Spatial Granular Synthesis With Ambitools And Supercollider

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Introduction

- Granular synthesis is originally based on pioneer works by Gabor[1] and Xenakis [2] .
- The principle is to break down an audio signal into small segment called "grains".
- Rich textures and complex sounds are obtained by playing on grain duration, overlap, envelops, position, etc.
- Granular spatialization is a natural evolution of granular synthesis [3] [4]
- In this work: grains swarm in HOA format of any order [5]
- The "Granulator" is part of ambitools v1.3 and integrated in Antescollider library [6]
- Our approach offers fine control of the grain swarm, temporal sequencing and synchronization with a musician and 3D visualization

[1] Dennis Gabor, "Acoustical quanta and the theory of hearing," *Nature*, vol. 159, pp. 591–594, 1947

[2] Iannis Xenakis, "Formalized music. bloomington, indi-ana," 1971

[3] Scott Wilson, "Spatial swarm granulation," in *ICMC*, 2008

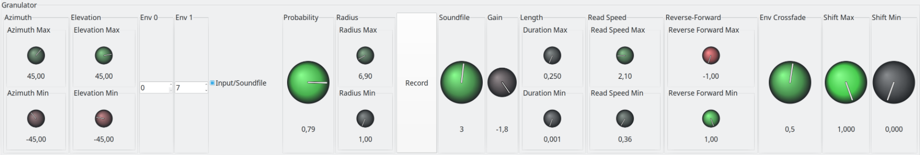
[4] Nicholas Mariette, "Ambigrainer-a higher order ambisonic granulator in pd," in *Ambisonics symposium*, 2009

[5] Pierre Lecomte, "Ambitools: Tools for Sound Field Synthesis with Higher Order Ambisonics - V1.0," in *International Faust Conference*, Mainz, 2018, pp. 1–9

[6] José Miguel Fernandez, Jean-Louis Giavitto, and Pierre Donat-Bouillud, "Antescollider: Control and signal processing in the same score," in *ICMC 2019-International Computer Music Conference*, 2019

The Granulator

- N parallel stream of sound grains ($N \in \mathbb{N}$ set at compile time)
- Each grain is indivually spatialized on a spherical shell sector in the HOA format



Granulator

Azimuth
Azimuth Max 45,00
Azimuth Min -45,00

Elevation
Elevation Max 45,00
Elevation Min -45,00

Env 0: 0

Env 1: 7

■ Input/Soundfile

Probability 0,79

Radius
Radius Max 6,90
Radius Min 1,00

Soundfile 3

Gain -1,8

Length
Duration Max 0,250
Duration Min 0,001

Read Speed
Read Speed Max 2,10
Read Speed Min 0,36

Reverse-Forward
Reverse Forward Max -1,00
Reverse Forward Min 1,00

Env Crossfade 0,5

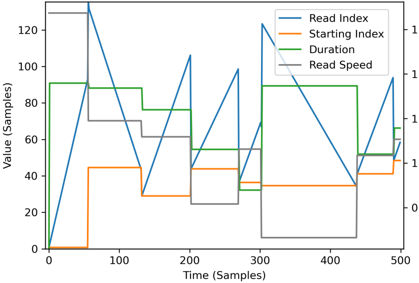
Shift Max 1,000

Shift Min 0,000

GUI of the Granulator compiled with `faust2jack` script.

Grain Stream Generation

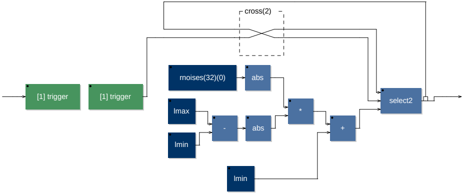
- A stream of grain is a signal made of concatenated grains (no silence)
- The grains are read from a buffer (choice at runtime) either from:
  1. Soundfile
  2. Input signal
- A read index signal is constructed according to grain parameters:
  1. Duration,
  2. Reading speed,
  3. Starting index,
  4. Reading direction.



The read index signal for a stream of grains (in blue): the slope is proportional to the read speed. Its sign gives the read direction. Once the read index minus the starting sample equals the duration, a new set of parameters is randomly chosen within the parameter ranges.

Trig function

- For each grain of each stream the parameters are set randomly using `no.rnoises`[a]
- The noises signals are scaled and shifted according to UI controllers and fed into a sample and hold function triggered by an impulse signal.
- The set of grain parameters are hold until the next non-zero `trigger` signal.
- The `trigger` impulse signal is non-zero only when the read index value minus the starting index equals the grain duration (always computed for the forward reading direction).

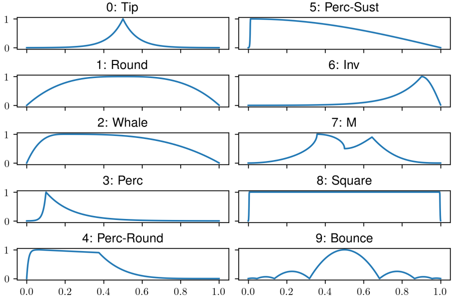


Block diagram of the `trig` function, i.e., a sample and hold function triggered by a impulse signal. Here the 0-th noise among 32 noises signals (`rnoises(32)(0)`) is scaled and shifted to give a random signal between `lmin` and `lmax`. A value of this signal is hold until an impulse is received (`trigger`).

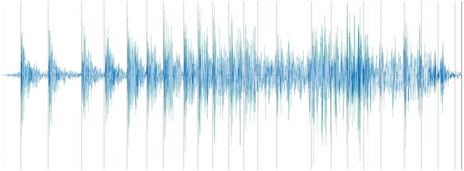
[a] We don't use `no.noises` as we need decorrelated noises with new seeds at each initialization.

Extra Control Parameters

- **Grain Envelopes** provides controls over dynamics and prevent audible clicks at each grain change. A crossfade between two enveloppes is used
- **Grain Probability** controls the density of grains during playbacks,
- **Markers** as sample index can be used to set time instants of interest in the soundfiles.



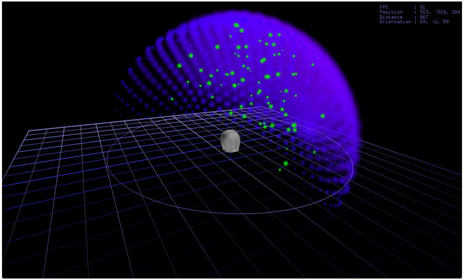
The various envelopes used on a grain stream. A crossfade allows interpolation between two envelopes among this bank at runtime.



Markers in red are used to supervise the starting index choice for each grain in the sound sample.

Grains Spatialization

- For each grain, the spherical coordinates are randomly chosen within intervals set with the UI.
- The resulting grains position (r, θ, ϕ) is encoded as a point source in HOA format with ambitools' `encoder.dsp`
- The HOA order $L \in \mathbb{N}$ is set a compilation time.
- Optionnaly, the coordinates and amplitudes signals are sent to `bargraphs` for transmission using OSC within SuperCollider.

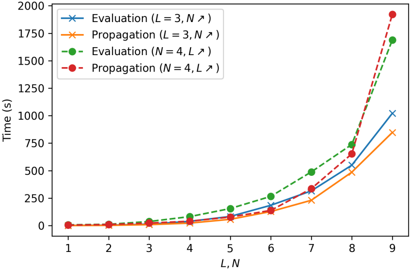


```
FPS         : 51
Position    : 513, -318, 284
Distance    : 667
Orientation : 69, -2, 59
```

The 3D visualization of the grain swarm. Here $N = 30$ grain streams are used. The grains are represented in green, their size is proportional to they amplitude. The acoustic energy of the resulting HOA scene is shown in purple. A dummy head facing the front direction is placed at origin and represented in grey.

Faust Compilation

- 8 decorellated random noise signal for each of the N streams of grains[a]
- $(L+1)^2$ HOA signals
- 10×2 signals for the grains enveloppes
- To switch at runtime between live buffer or audio signal, both are computed,
- Finally $28 \times N + (L+1)^2$ signals at audio rate at runtime
- As L and N increases, the FAUST compiler takes an rapidly increasing time to evaluate and propagate the code.
- We suggest to keep N low and run multiple instances of the Granulator[b]



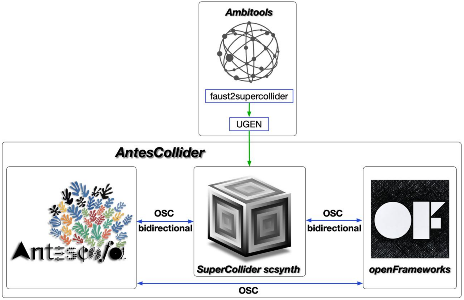
The time spent by the FAUST on the evaluation and propagation steps for: A constant HOA order $L = 3$ and increasing number of grain streams N; A constant grain streams number $N = 4$ and increasing HOA order. The values are obtained using `faust -time -t 0 granulator.dsp` on a conventional laptop.

[a] duration, reading speed, starting index, reading direction, probability, radius, azimuth, elevation

[b] `no.rnoises` is essential here to ensure different seeds between instances

Antescollider

- Antescollider [7] is a library for composition of electronic music using Antescofo [8] and Supercollider [9]
- It allows to dynamically create real-time audio processing chains with fine controls over the parameters
- The Granulator is integrated in Antescollider as a Unit Generator (UGEN) using `faust2supercollider` script.



Interaction between Ambitools and Antescollider.

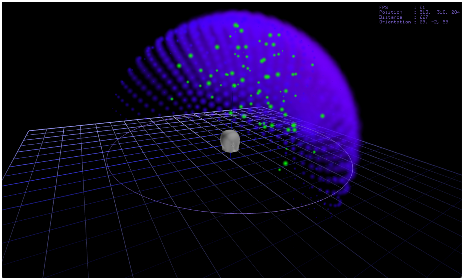
[7] José Miguel Fernandez, Jean-Louis Giavitto, and Pierre Donat-Bouillud, "Antescollider: Control and signal processing in the same score," in *ICMC 2019-International Computer Music Conference*, 2019

[8] Arshia Cont, "Antescofo: Anticipatory synchronization and control of interactive parameters in computer music.," in *International Computer Music Conference (ICMC)*, 2008, pp. 33–40

[9] James McCartney, "Rethinking the computer music language: Super collider," *Computer Music Journal*, vol. 26, no. 4, pp. 61–68, 2002

3D Visualization

- A visualizer is developped in OpenFrameworks library
- And OSC connection is used with SuperCollider
- OSC messages of grains position and amplitude are used to visualize the swarm
- A 3D Ambisonic energy visualizer using the `sampling_decoder.dsp`[a] allows to display energy on a spherical surface (974-nodes Lebedev grid)



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[a] `https://sekisushai.net/ambitools/docs/sampling_decoder.html`

Conclusions

- Spatial granular synthesis tool "The Granulator",
- Results of research and creation at GRAME during spring 2024,
- Real-time use within Antescollider
- FAUST compilation is still a issue for high L and N as well as computational load (`on-demand` primitive?)
- The Granulator will be extensively used for the creation of a new piece for trumpet and live electronics, "Gnomon", commissioned by GRAME and to be premiered in June 2025in Lyon, France (at JIM-LAC Conference).

Demo

Thank you for your attention!

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It's time for a demo!