

Creative Misuse of ROOT

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Postdoctoral Research Fellow

Intelligent Instruments Lab

ROOT Users Workshop, 10th May 2022

Overview

- Intelligent Instruments Lab
- Misuses of ROOT
 - Cling in musical live coding
 - Cling in embedded digital musical instrument design
 - SOFIE in intelligent instrument design
- Discussion



Understanding 21st century AI through creative music technologies.



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European Research Council



European Research Council

Established by the European Commission

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LISTAHÁSKÓLI ÍSLANDS
Iceland University of the Arts



1 September 2021



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30 November 2021

Research Themes



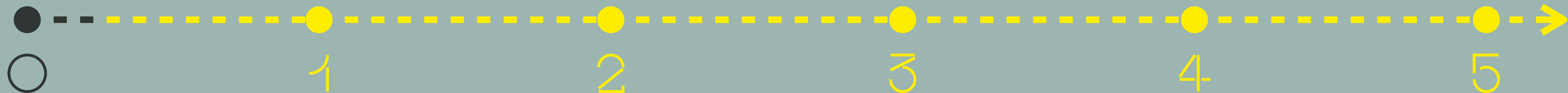
1. Self PhD 1



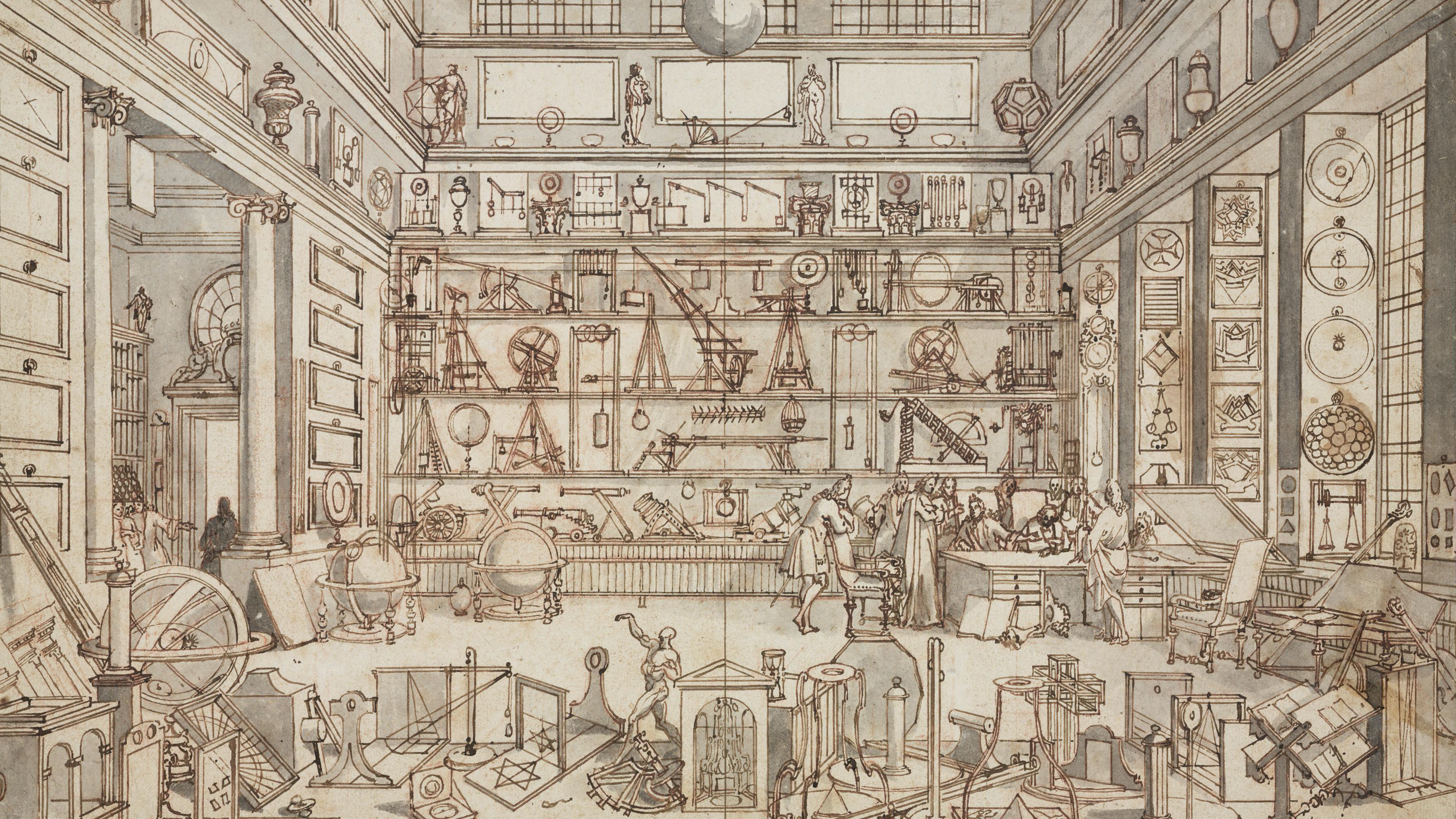
2. Others PhD 2



3. Knowledge PhD 3

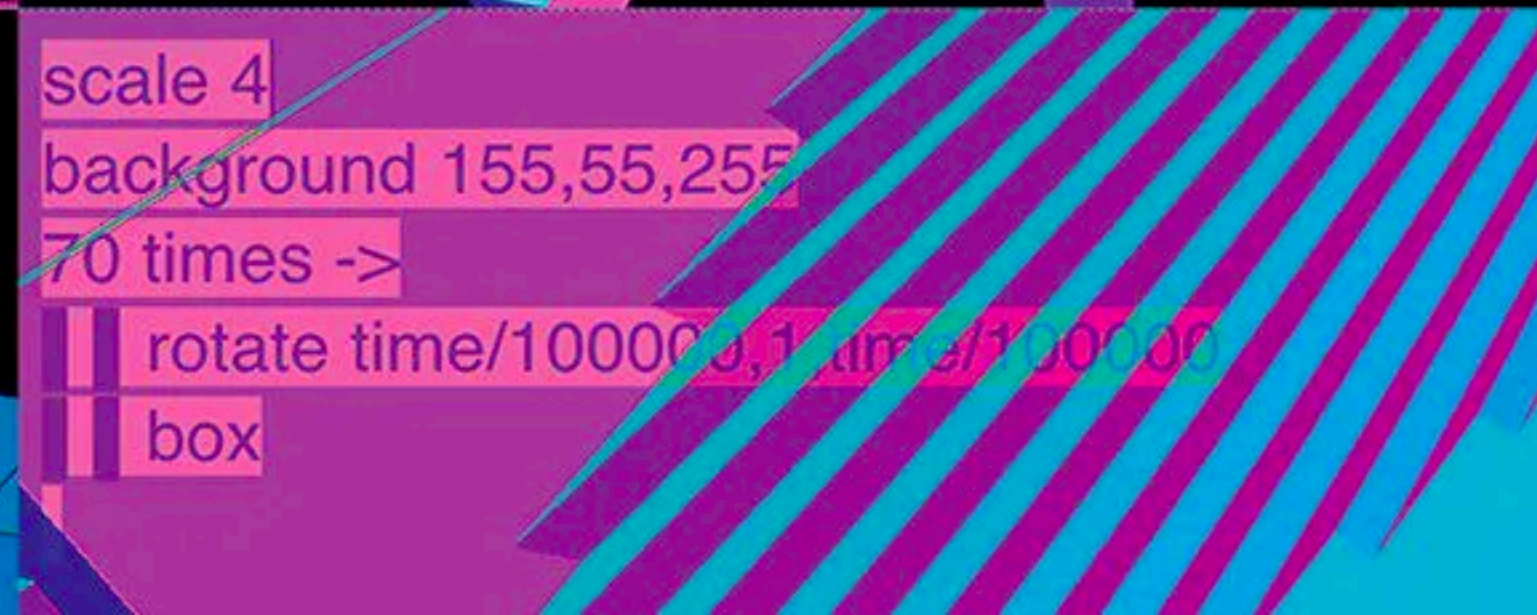
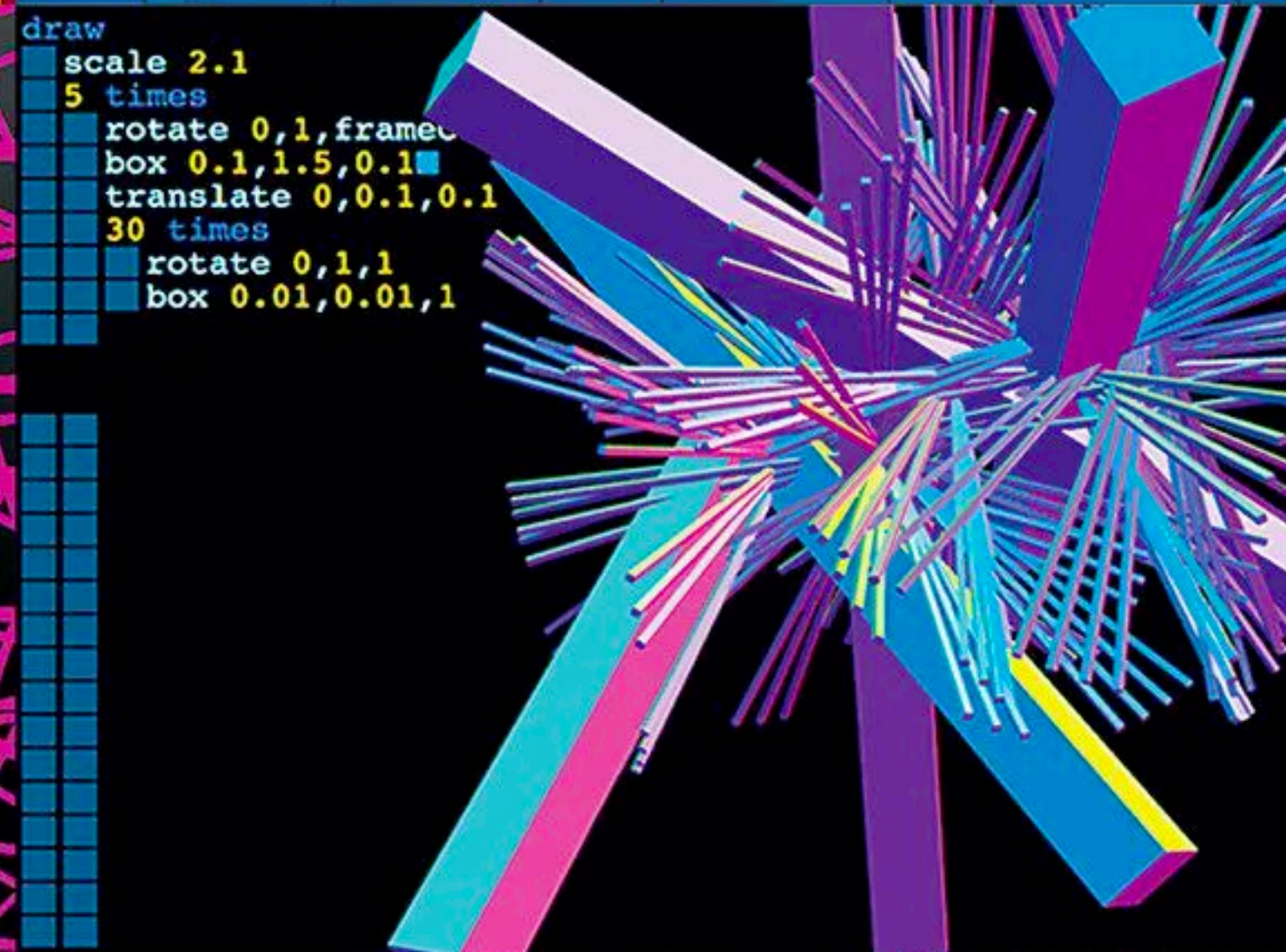
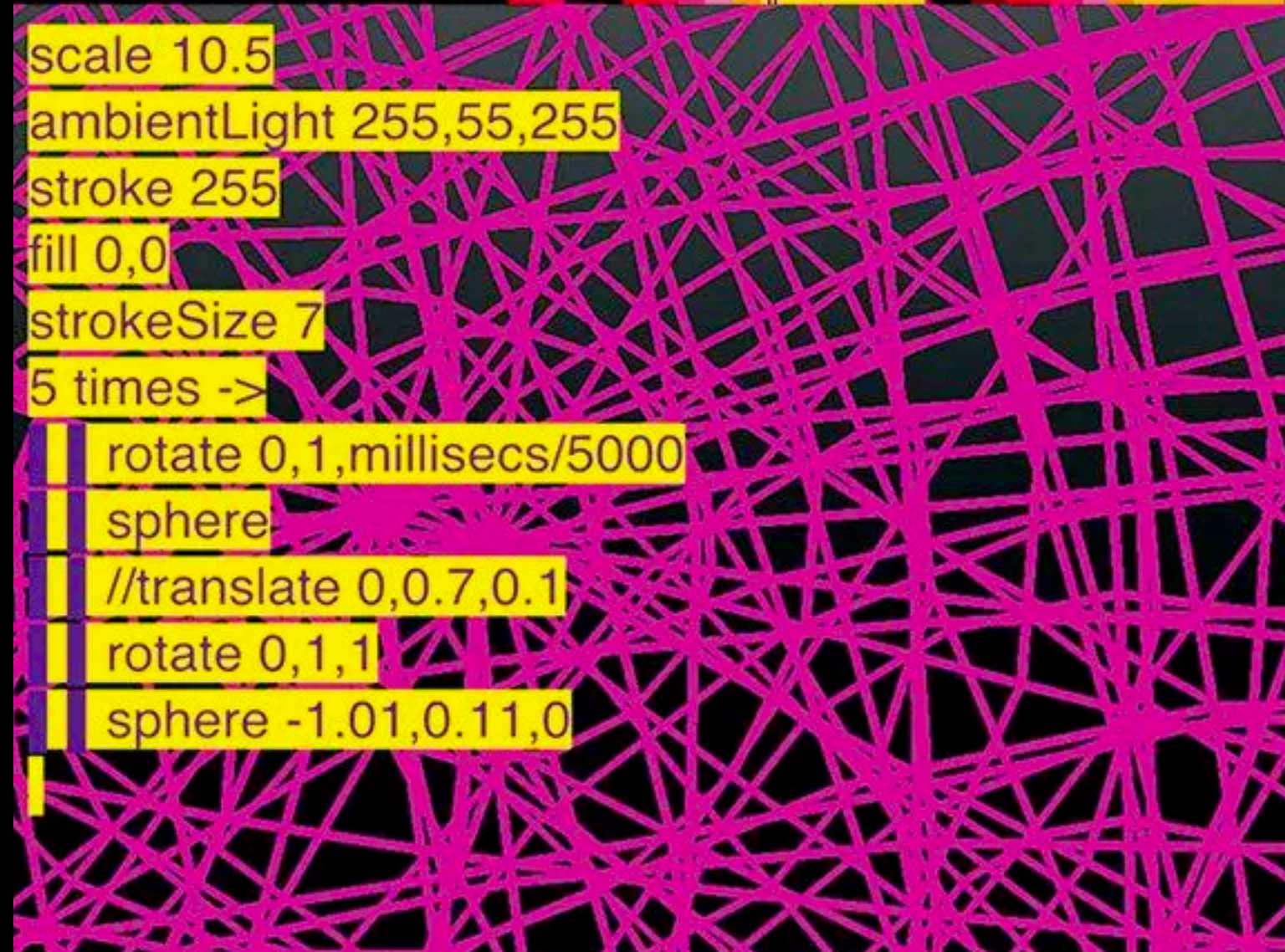
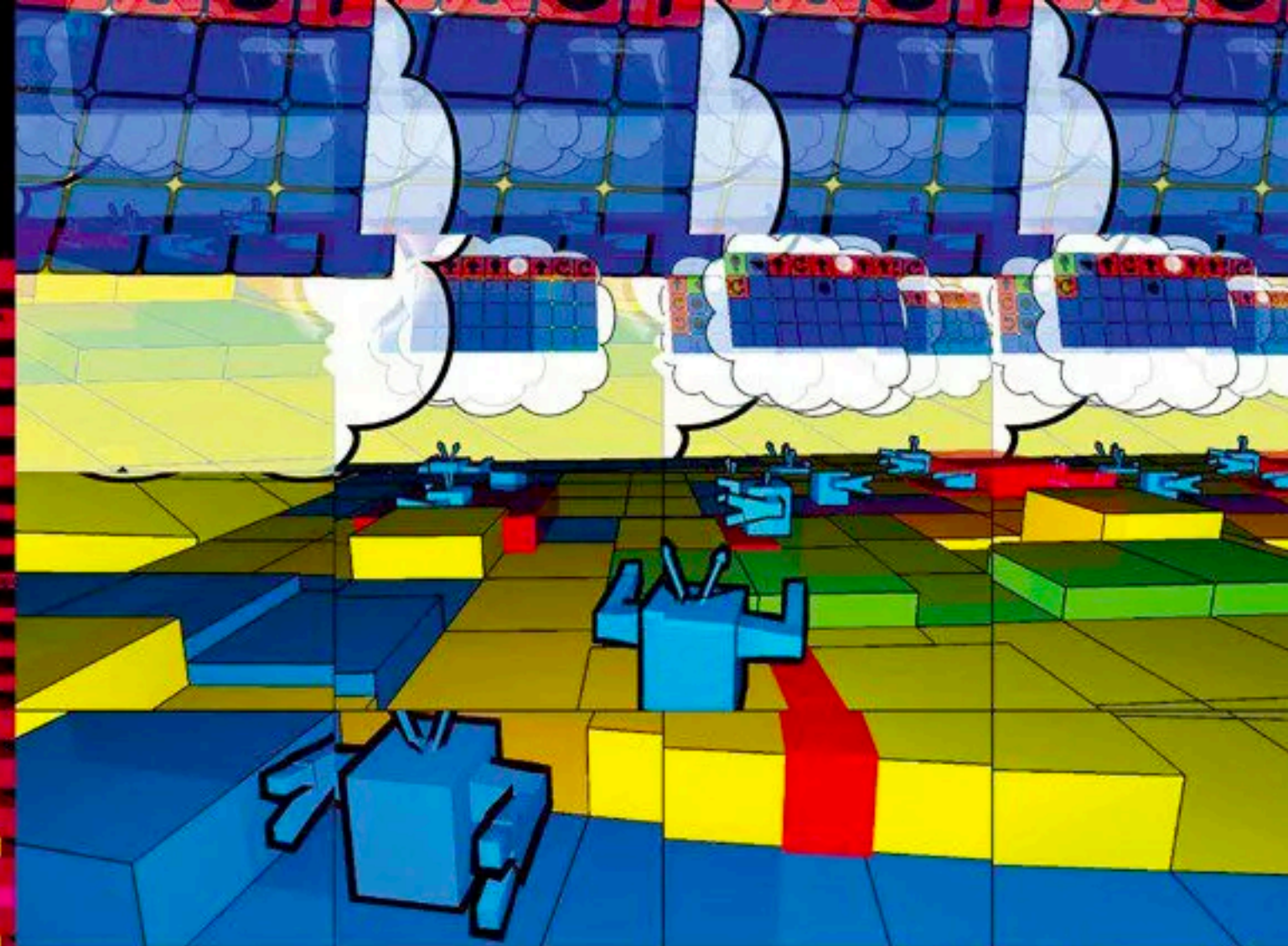
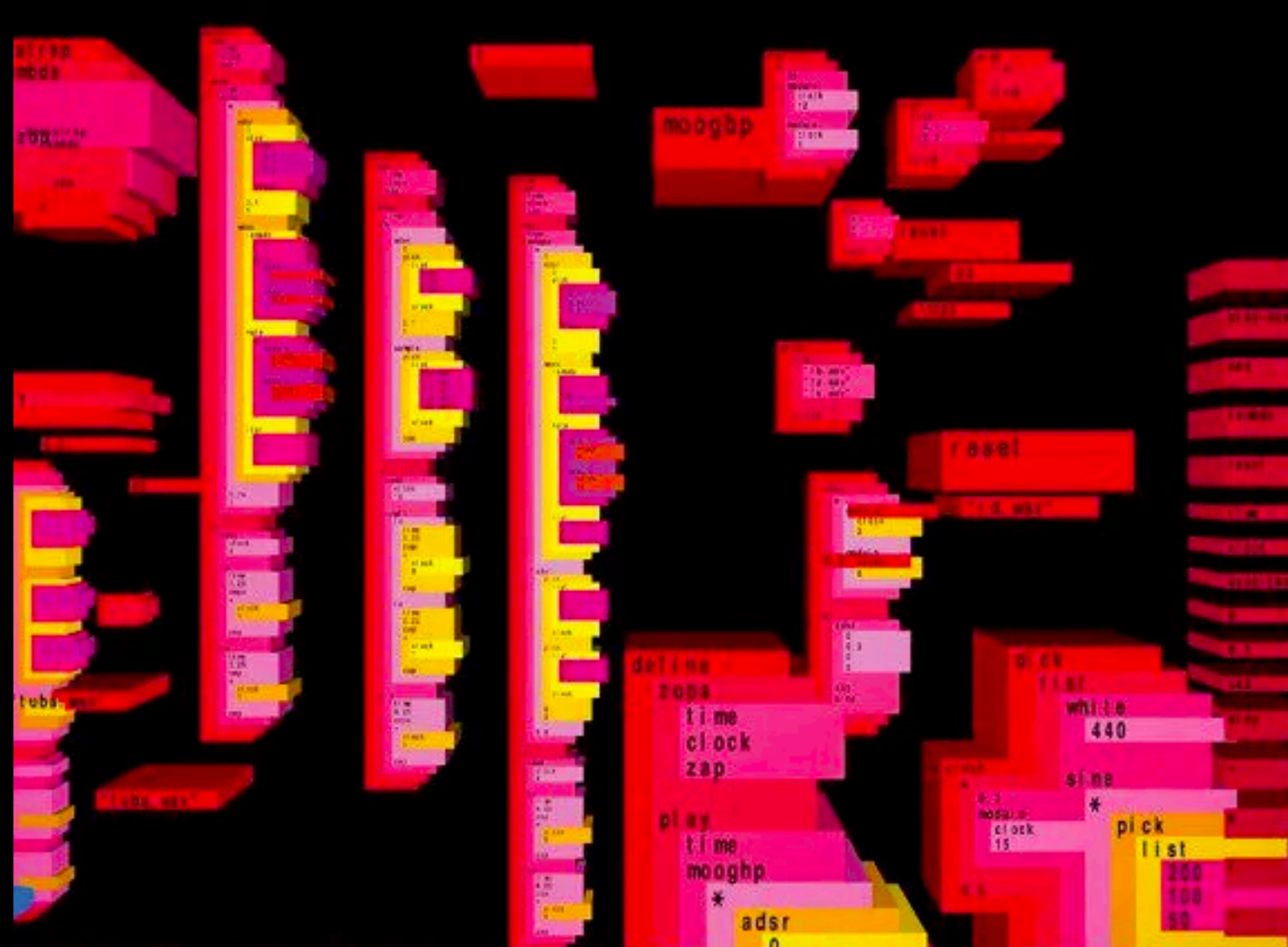


Years



1. tiny-spec-cling

Tiny spectral synthesizer with live coding support.





TOPLAP

933 Tweets



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TOPLAP

@toplapporg

The home of Live Coding

Blog - toplapp.org

Discussion - forum.toplap.org

Chat rooms - discord.com/invite/D4Enr5u...

See also: [@incolico](#) [@algorave](#)



toplapp.org



Joined October 2011

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ARTS

Algorave — the nerdiest clubbing trend of them all

It's the dance sensation where brainy DJs with PhDs play unpredictable music made from live coding and algorithms to ravers

Will Hodgkinson

Thursday May 09 2019, 12.01am,
The Times



Last night a DJ saved my life (and did my maths homework): algoraves

ANTONIO ROBERTS

Music

+ Add to myFT

Electronic dance music and ‘algorave’ – how live coding got cool

Music, visuals and computer code are being blended to create an entrancing experience

🐦

f

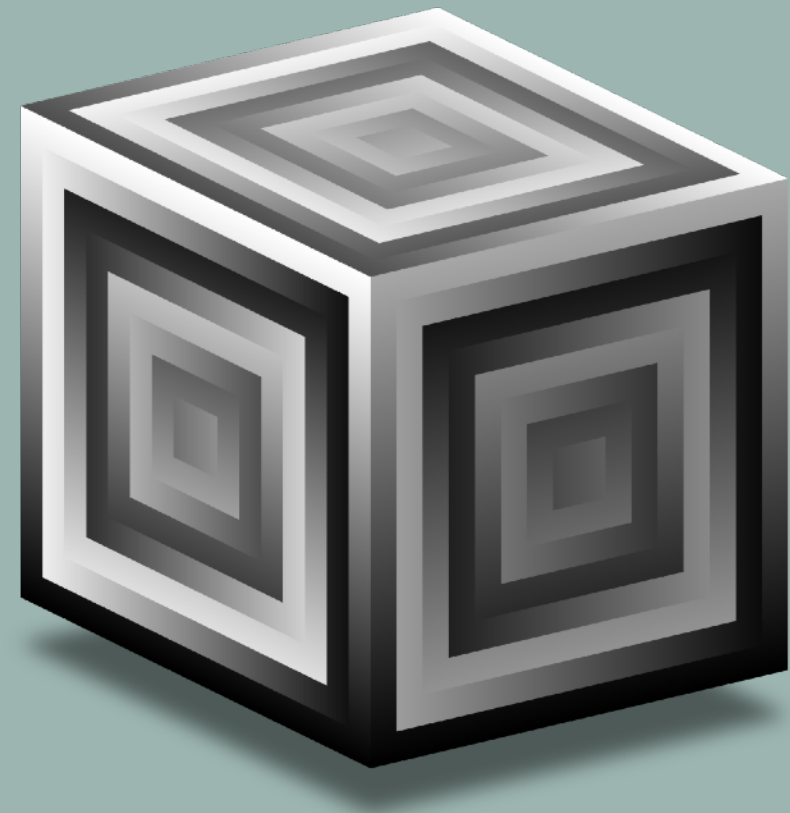
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🔖
Save



Events such as this one curated by Algorave have brought live coding in from the fringes

Live coding systems for music



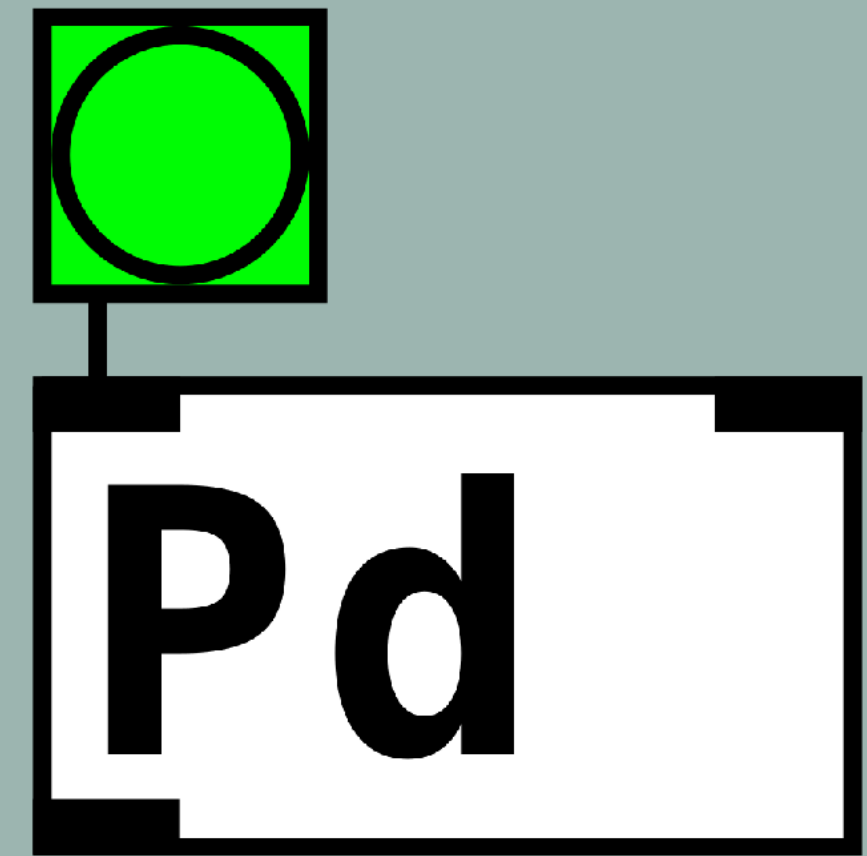
SuperCollider

- Inspired by Smalltalk
- Object-oriented / message passing



TidalCycles

- Haskell library
- String-based notation of pattern



Pure Data

- Dataflow programming
- Open source cousin of Max/MSP

tinyspec-cling

tiny spectral synthesizer with live coding support

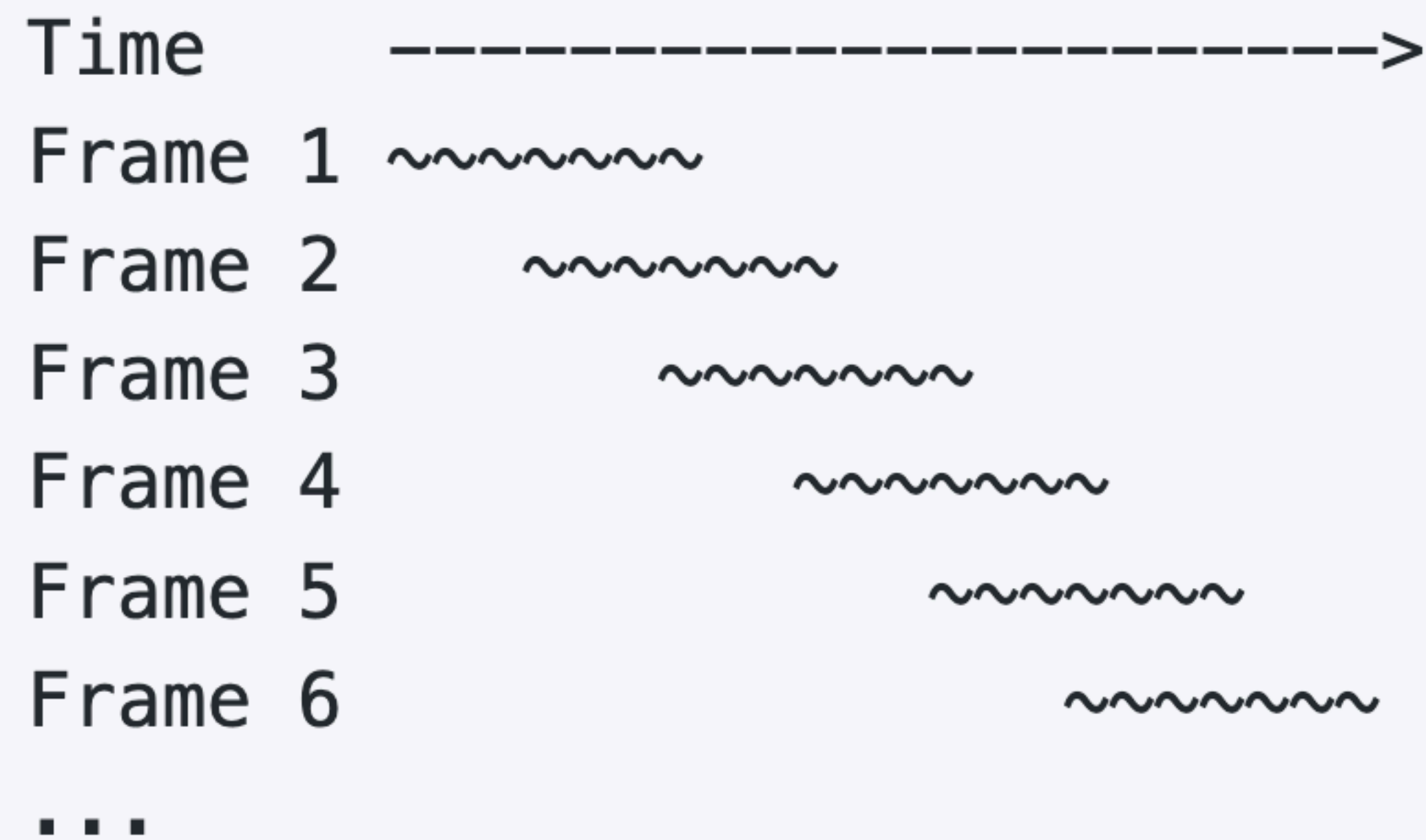
- A tiny C++ live-coded overlap-add (re)synthesizer for Linux, which uses cling to add REPL-like functionality for C++ code.
- create novel audio effects using FFT, phase vocoders and more, and control them with Open Sound Control (OSC)
- create synthesizers, granular synthesis, bytebeats (time and frequency domain)
- control other software with OSC
- use these synthesizers and effects with DAWs, other synthesizers, etc using JACK
- do all of this in a live performance (with some caveats)



Created by Noah Weninger
byte.observer

Overlap-add (re)synthesis

- A function is called periodically to process a frame of audio.
- E.g., phase vocoding is often performed a 4:1 frame size to hop size ratio
- In this example, the “hop” is 3 samples, and the frame size is 7:



1 // Simple bytebeat synth achieved by setting both frame size and hop to 1 sample.
2 set_num_channels(0,1);
3 connect(CLIENT_NAME, "system");
4
5 set_process_fn([&](WaveBuf&, WaveBuf& out, double ts){
6 double t = ts*2000;
7 int y = t;
8 int s = int(fmod(t, (1+(t/(1.0+(y&(y>>9^y>>11)))))));
9 out[0][0] = s%256/128.0-1;
10 next_hop_samples(1,1);
11 });

~

~

11,3

All

./tinyspec /tmp/cmd1

ts@docker-desktop:~/tinyspec-cling\$./tinyspec /tmp/cmd1

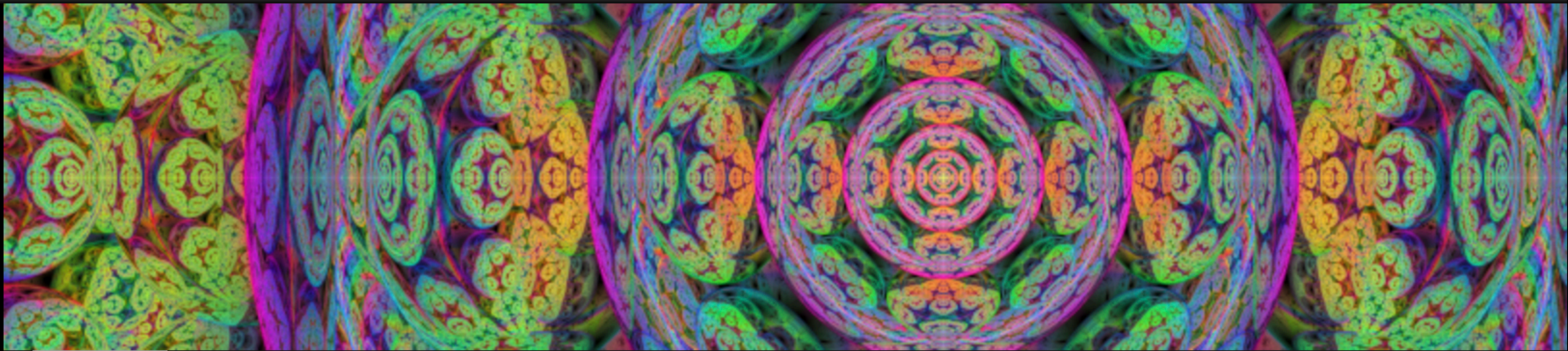
Cannot lock down 82280346 byte memory area (Cannot allocate memory)

INFO: set sample rate to 48000

Playing...

“bytebeat”: somewhat melodic music with no score, no instruments, and no real oscillators

```
5 set_process_fn( [&] (WaveBuf&, WaveBuf& out, double ts){  
6     double t = ts*2000;  
7     int y = t;  
8     int s = int(fmod(t, (1+(t/(1.0+(y&(y>>9^y>>11)))))));  
9     out[0][0] = s%256/128.0-1;  
10    next_hop_samples(1,1);  
11 });
```

music

community

boat style

by [byte.observer](#)



00:00 / 22:08



Digital Track

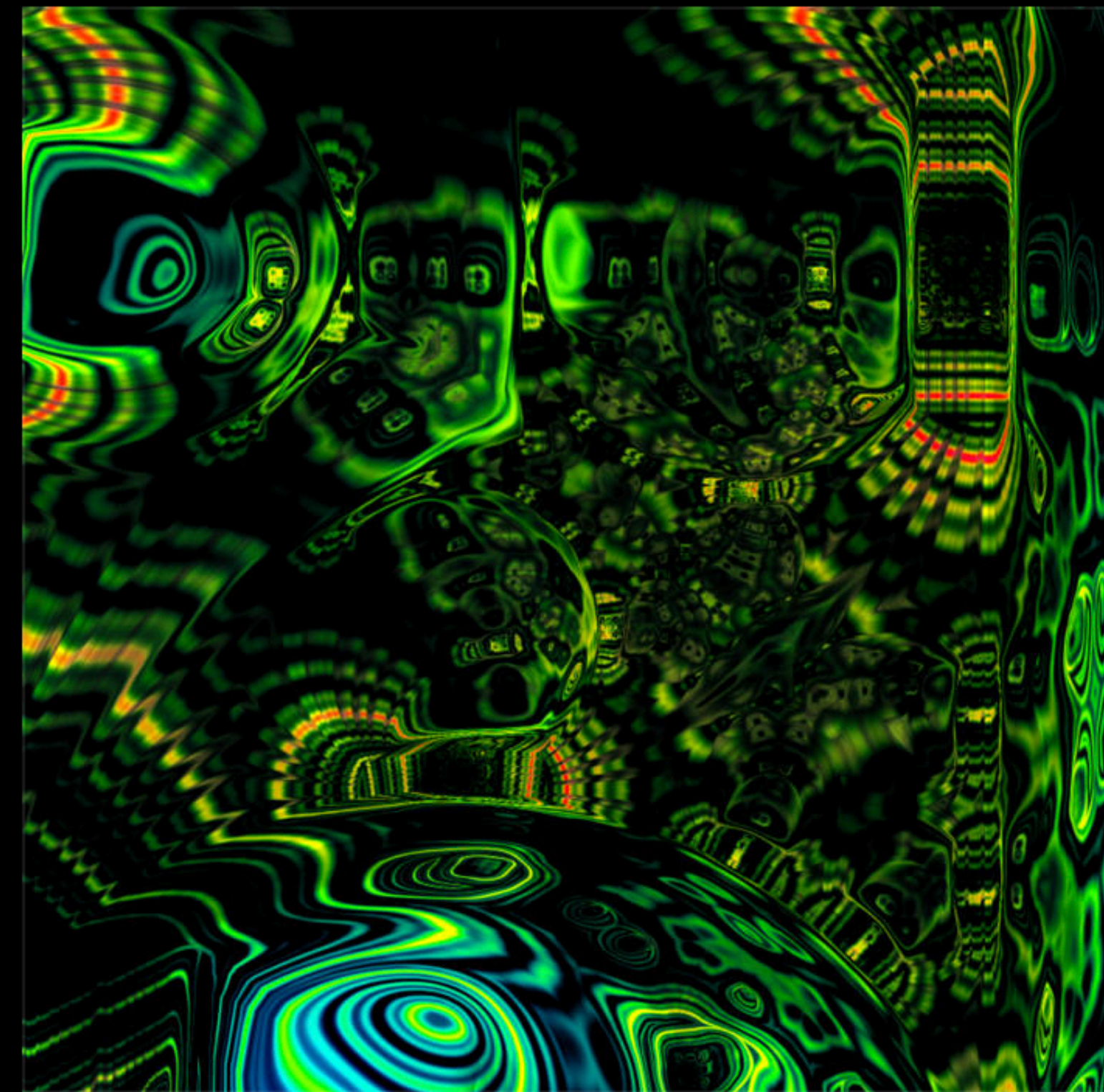
Streaming + Download

Free Download

100% produced with [github.com/nwoeanhinnogaehr/tinyspec-cling](#)
and [github.com/musikinformatik/SuperDirt](#)

released July 13, 2019

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 [Share / Embed](#)

tinyspec-cling

github.com/nwoeanhinnogaehr/tinyspec-cling

[byte.observer](#)

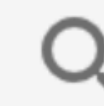
2. Cling in embedded instruments

Using the Bela interactive audio platform.

**NIME**

International Conference on New Interfaces
for Musical Expression (nime.org)

- “NIME gathers researchers and musicians from all over the world to share their knowledge and late-breaking work on new musical interface design.”
- Started as a workshop at the Conference on Human Factors in Computing Systems (CHI) in 2001.
- Annual series of conferences held around the world, hosted by research groups dedicated to interface design, human-computer interaction, and computer music.



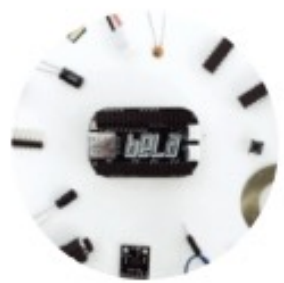
 Top publications

Categories > Humanities, Literature & Arts > **Music & Musicology** ▼

	Publication	<u>h5-index</u>	<u>h5-median</u>
1.	International Society for Music Information Retrieval Conference	<u>37</u>	60
2.	Psychology of Music	<u>34</u>	49
3.	Music Education Research	<u>22</u>	31
4.	Journal of Research in Music Education	<u>21</u>	34
5.	Musicae Scientiae	<u>21</u>	30
6.	Music Perception: An Interdisciplinary Journal	<u>21</u>	28
7.	International Journal of Music Education	<u>20</u>	28
8.	Journal of New Music Research	<u>19</u>	29
9.	Nordic Journal of Music Therapy	<u>18</u>	25
10.	Medical Problems of Performing Artists	<u>17</u>	23
11.	New Interfaces for Musical Expression (NIME)	<u>17</u>	20

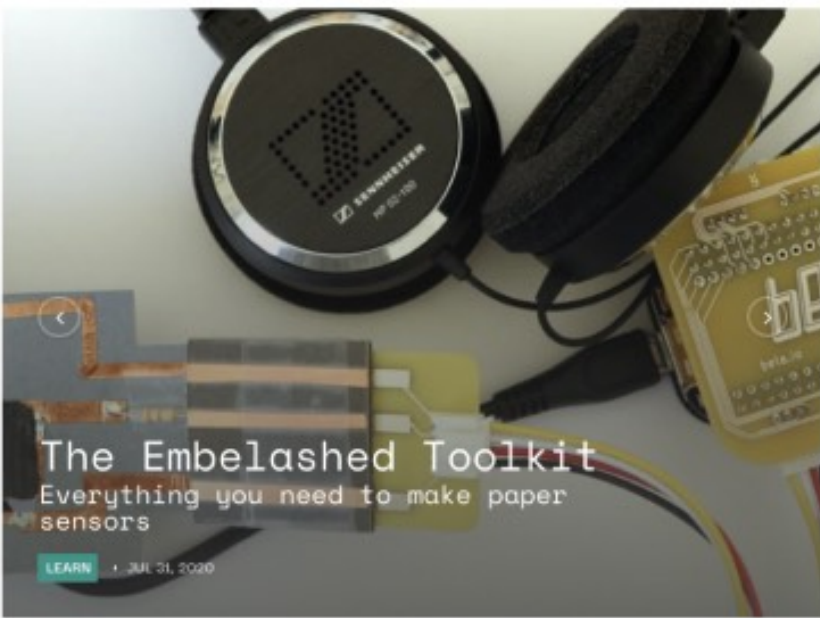


bel.a.io



The Bela Blog

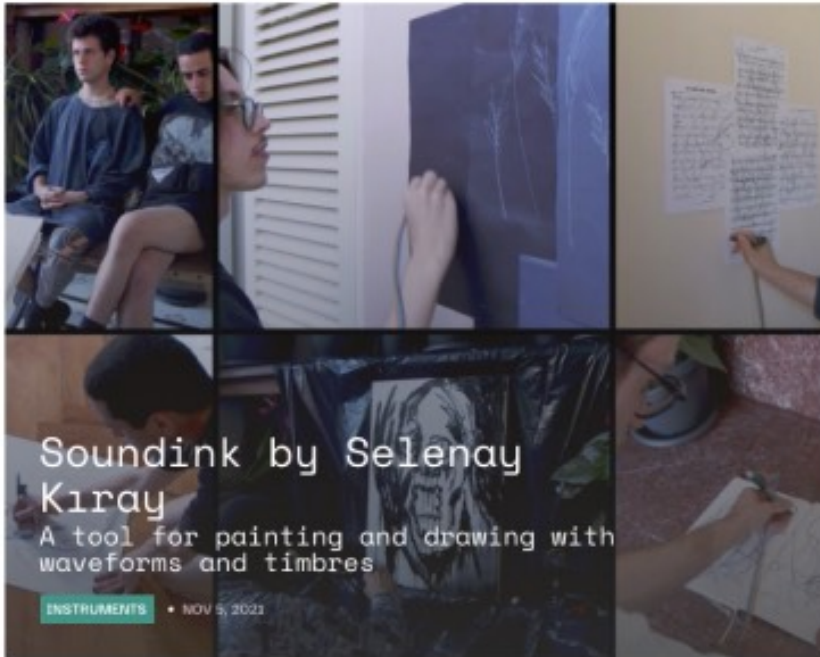
Beautiful, inspiring projects from Bela's worldwide community of ambitious creators.



The Embelashed Toolkit

Everything you need to make paper sensors

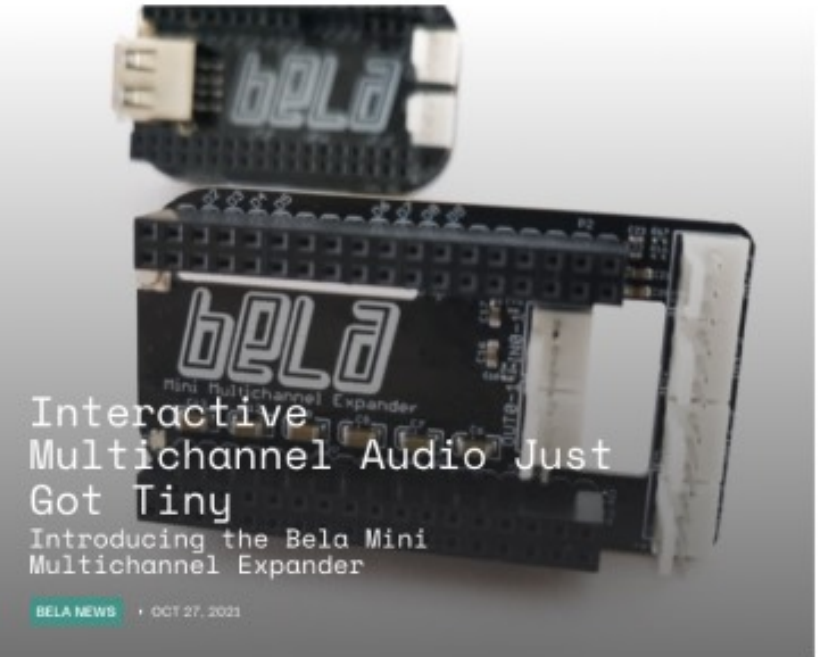
LEARN • JUN 31, 2020



Soundink by Selenay Kiray

A tool for painting and drawing with waveforms and timbres

INSTRUMENTS • NOV 5, 2021



Interactive Multichannel Audio Just Got Tiny

Introducing the Bela Mini Multichannel Expander

BELA NEWS • OCT 27, 2021



Suspended Circles

Interactive hanging mobile with knitted sensors, Trill Craft and Bela

ART INTERACTION • JUL 30, 2021



Custom Macro Keyboard

Machine learning for gesture detection with Trill

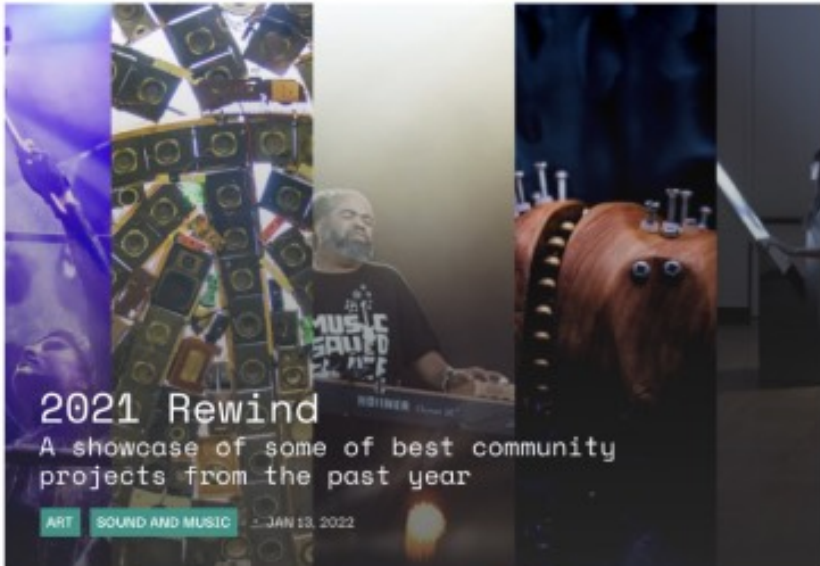
INTERACTION • JUL 23, 2021



Brassynth

A wind instrument for the 21st Century

INSTRUMENTS • FEB 1, 2022



2021 Rewind

A showcase of some of the best community projects from the past year

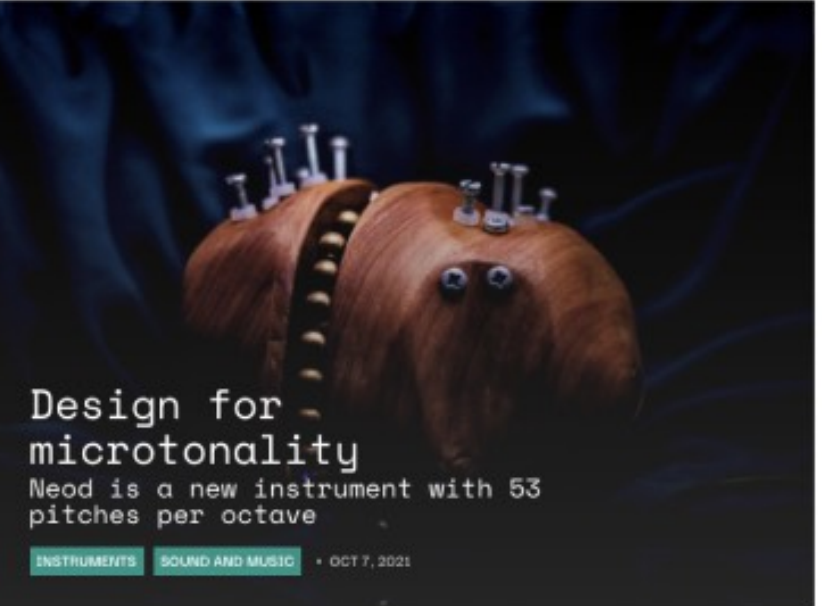
ART SOUND AND MUSIC • JAN 13, 2022



Bela turns 5!

Celebrating half a decade of beautiful digital interaction

BELA NEWS • OCT 20, 2021



Design for microtonality

Need is a new instrument with 53 pitches per octave

INSTRUMENTS SOUND AND MUSIC • OCT 7, 2021



Audio Igloo

A shelter for homeless loudspeakers

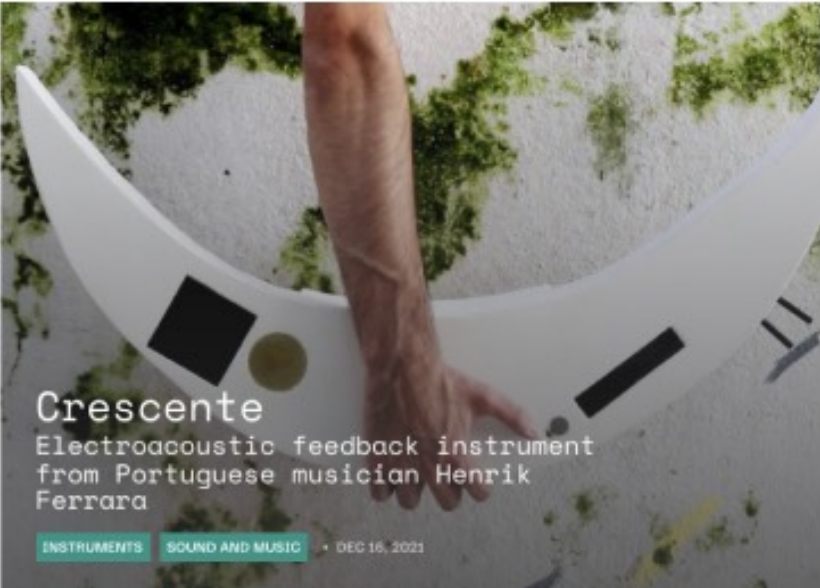
ART INTERACTION • JUL 16, 2021



Trill Guitar

Building a MIDI instrument with the Pi Pico and our Trill touch sensors

LEARN INSTRUMENTS • JUL 9, 2021



Crescente

Electroacoustic feedback instrument from Portuguese musician Henrik Ferrara

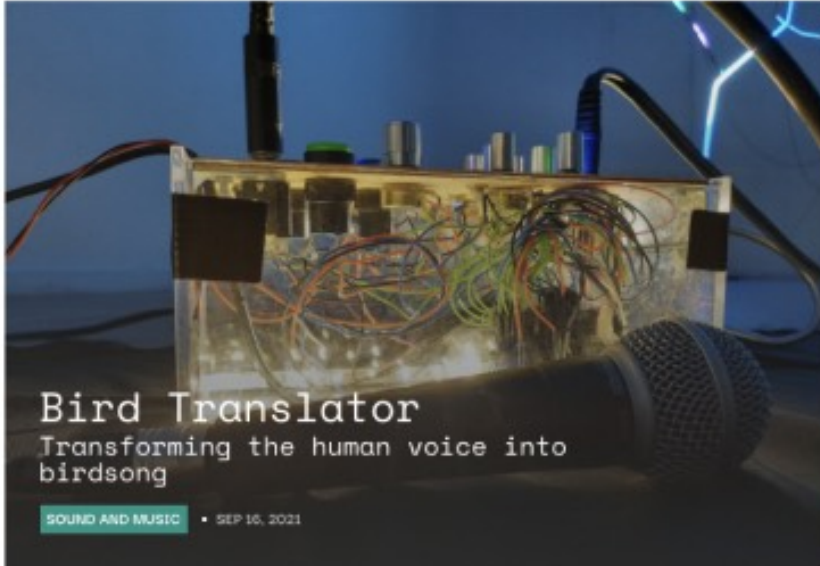
INSTRUMENTS SOUND AND MUSIC • DEC 16, 2021



Degrees of Granularity

Porcelain sculpture and interactive sound installation

ART SOUND AND MUSIC • DEC 7, 2021



Bird Translator

Transforming the human voice into birdsong

SOUND AND MUSIC • SEP 16, 2021



Teaching Spotlight

Music and Audio Programming at Queen Mary University of London

LEARN INSTRUMENTS • SEP 8, 2021



Teaching Spotlight

Embedded Computing for Music at Case Western Reserve University

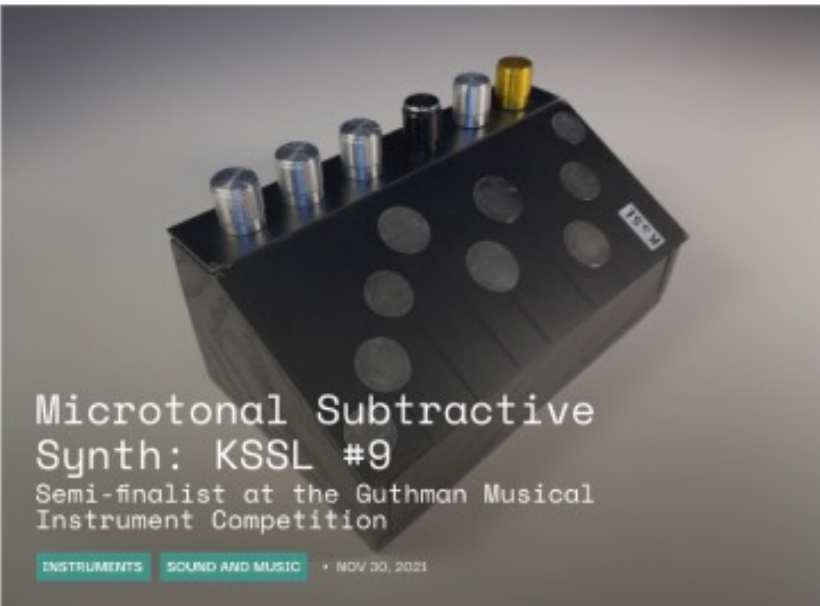
LEARN • JUL 1, 2021



Pamela Z Award for Innovation

Recognising research that champions diversity in music technology

INNOVATION • JUN 24, 2021



Microtonal Subtractive Synth: KSSL #9

Semi-finalist at the Guthman Musical Instrument Competition

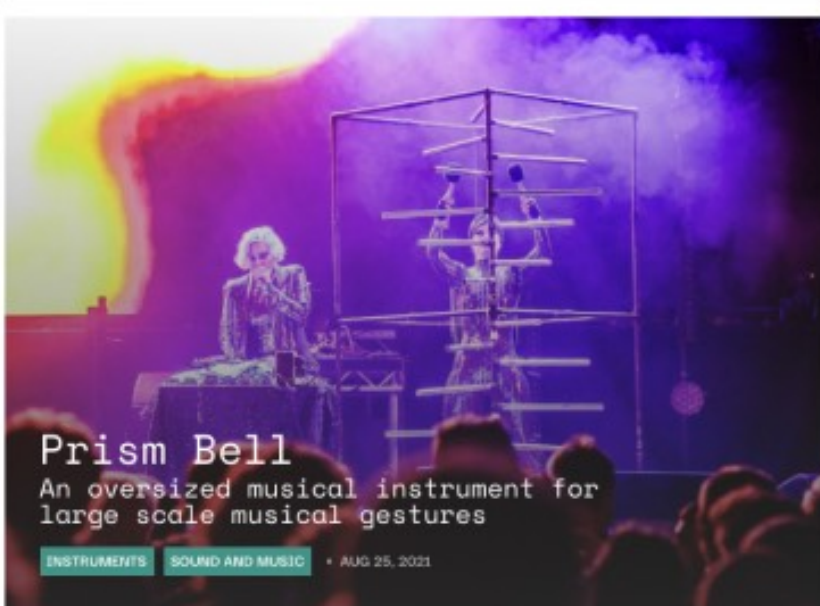
INSTRUMENTS SOUND AND MUSIC • NOV 30, 2021



Stramare Sound Machines

Large scale metallic interactive sound installations created by Italian arts collective

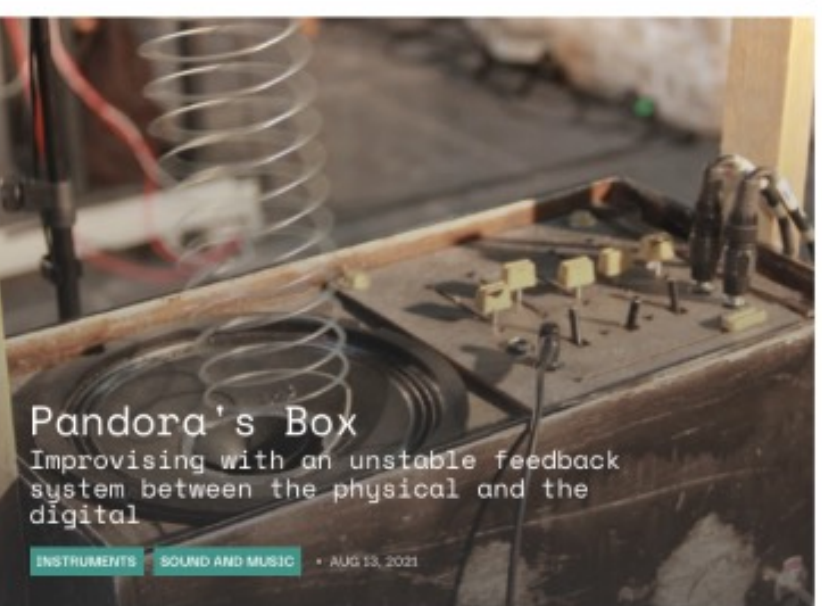
ART • NOV 12, 2021



Prism Bell

An oversized musical instrument for large scale musical gestures

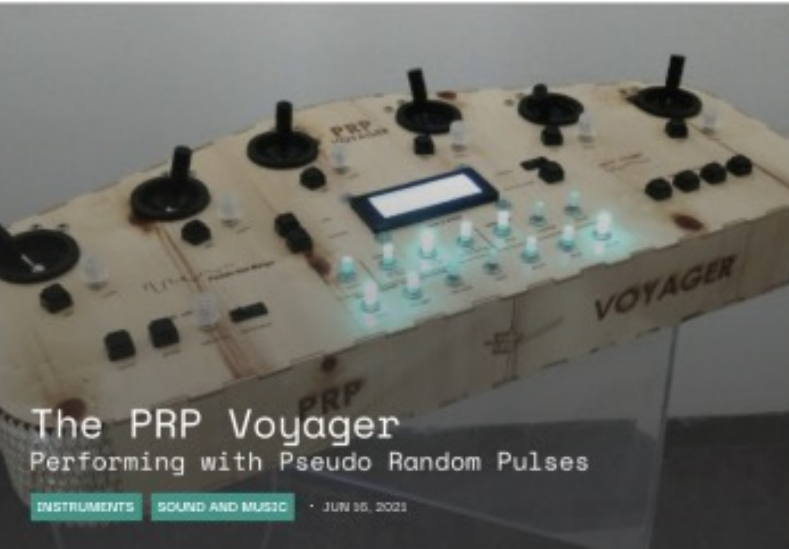
INSTRUMENTS SOUND AND MUSIC • AUG 25, 2021



Pandora's Box

Improvising with an unstable feedback system between the physical and the digital

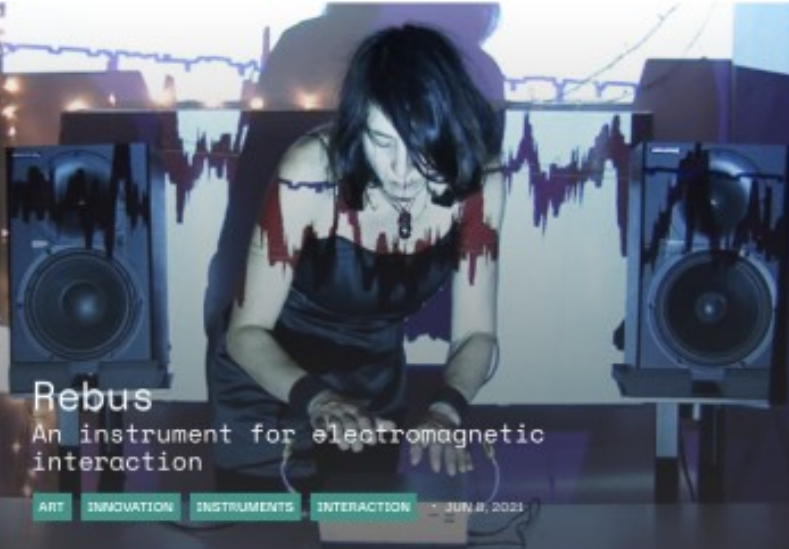
INSTRUMENTS SOUND AND MUSIC • AUG 13, 2021



The PRP Voyager

Performing with Pseudo Random Pulses

INSTRUMENTS SOUND AND MUSIC • JUN 10, 2021



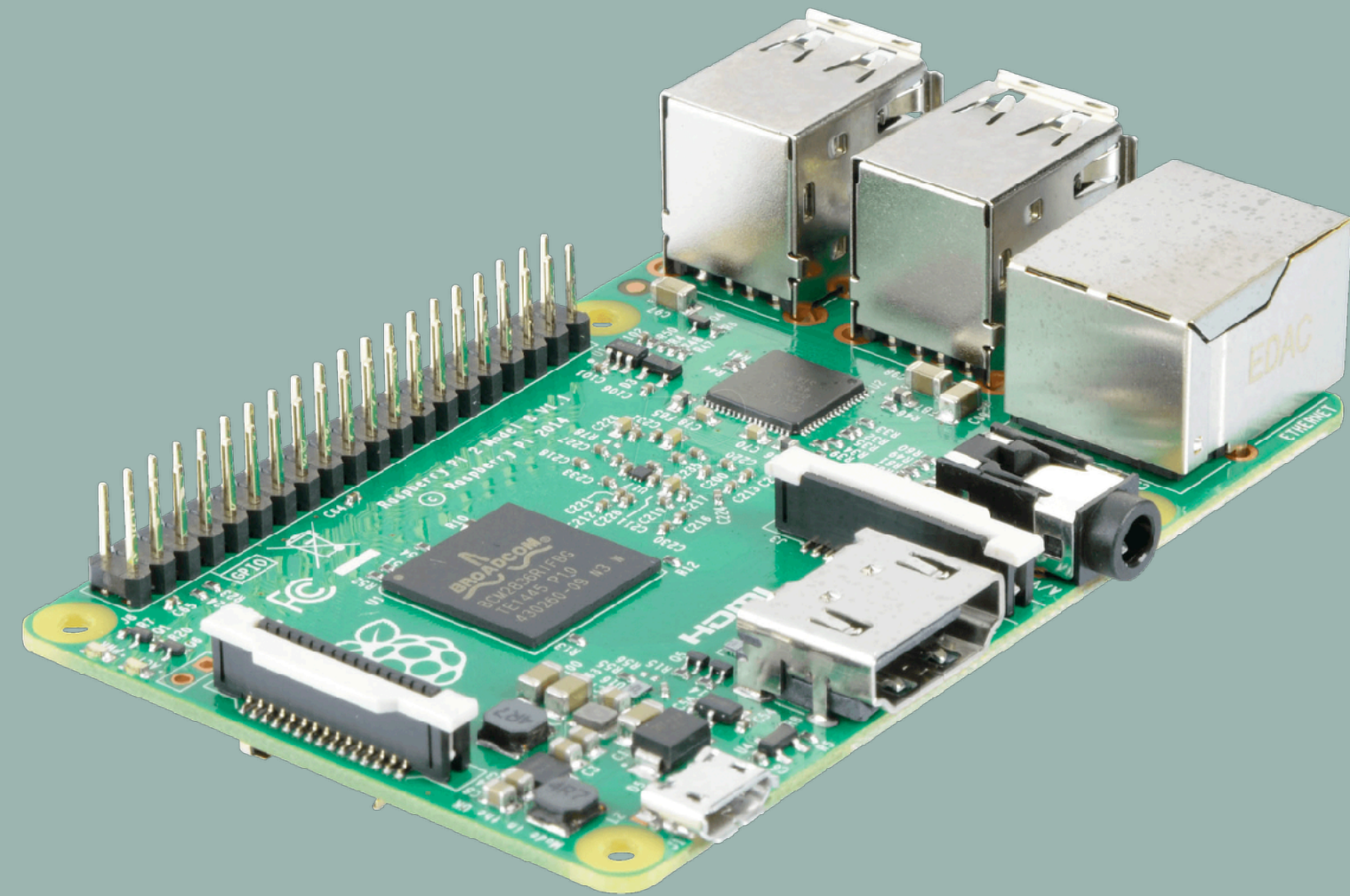
Rebus

An instrument for electromagnetic interaction

ART INNOVATION INSTRUMENTS INTERACTION • JUN 8, 2021

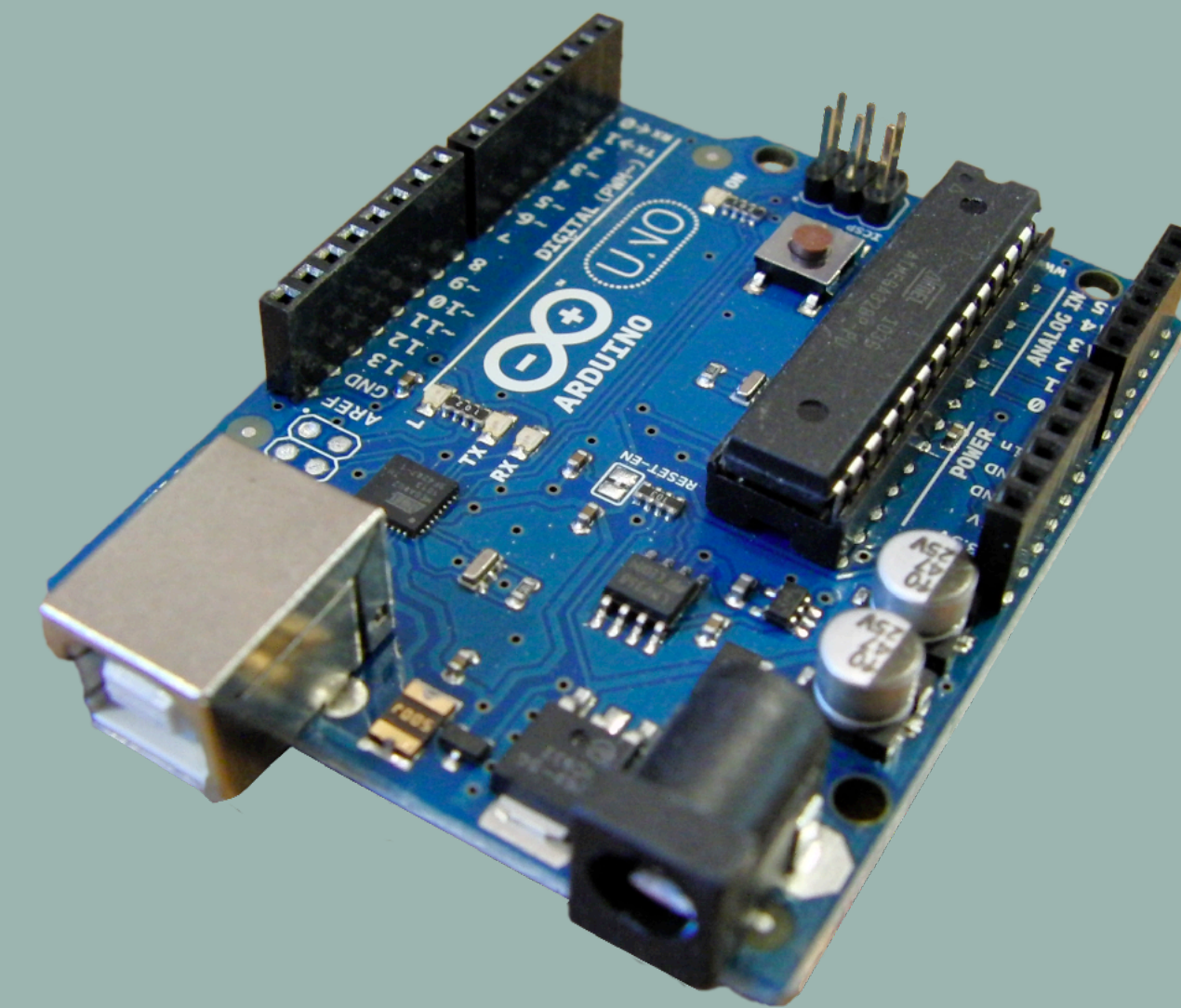


Embedded platforms for instrument makers



Raspberry Pi

- Embedded Linux with user space
- Low quality audio hardware
- High latency and jitter due to OS



Arduino

- Microcontroller - good for IO!
- No OS = no latency/jitter
- Insufficient CPU, harder to program

Bela: open source platform for interactive audio projects

- Hardware cape for BeagleBoard Black & Mini
 - PRUs enable microcontroller-level IO control & performance
- Software OS based on Xenomai “hard real-time” Linux
 - Custom real-time process with higher priority than entire OS
 - 1ms roundtrip audio latency (~10ms considered “good”)
- User friendly IDE, large examples library, online knowledge base & teaching courses
- Polyglot: C++, SuperCollider, Pure Data, Faust, Csound, Rust, Python...
- BUT! Slow(er) compile times & no live coding is frustrating for makers who need real-time feedback and iteration!



instrumentslab.org

Bela C++ API

Project: sinetone (example) File: render.cpp

```
1  #include <Bela.h>
2  #include <cmath>
3
4  float gFrequency = 440.0;
5  float gPhase;
6  float gInverseSampleRate;
7
8  bool setup(BelaContext *context, void *userData) {
9      gInverseSampleRate = 1.0 / context->audioSampleRate;
10     gPhase = 0.0;
11     return true;
12 }
13
14 void render(BelaContext *context, void *userData) {
15     for(unsigned int n = 0; n < context->audioFrames; n++) {
16         float out = 0.8f * sinf(gPhase);
17         gPhase += 2.0f * (float)M_PI * gFrequency * gInverseSampleRate;
18         if(gPhase > M_PI) gPhase -= 2.0f * (float)M_PI;
19         for(unsigned int channel = 0; channel < context->audioOutChannels; channel++)
20             audioWrite(context, n, channel, out);
21     }
22 }
23
24 void cleanup(BelaContext *context, void *userData){}
```

Programming Bela with Cling?

- Cross-compile Cling for BeagleBoard ARMv7 with hard-float architecture
- Expose Bela's `render()` function as `gBelaRender` so Cling can replace it

```
.I /root/Bela/include  
.L /root/Bela/lib/libbela.so  
.L /root/Bela/lib/libbelaextra.so  
.x /root/Bela/projects/[project_folder]/[project_main].cpp
```

```
gBelaRender = cling_render // some new render function!
```

REPL access to BelaContext and Bela APIs!

```
[cling]$ bela->audioSampleRate
```

```
(const float) 44100.0f
```

```
[cling]$ analogRead(bela, 0, 0)
```

```
(float) 0.000259399f
```

Future work

- Updating to latest Cling
- Bela IDE integration
 - Integrated Cling REPL feedback into IDE terminal
 - Toolbar for loading files into the REPL, easy access to undo, etc
- Develop strategies for live coding musical instruments
 - More flexible C++ API suited to live coding
 - Preventing / catching errors
- Optimising Cling for hard real-time performance...?

3. SOFIE in intelligent instruments

In search of embedded AI for musical instruments.



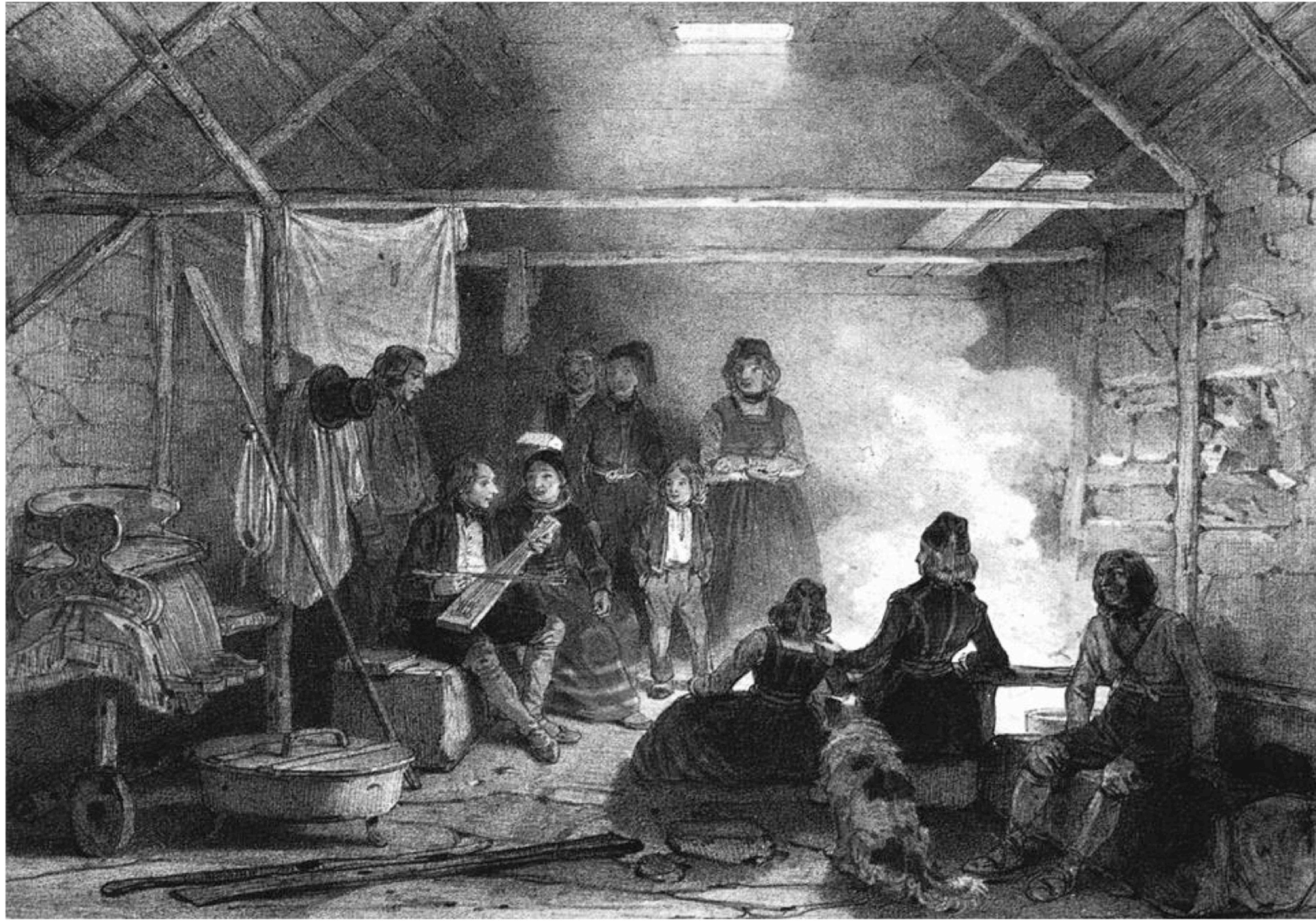
Understanding 21st century AI through creative music technologies.

The Icelandic langspil

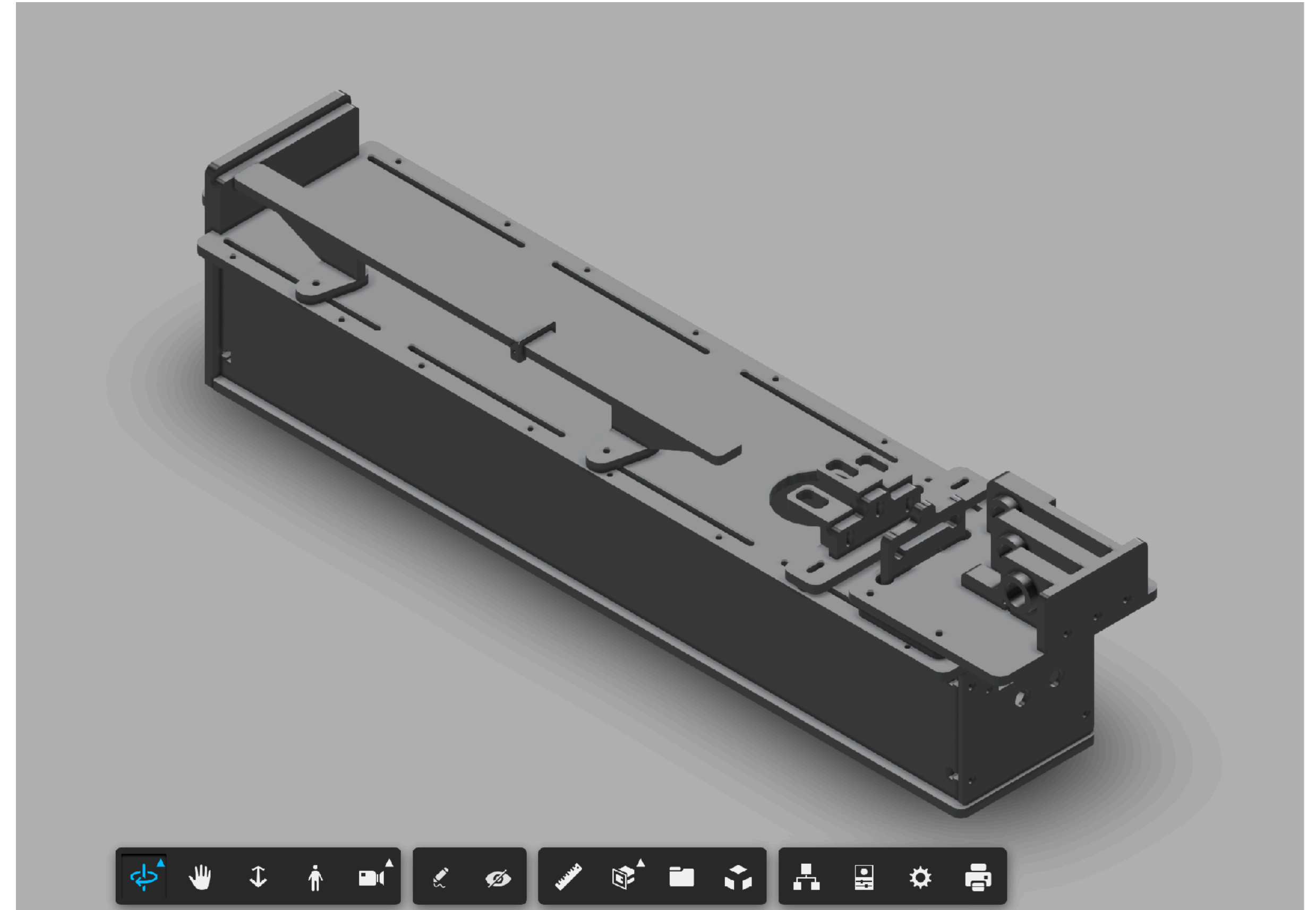
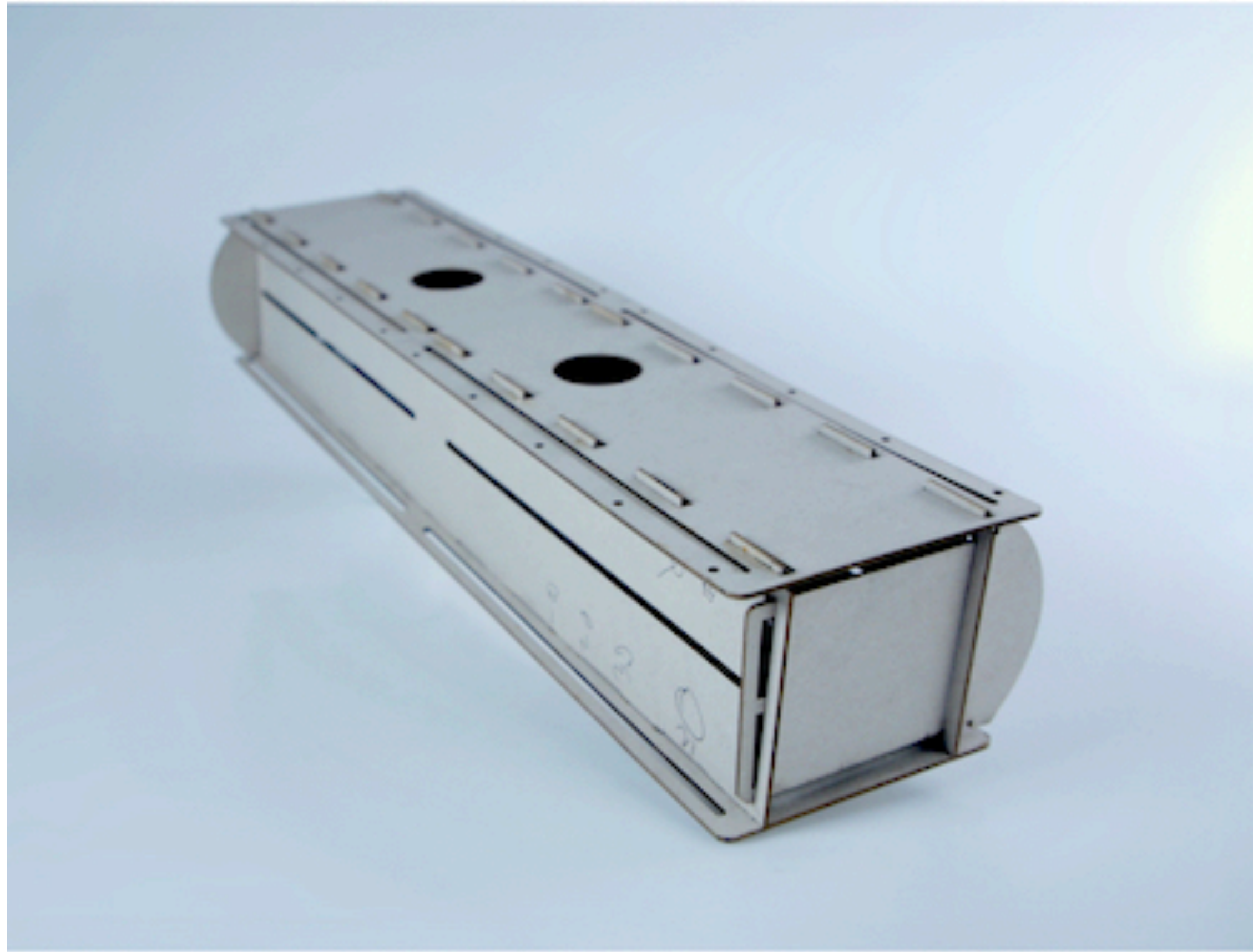


Icelandic version of the monochord is called langspil.

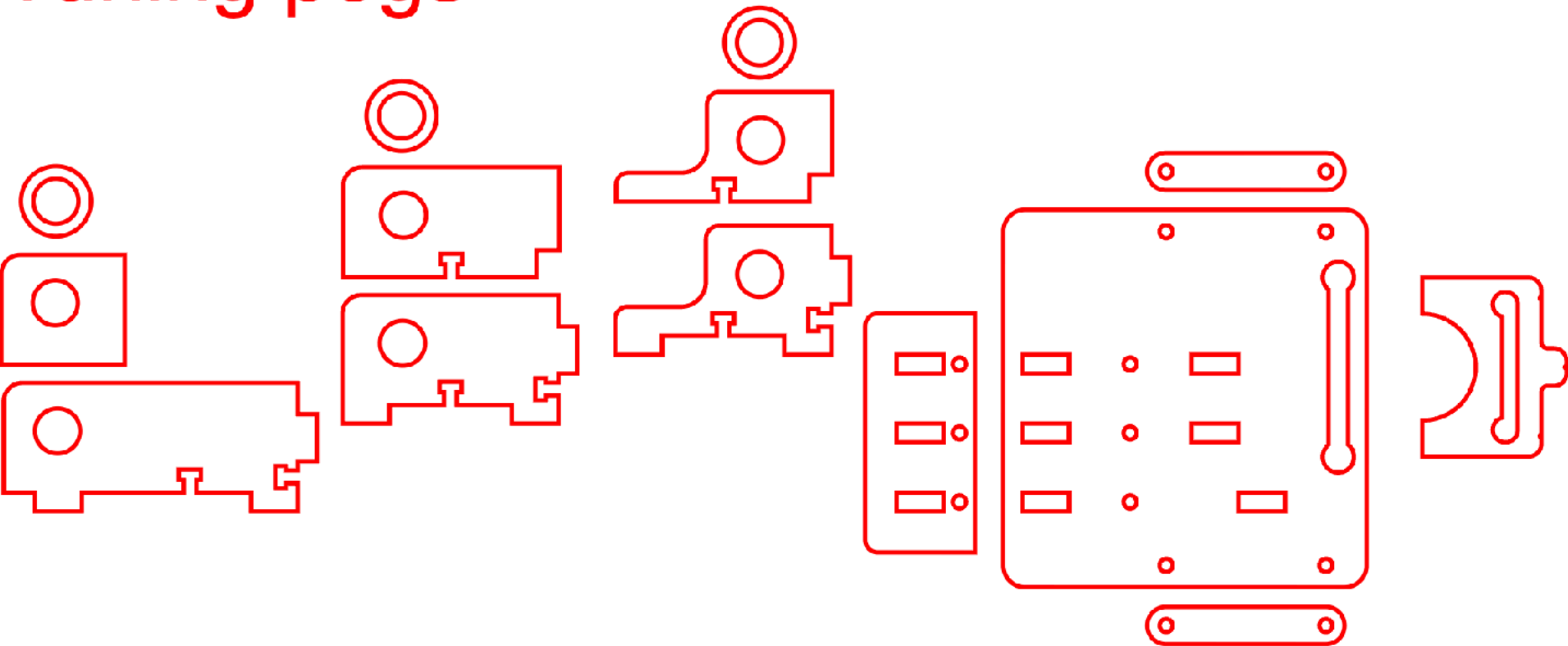
The instrument has one to six strings, where some are used as drone strings.



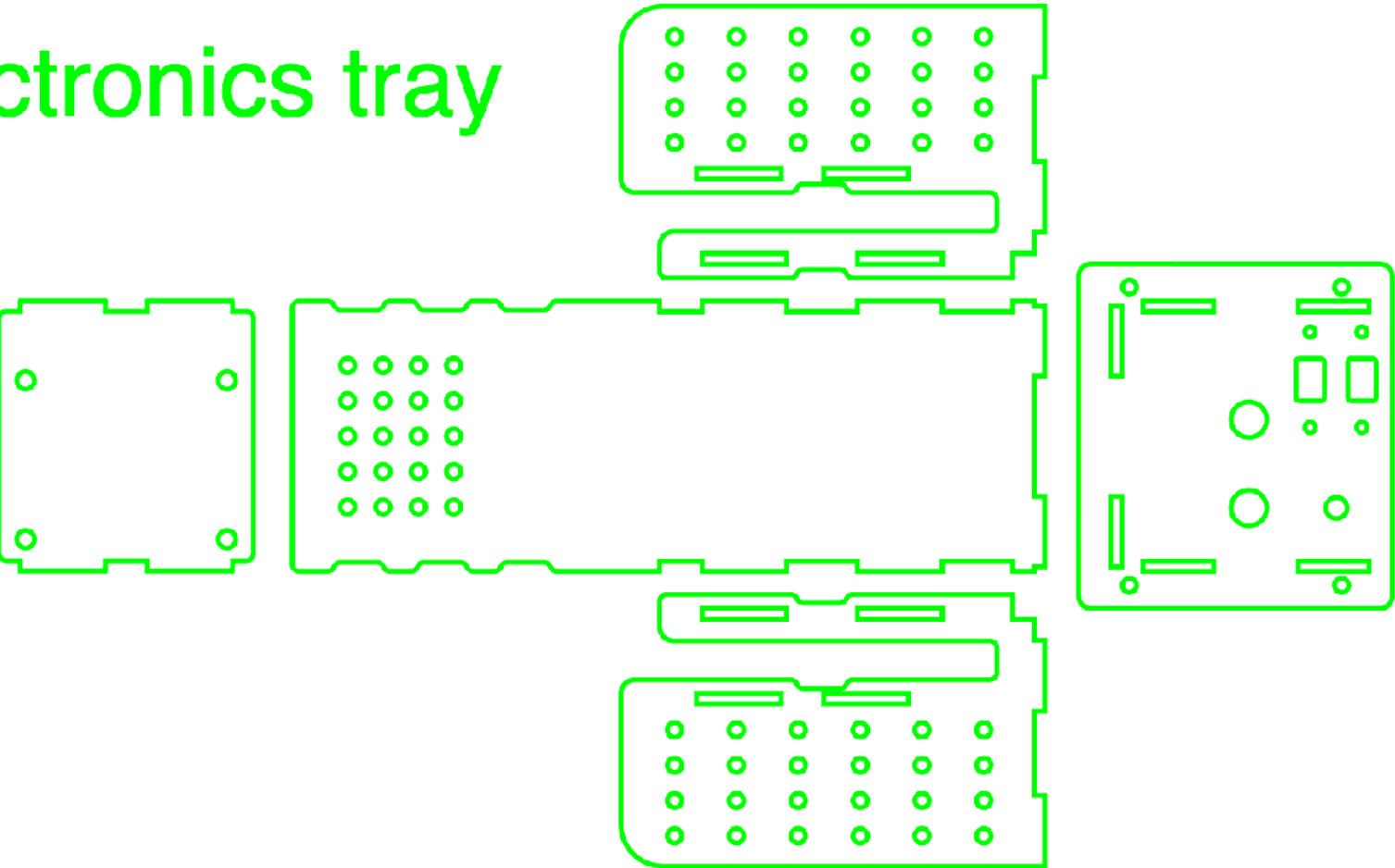
From cardboard to CAD...



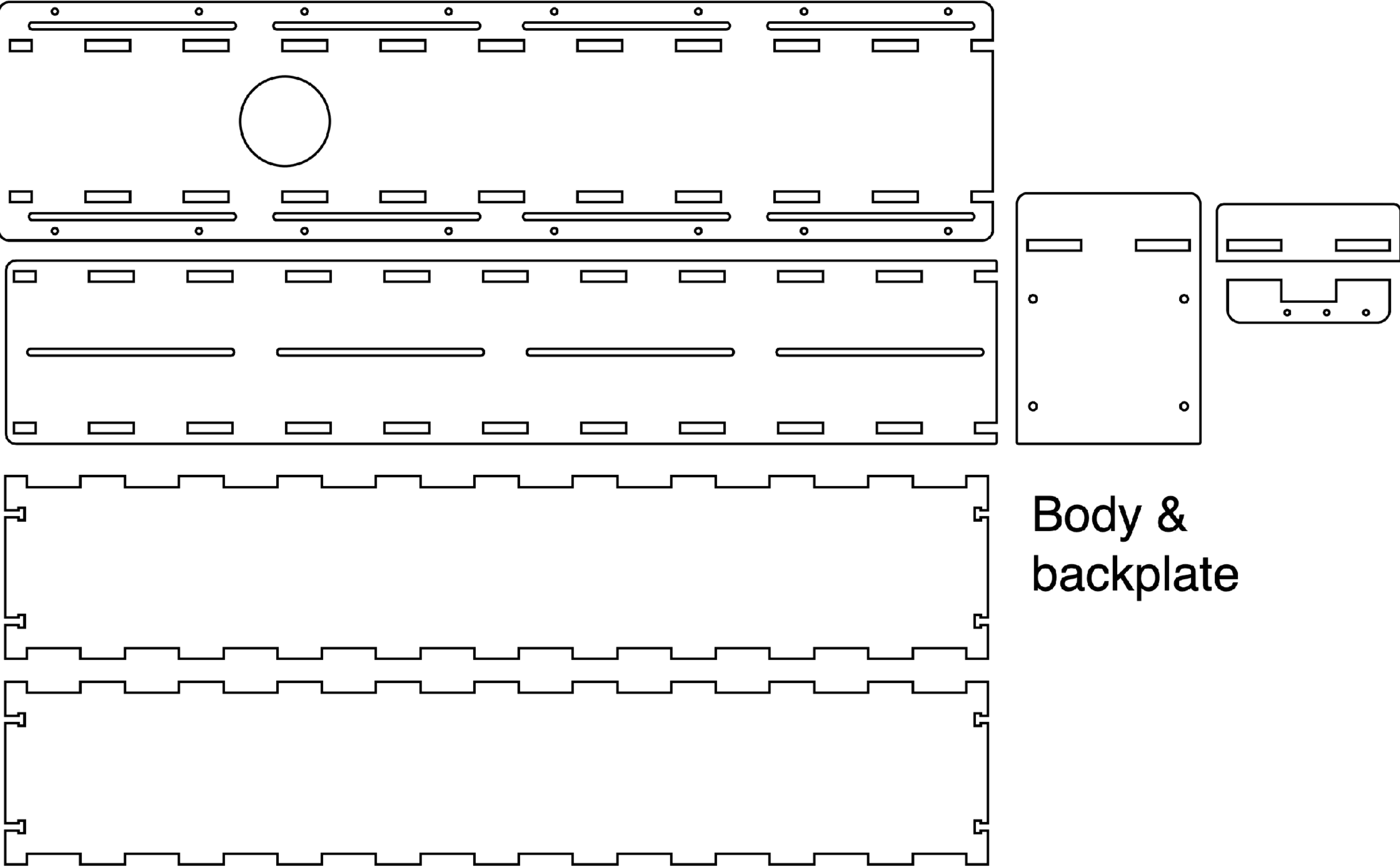
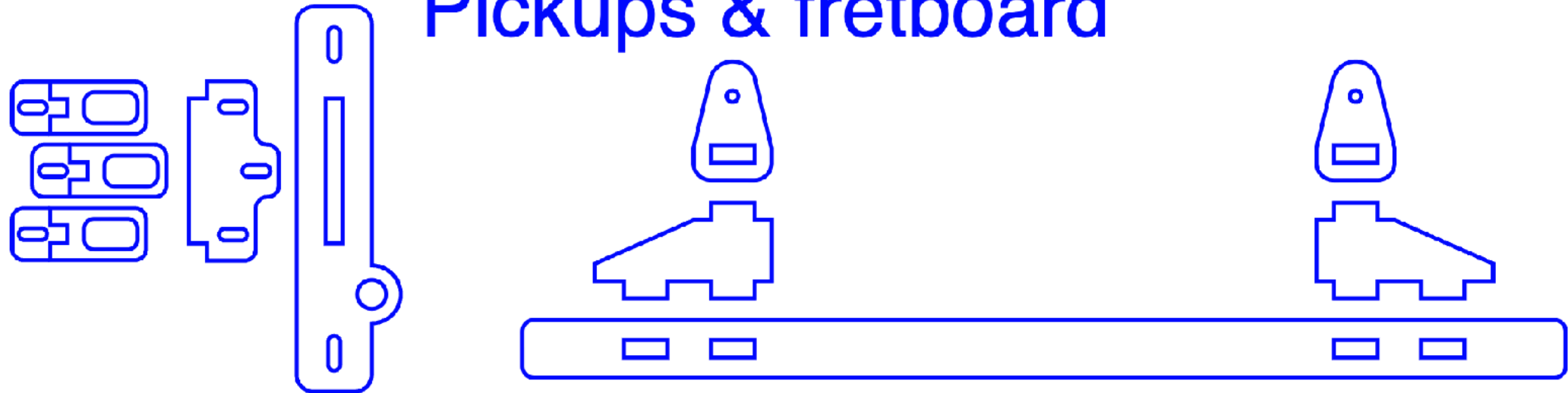
Tuning pegs



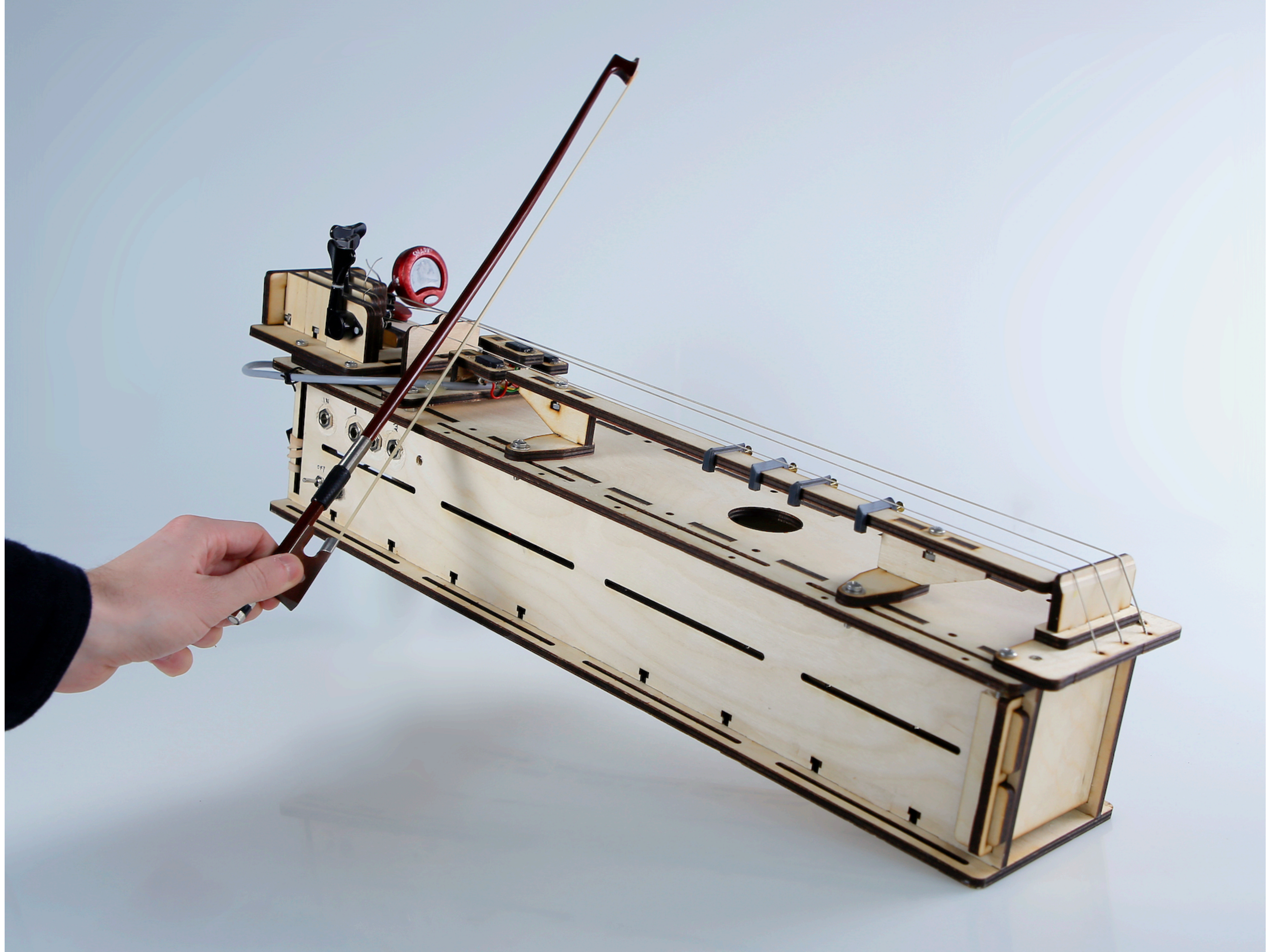
Electronics tray

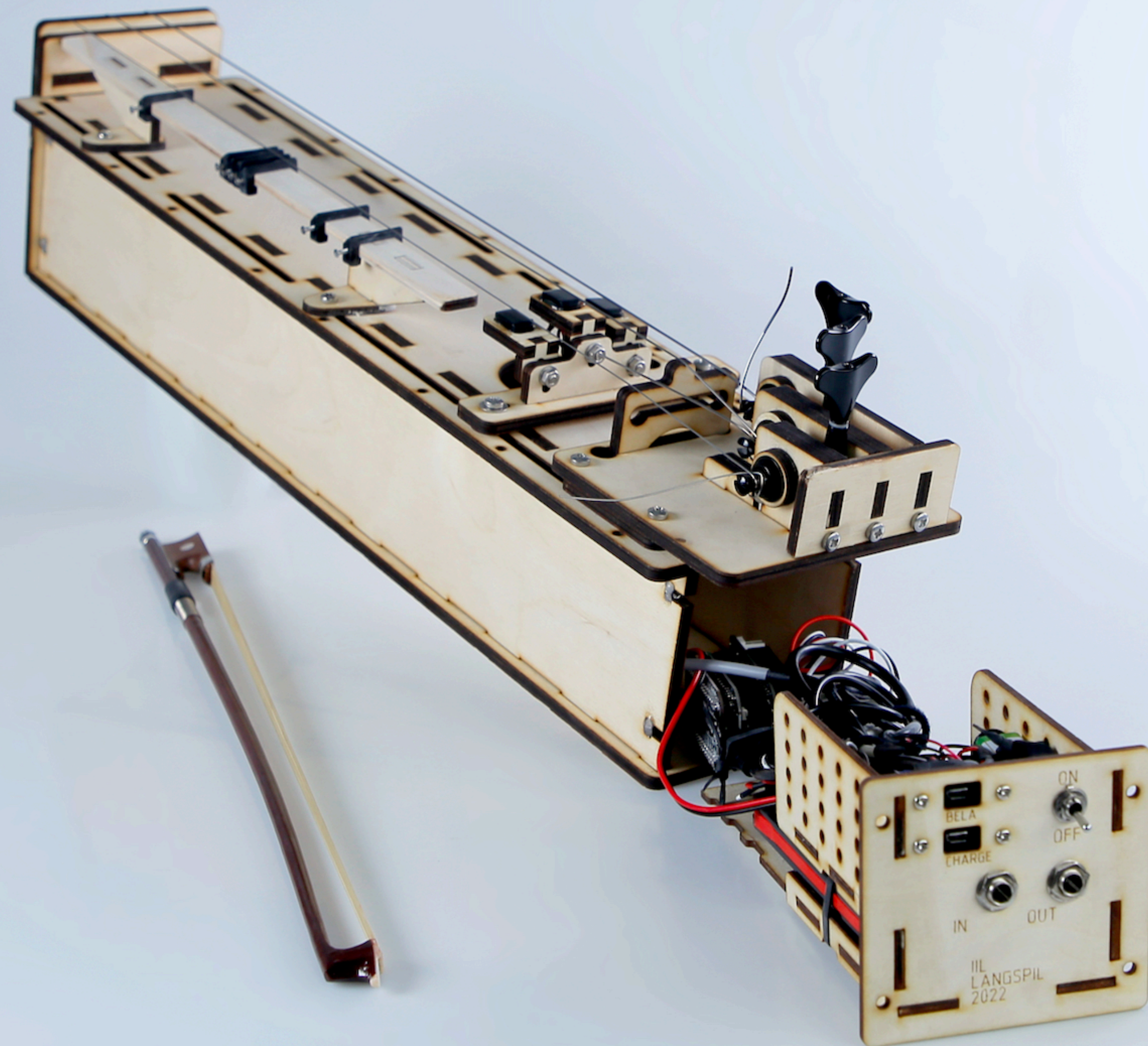


Pickups & fretboard

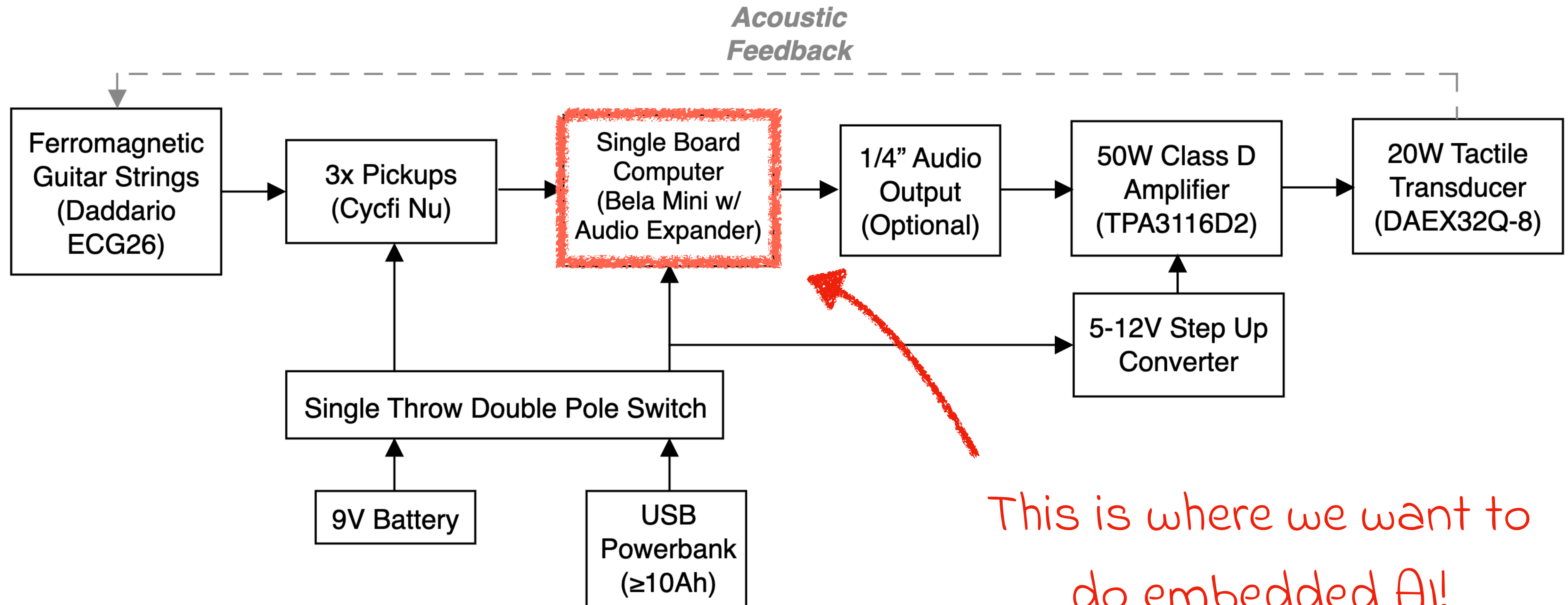


Body & backplate





Feedback as instrumental agency



Embedded AI for NIME: Challenges and Opportunities

Workshop at NIME 2022

<https://embedded-ai-for-nime.github.io/>

design strategies ◦ conceptual frameworks
interaction paradigms ◦ neural audio synthesis
AR/MR/VR ◦ mobile computing ◦ AI musicality
dev workflows ◦ interactive machine learning
ethical issues ◦ inclusivity & diversity

Submit proposals by **June 3rd.**

DeepLearningForBela

Tensorflow Lite

Tensorflow Lite uses [delegates](#) to accelerate certain operations on different hardware. By default, operators are optimized for Neon on ARM devices and the [default delegate is XNNPACK](#).

ArmNN also provides a custom delegate that can be used with TFLite.

ArmNN

ArmNN provides 3 backends: CpuRef, CpuAcc and GpuAcc. However, it is also possible to [implement custom backends](#).

RTNeural

RTNeural provides 3 backends, STL, xsimd, and Eigen. By default Eigen is used, more information about the backends and their selection can be found [here](#)

Initial experiments with Σ OFIE on Bela

- It runs!
- The single header file approach is ideal for embedded musical instruments
- As expected, slower than hardware-accelerated libraries
- (Hopefully) Google Summer of Code project exploring this further...

How can ROOT benefit from its misuse?

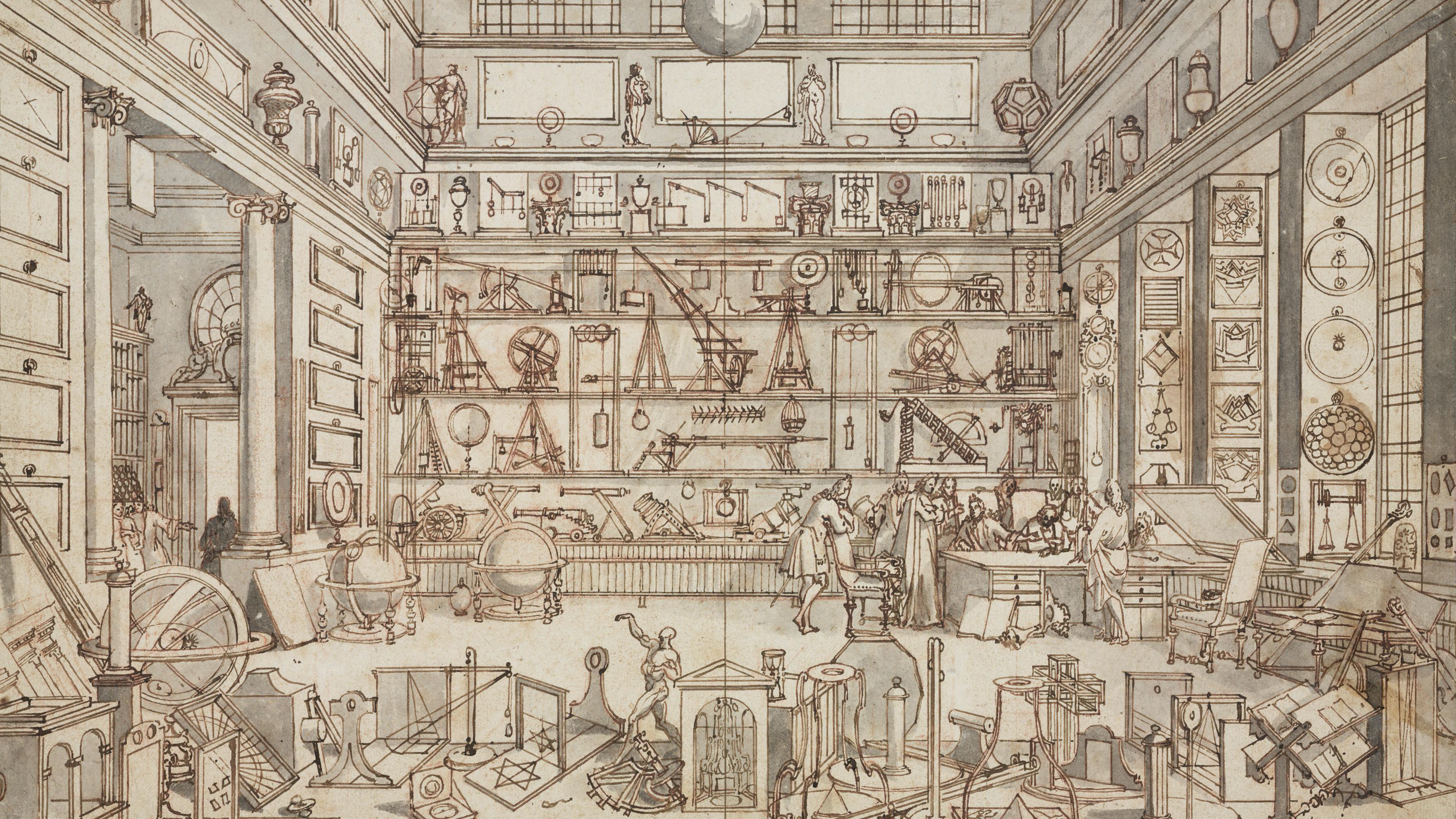
"In the grand scheme of things, there are three levels of design: standard spec., military spec., and artist spec.

Most significantly, I learned that the third was the hardest (and most important), but if you could nail it, then everything else was easy.

After my work with artists, my research career at the University of Toronto and Xerox PARC was relatively simple."

– billbuxton.com/luthier







IIL Research Themes



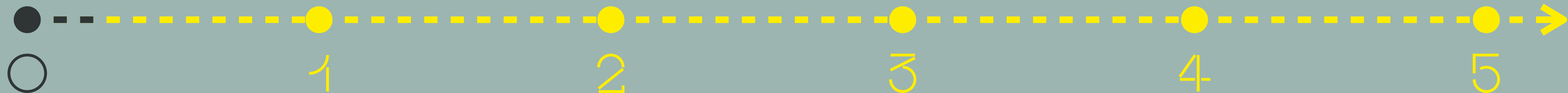
1. Self PhD 1



2. Others PhD 2



3. Knowledge PhD 3



Years

Embodied Scientific Instruments

- Hypothesis: interactive haptic intelligent instruments can give novel and alternative scientific insights when applied in the exploration of large data sets.
- How can intelligent instruments serve as epistemic tools for scientific enquiry?
- How can creative AI benefit data display with haptic feedback and sonification?
- How can we gain new knowledge of performance with data sonification of instruments?
- How does AI change our notions of creativity? What is the ethical and aesthetic impact?

