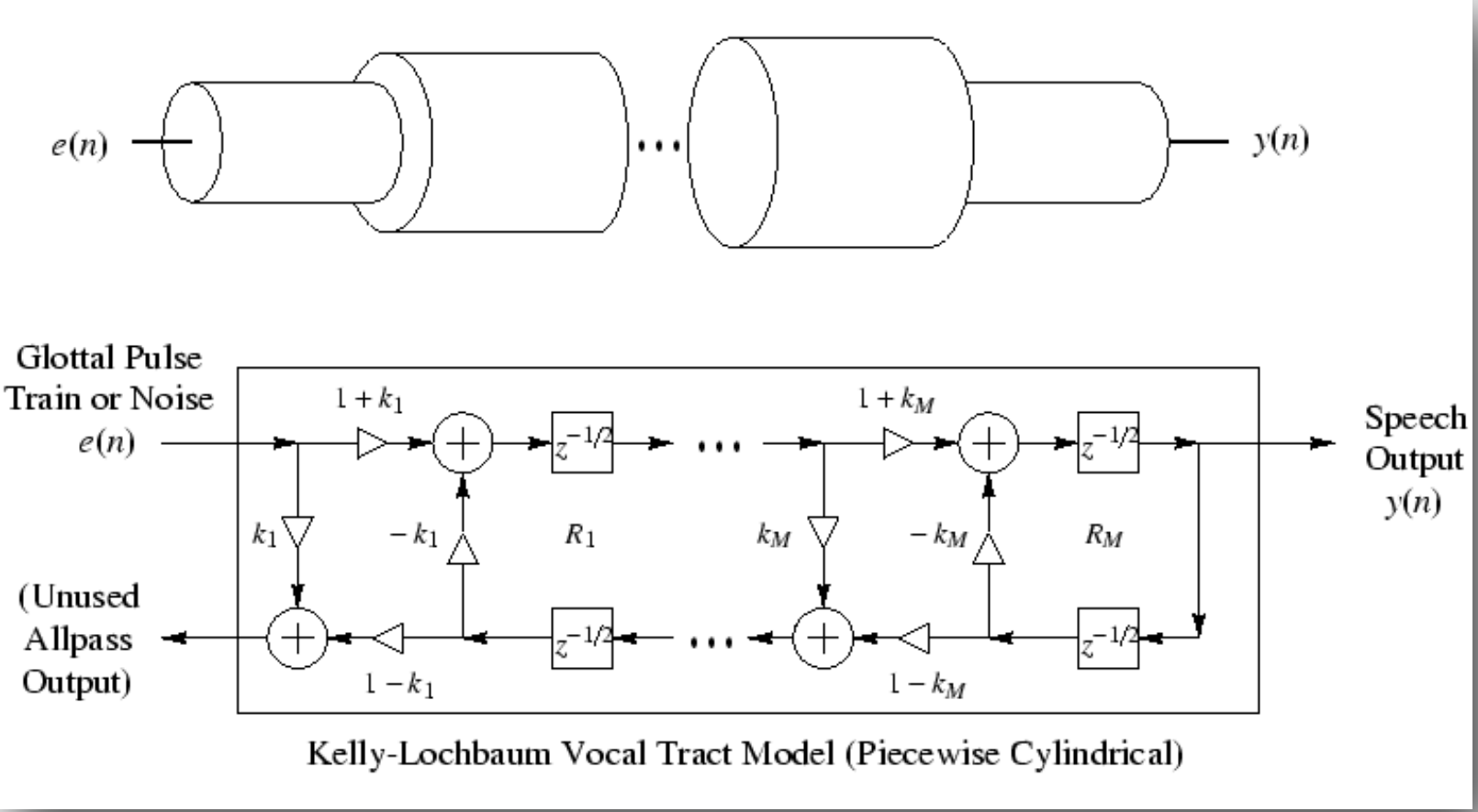


Fig. 8—Schematic circuit of the voder.

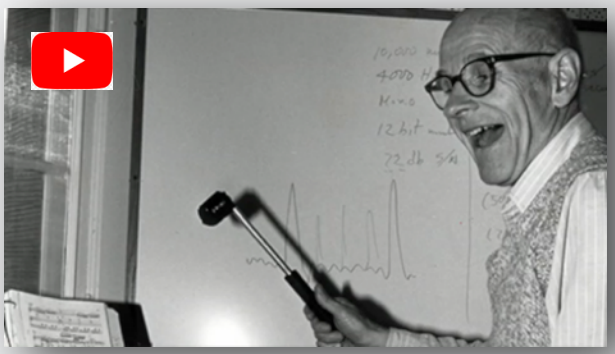
Kelly-Lochbaum Vocal Tract Model (1961)

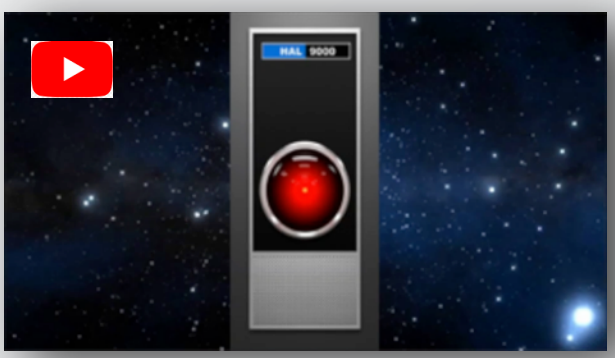


Kelly-Lochbaum Vocal Tract Model (Piecewise Cylindrical)

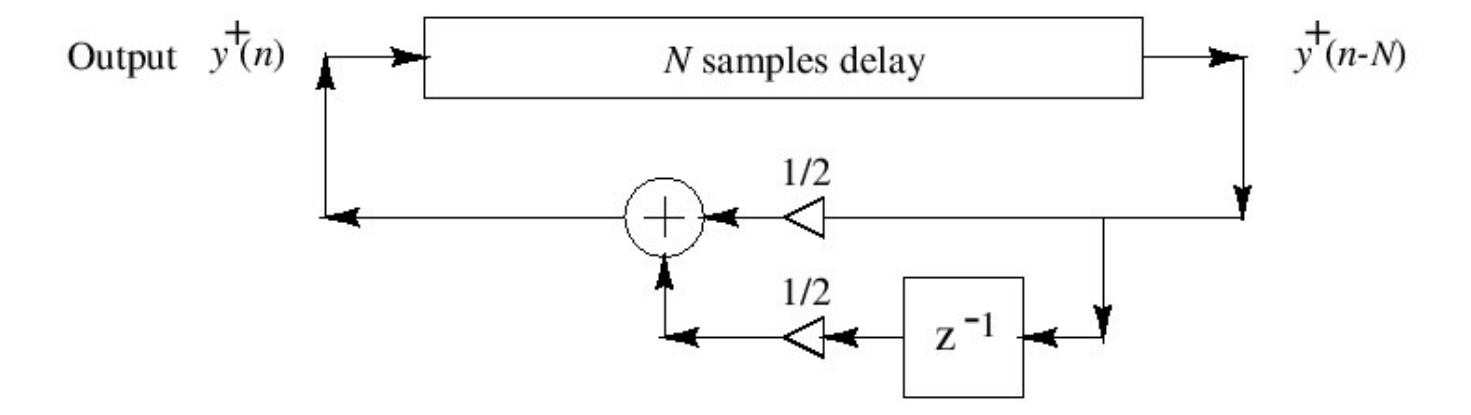
Daisy Bell (1961)

- Daisy Bell
- 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"



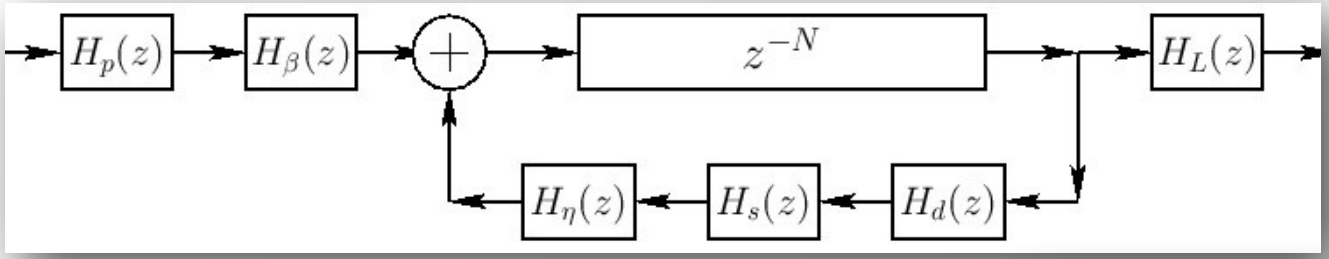


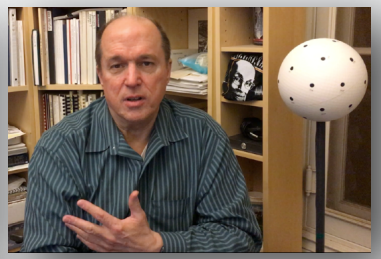
Karplus-Strong (KS) Algorithm (1983)



- Discovered (1978) as “self-modifying wavetable synthesis”
- Wavetable is preferably initialized with random numbers
- Licensed to Mattel
- The first musical use of the algorithm was in the work *“May All Your Children Be Acrobats”* written in 1981 by David A. Jaffe.

EKS Algorithm (Jaffe-Smith 1983)





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

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

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

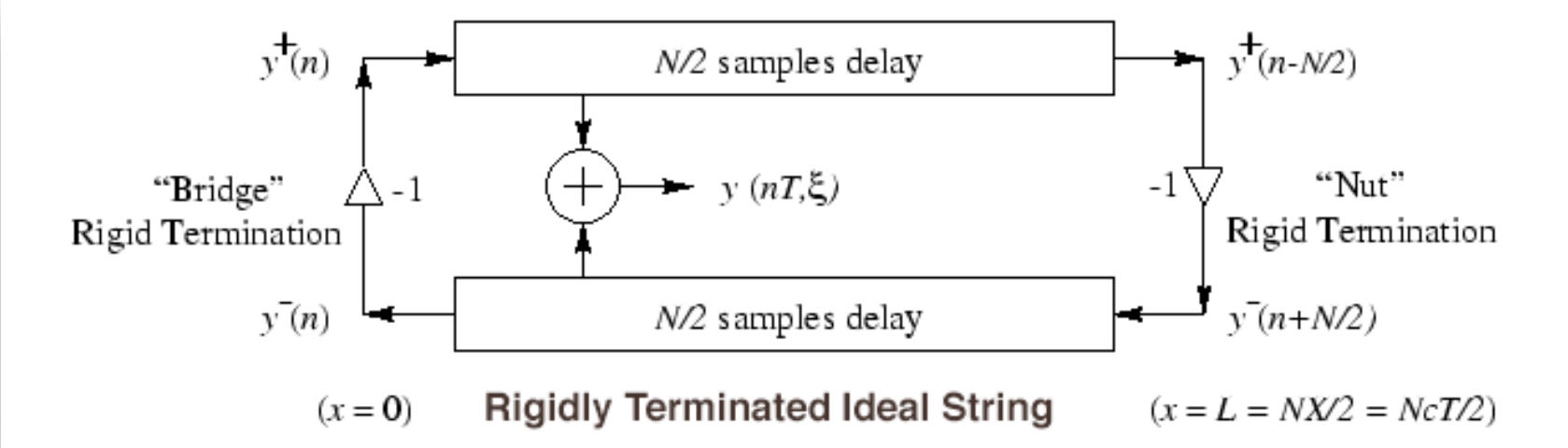
$$H_s(z) = \text{string-stiffness allpass filter (several poles and zeros)}$$

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

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

- Musical Example “Silicon Valley Breakdown” (Jaffe 1992)
- Musical Example BWV-1041 (used to intro the NeXT machine 1988)

Digital Waveguide Models (Smith 1985)



- Equivalent to d'Alembert's Solution to the Partial Differential Equation for a string (1747)
- Used for the Yamaha VL Family (1994)
- Shakuhachi, Tenor Sax

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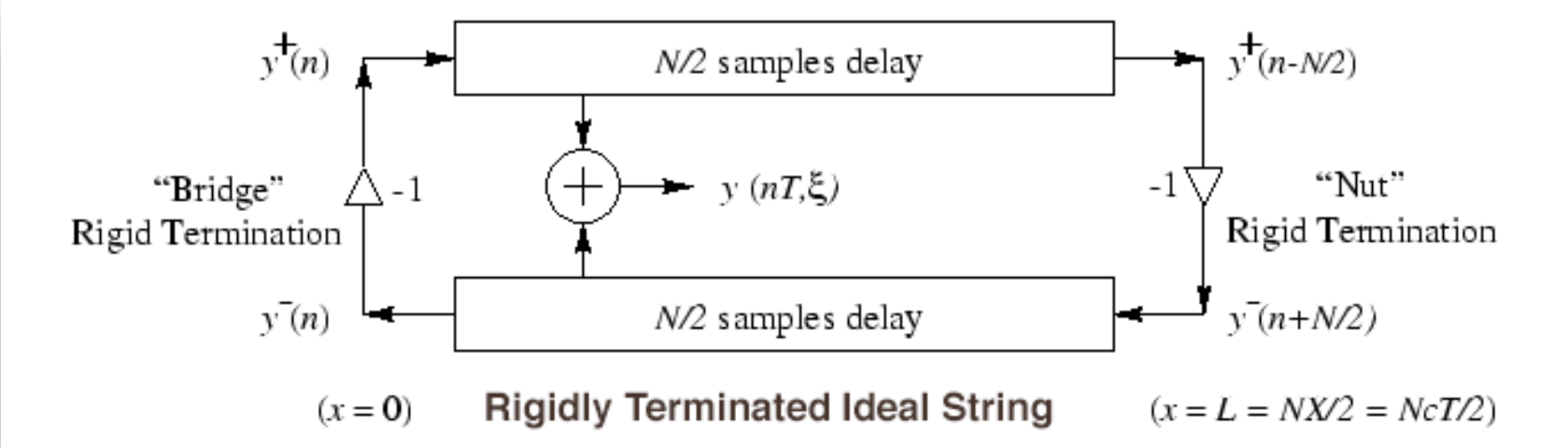

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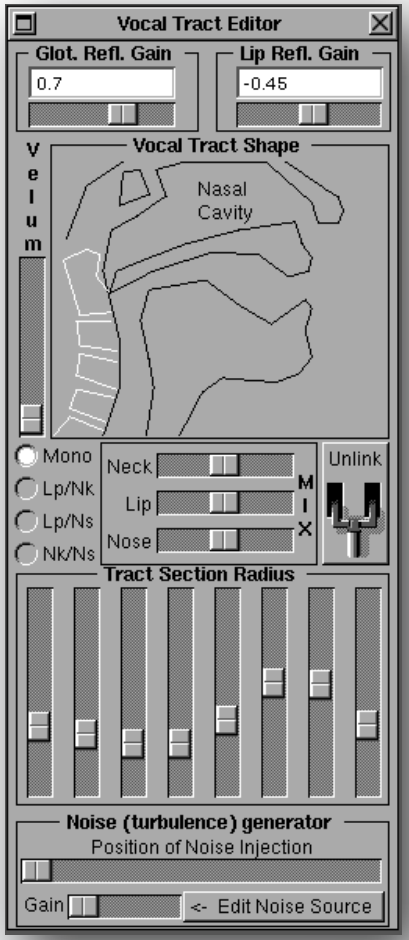
Sheila Vocal Track Modeling (Cook 1990)



Perry Cook's SPASM **"Singing Physical Articulatory Synthesis Model"**

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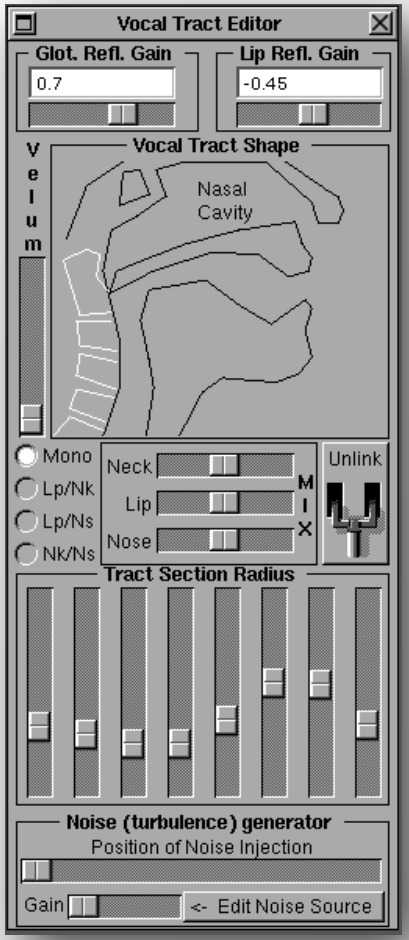

Perry Cook's SPASM **"Singing Physical Articulatory Synthesis Model"**

Coupled Mode Synthesis (CMS) (Van Duyne) (1996)

- Modeling of percussion sounds
- Modal technique with coupling
- Tibetan Bell Model
- Wind Chime Model
- Tubular Bells Model
- Percussion Ensemble
- Taiko Ensemble

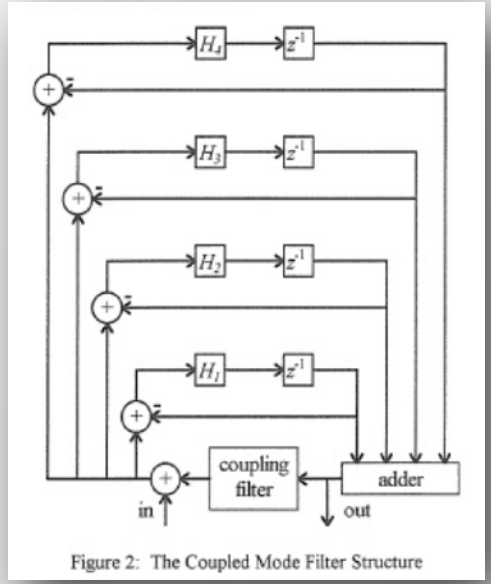

Figure 2: The Coupled Mode Filter Structure

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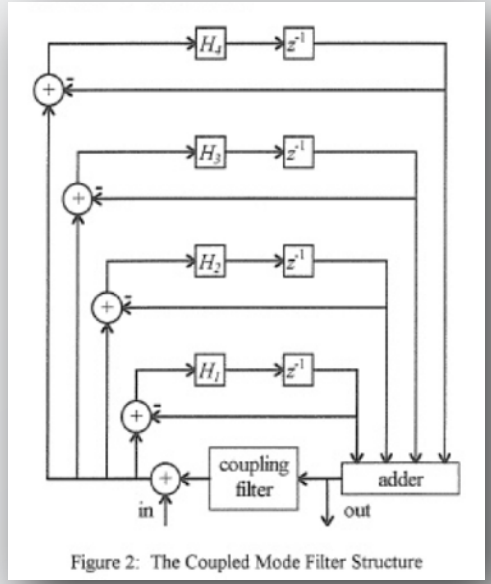

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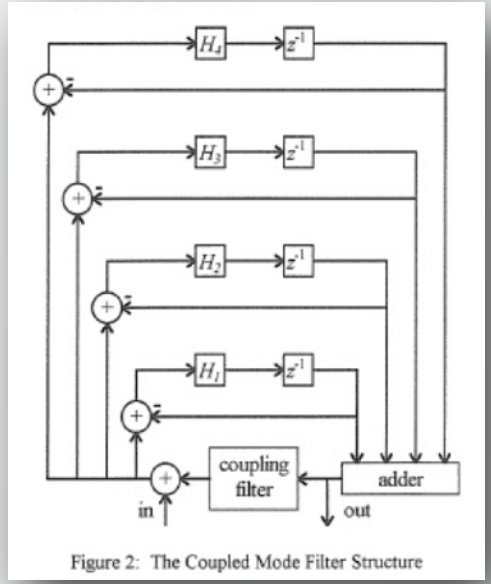

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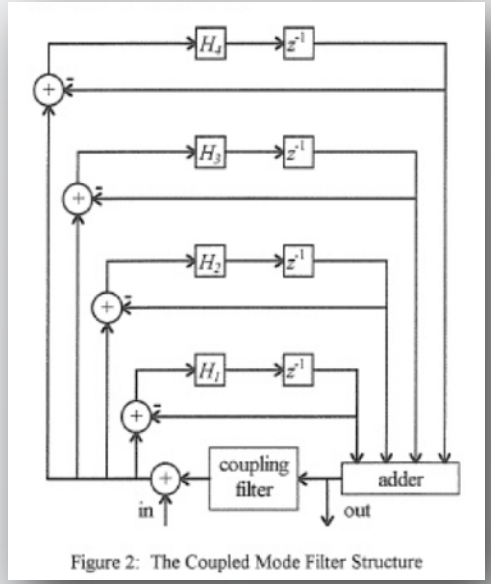

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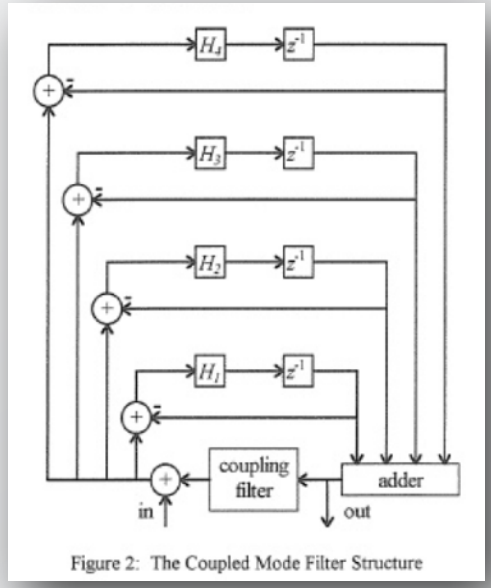
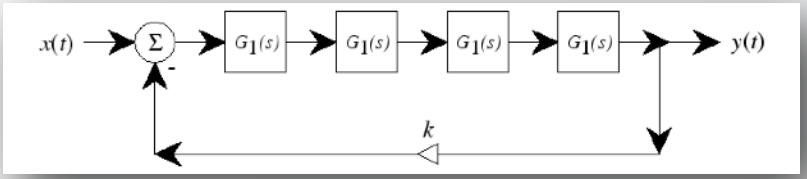
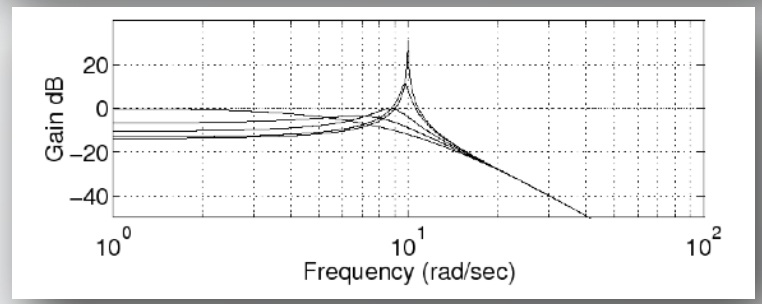


Figure 2: The Coupled Mode Filter Structure

Virtual Analog (Stilson-Smith) (1996)

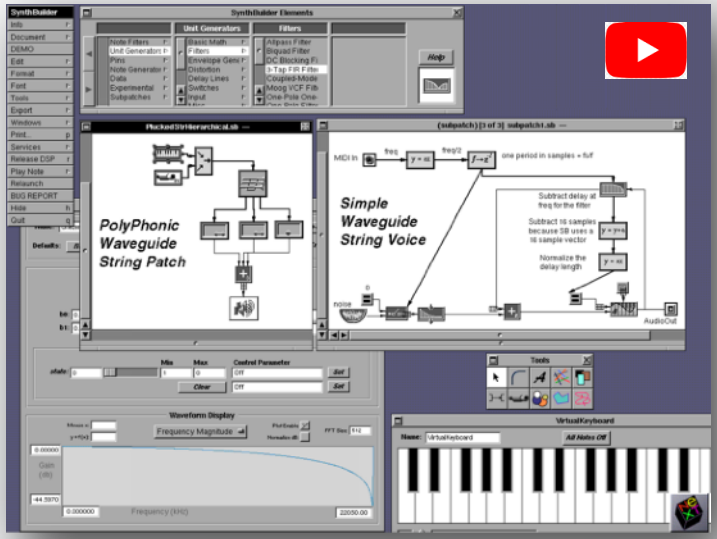
- Alias-Free Digital Synthesis of Classic Analog Waveforms
- Digital implementation of the Moog VCF. Four identical one-poles in series with a feedback loop.
- Sounds great!

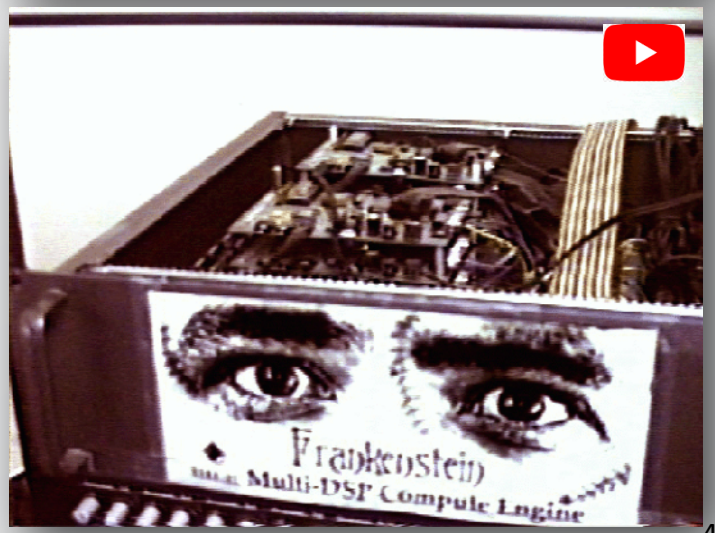




Full Ensembles all Physical Modeling (1997)

- Stanford OTL/CCRMA created the Sondius project to assist with commercializing physical modeling technologies.
- The result was a modeling tool known as SynthBuilder, 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.





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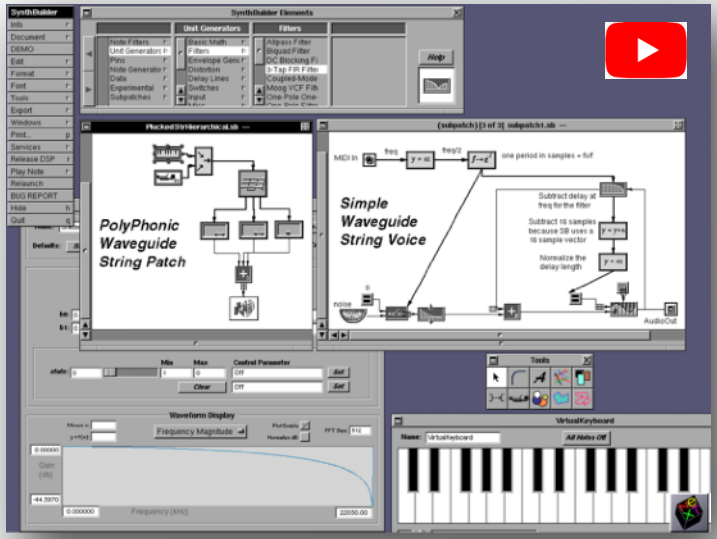
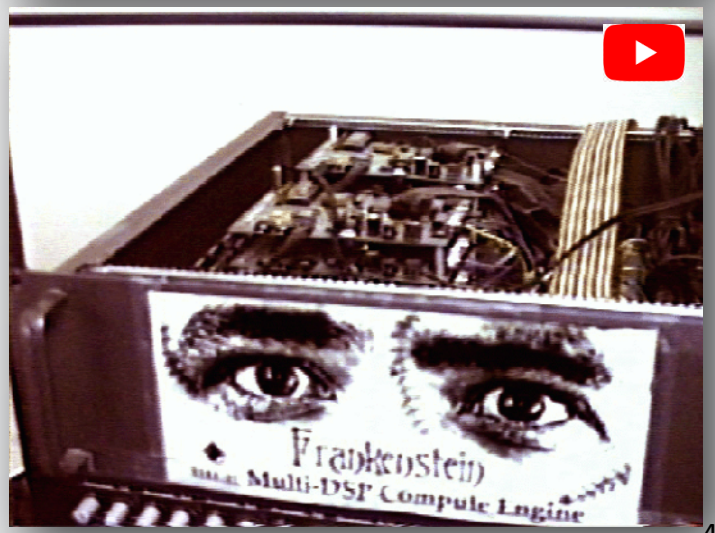
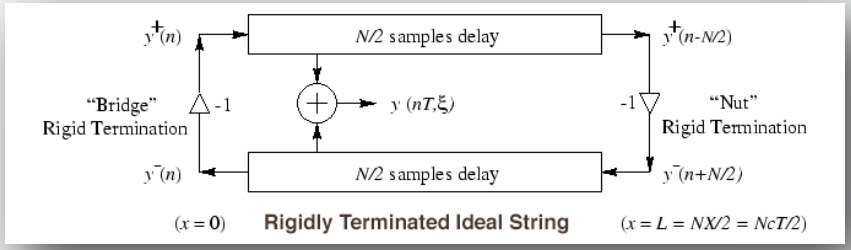
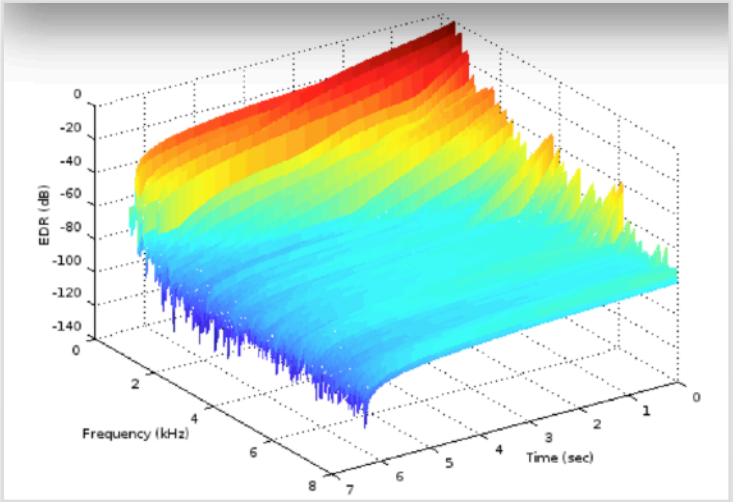




The GeoShred Model

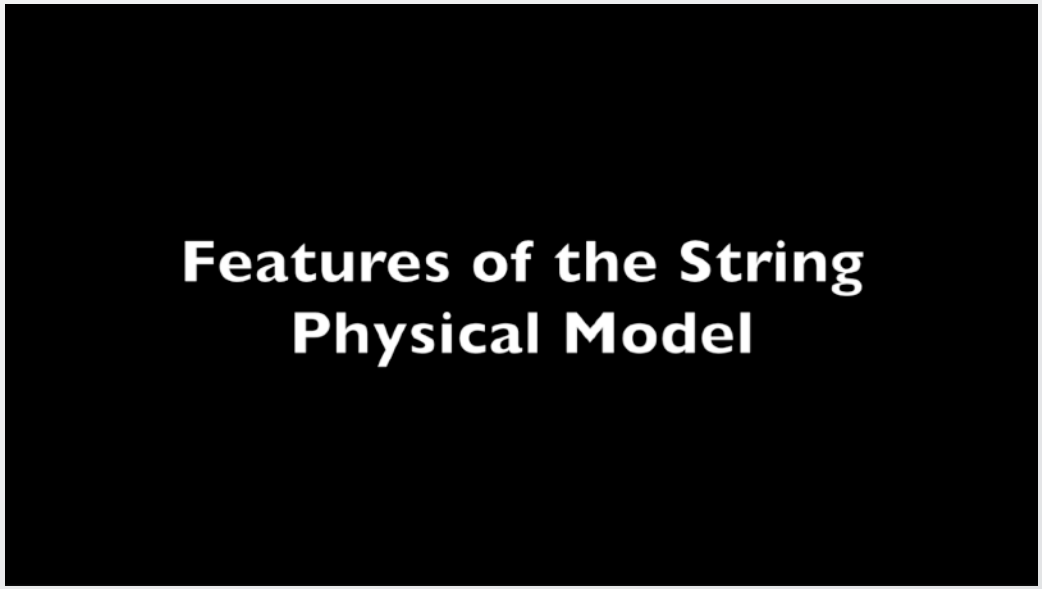
- A hybrid of Extended Karplus-Strong, Waveguide, Commuted Synthesis with extensions:
  - Harmonics and pinch harmonics
  - Pre-computed pickup excitations
  - Collisions for fret excitation
  - Sitar Bridge model
  - Body Model
  - Hexaphonic split
  - Doubling of courses
  - Statistical variations
- Calibrated from real recordings





String Model Physical Parameters

- Feedback with Deep Dive
- Material
- Fret Scraping
- Harmonics
- String Scraping
- Pick Position
- String Stiffness
- String Doubling
- Sitar Bridge
- Statistical Variations



Effects

- 21 Build in effects
- Many are circuit models
- EQs, Distortions, Wah, Moog Filter, Phaser, Flangers, Tremolo, Echos, Reverb
- Any of the 200 parameters in GeoShred can be tied to musically expressive controls including Key[X|Y|Z], Expression [X|Y] and Sliders

And Support for South Asian Music

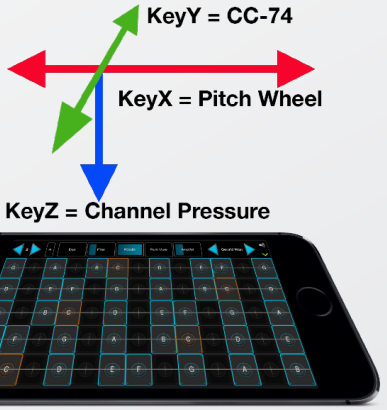
- Pitch Rounding Supports Gamakas
- Sitar Model with Sympathetic Strings
- Svara Note Names
- 200 Built-in Ragas
- Sympathetic Resonator and Tanpura

Beyond Real

- Any of the 200 parameters in GeoShred can expressed musically.
- Multiple Parameters can be expressed with a single control.
- Parameters can be manipulated by a lookup table system called “Curves”.
- New sounds can be created that are beyond real.

Pro Features

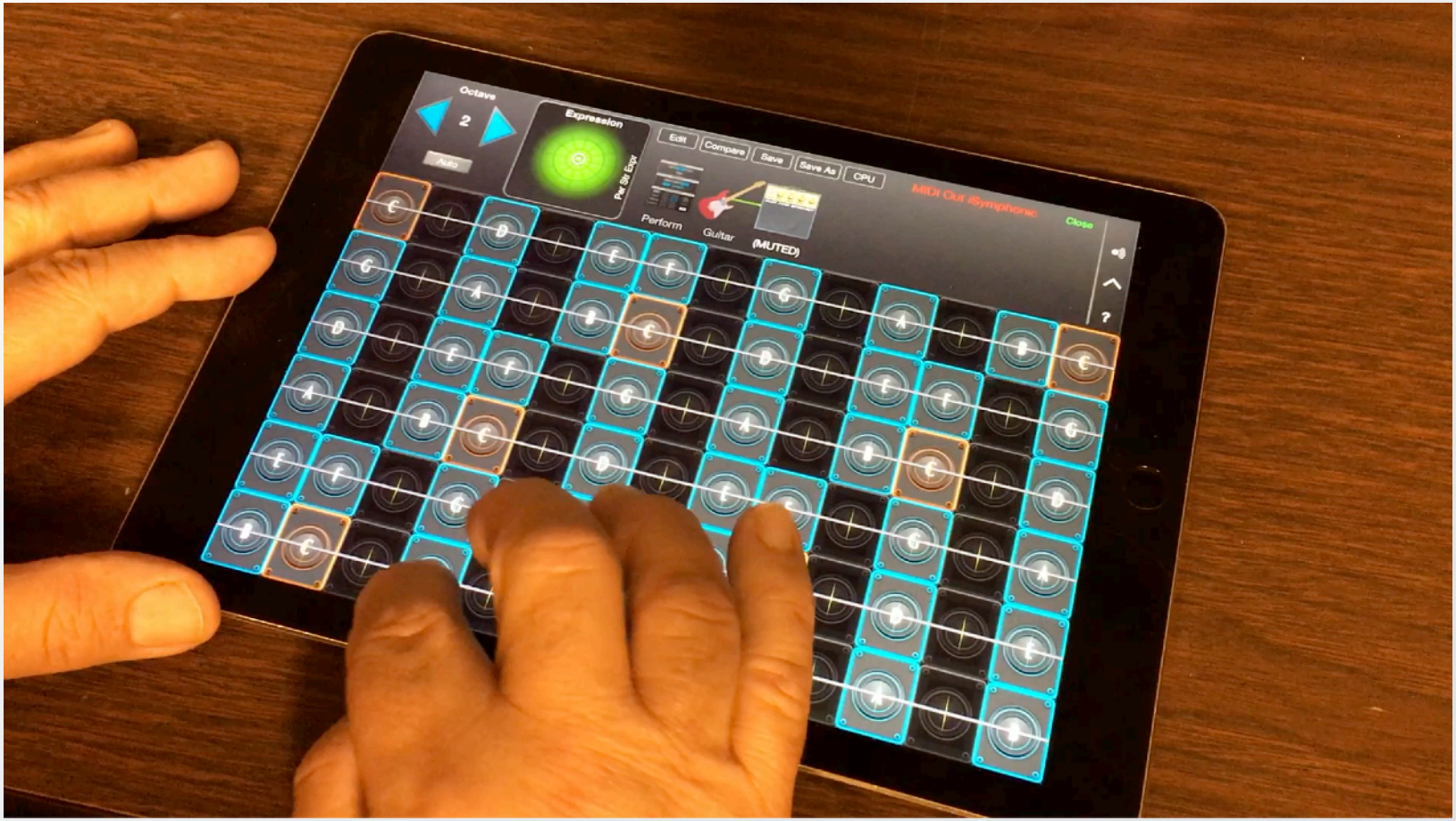
- MIDI IN/OUT



- MPE (MIDI Poly Phonic Expression) IN/OUT
- AudioBus
- InterApp Audio

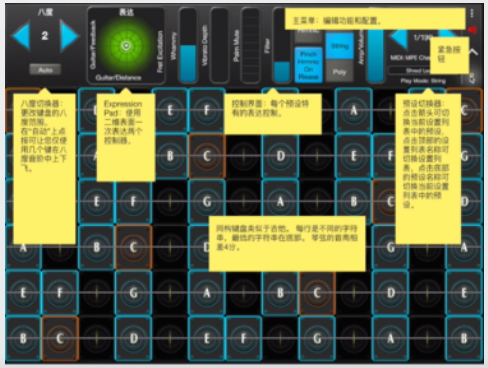
- AUv3 Plugin

GeoShred's Expressive Control Used with other Synthesizers



What Comes Next?

- Desktops, AU/VST
- Localization (Chinese First)
- GeoShred as an instrument platform. More modeling algorithms from the back room
  - Additional Models
  - Virtual Analog
  - Percussion
  - Woodwinds
  - FM
  - Other
- Hardware
- Maybe, Alien Orchestras



Chinese Localization (2020)

Thanks!

Quick Demo

Thanks!

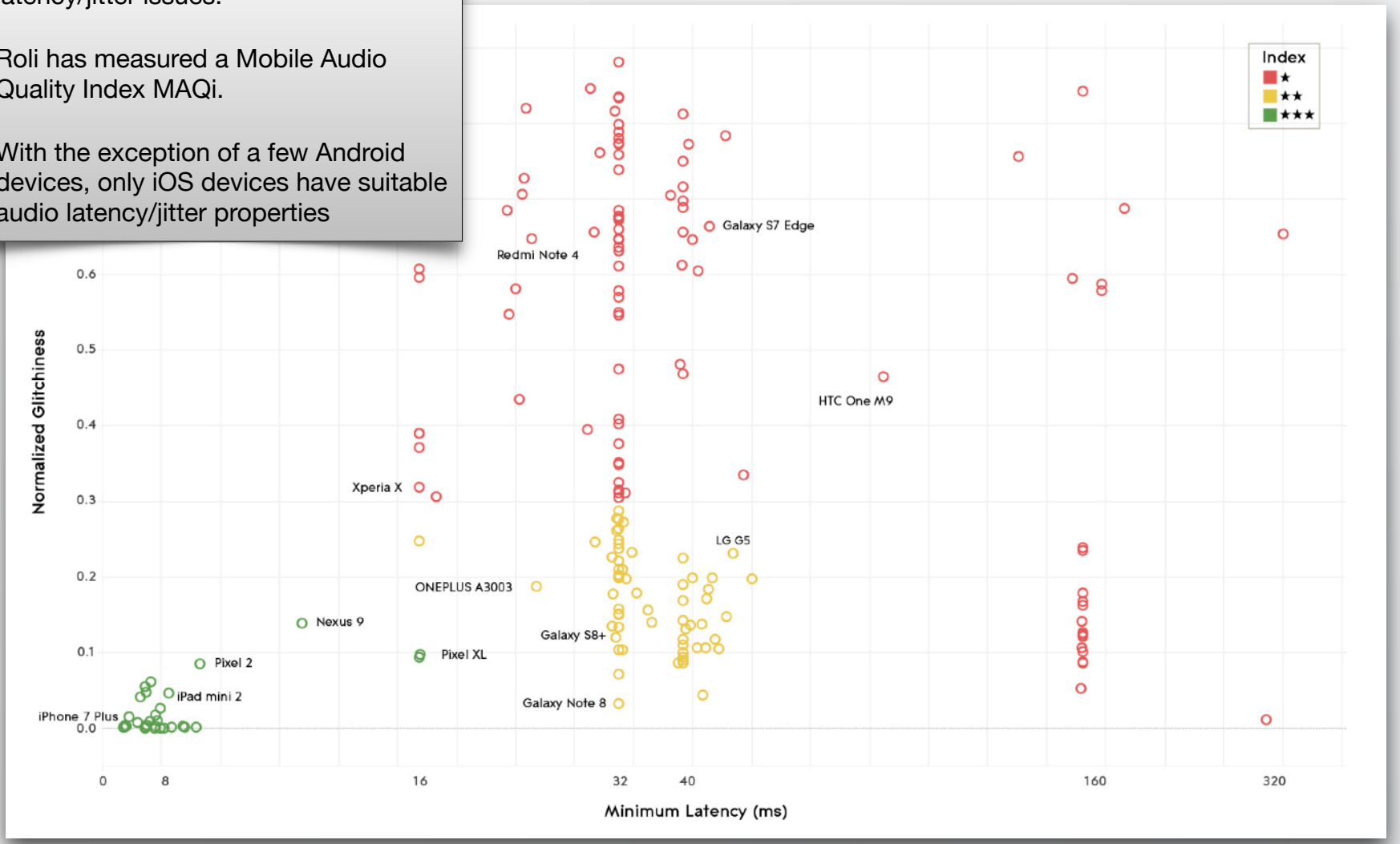
- Mary Albertson
- Simone Capitani
- Chris Chafe
- John Chowning
- Perry Cook
- Jon Dattorro
- David Jaffe
- Joe Koepnick
- Romain Michon
- Denis Labrecque
- Scott Levine
- Fernando Lopez-Lezcano
- Yann Orlarey
- Stephane Letz
- Stanford OTL
- Danny Petkevich
- Bill Putnam
- Danielle Rudess
- Kent Sandvik
- Tim Stilson
- David Van Brink
- Scott Van Duyne
- Yamaha

And CCRMA

Anticipated Questions

Why Android is a Challenging Platform for Audio Products Targeted for Musicians

- Most Android devices have **audio** latency/jitter issues.
- Roli has measured a Mobile Audio Quality Index MAQi.
- With the exception of a few Android devices, only iOS devices have suitable audio latency/jitter properties



What about Latency?

- The largest source of latency (for ios) appears to between screen interaction and the guitar model. Note that the audio buffer latency is about 5ms.
- We started at 180ms screen to audio out.
- We brought this down to 25-35ms by replacing Apple's gesture handlers with a custom gesture handler. This makes sense. Gesture handling requires analysis of a moderate amount of state to initiate an action.
- MIDI to Audio Latency is about 20-30ms.
- PowerStomp which is audio-in/effects chain/audio out is around 18ms.
- Latency to the internal speakers on iOS devices seems to have gotten a bit poorer over time. Probably due to DSP processing for the head phone jack.