Sculpting the Sound Atom: Towards Per-Grain Parameterisation in Granular Synthesiser Design

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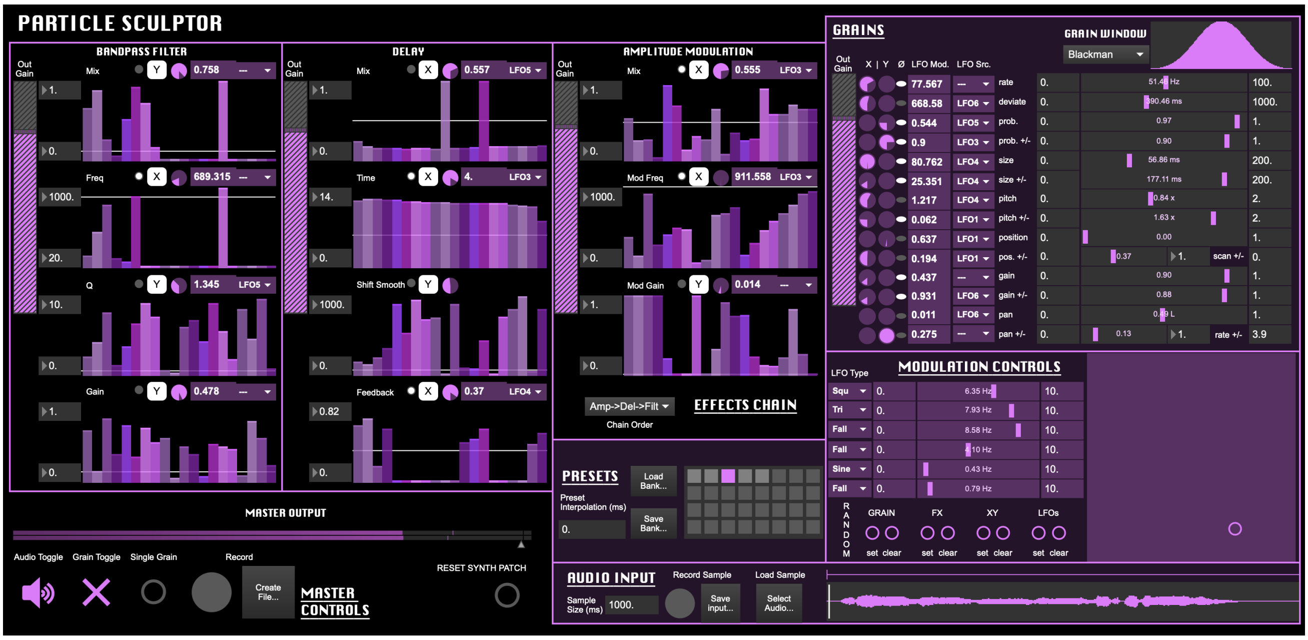

Figure 1: Particle Sculptor.

Abstract

This paper presents a number of custom-designed granular synthesisers built around interfacing with sound grains on an 'atomic' level. Developed in Max/MSP by the first author (Nathan Carter), these synthesisers explore per-grain voice parameterisation that uniquely interfaces with individual grain signal processing properties in larger granular sequences. The paper outlines how these synthesisers provided the sound materials to compose Carter's original soundscape work 'Matter and Void' – conceptually inspired by ancient Epicurean physics and painterly expositions on atomism in Lucretius' poem 'The Nature of Things' (c. 55 BC).

Keywords

Granular Synthesiser Design, Per-Grain Parameterisation, Atomism, Max/MSP, Practice-Based Research

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1 Introduction

Granular synthesis – an audio signal processing technique that fragments sound as streams of particles – has a fascinating theoretical origin. Dennis Gabor, researching acoustics and communication in the 1940s, formulated a matrix-based system of sound analysis – 'acoustical quanta' – that splits signals into grids of discrete time-frequency particles [9–11]. Iannis Xenakis translated Gabor's work into music, pioneering the 'sound grain' concept through tape-splicing sine waves for composition [27]. Building on Xenakis' process, Curtis Roads [18] and Barry Truax [26] solidified granular synthesis as a contemporary digital technology with their groundbreaking computer-based implementations. Many researchers, technologists, and sound artists have since expanded on this practice, and the techniques and tools that were once niche are now widely adopted within electronic music production circles.

Building on this rich history, this paper presents a collection of new granular synthesisers designed by the first author, Nathan Carter, in his master's research thesis project (supervised by co-authors Jim Murphy and Mo Zareei) exploring Epicurean-inspired granular synthesis and soundscape composition.[1] Custom-built in Max/MSP as stand-alone tools, Carter's implementations adopt an 'atomic' approach to granular synthesis. By 'atomic',

[1] Further information about the project – including synthesiser access – can be found here: https://www.alternatural.nz/conference-media

we mean a treatment of fragmented sound that emphasises individualised particles – as opposed to collective 'masses' of particles – as the basis of aesthetic and technical manipulation. This approach draws on various signal processing and visual interpretations of sound grains within the contemporary field of granular synthesisers and conceptual notions from the broader domain of microsound. This work is also inspired by the philosophical atomism sublimely expressed in the ancient Epicurean poem, 'The Nature of Things' (c. 55 BC), by Lucretius [16]. Through Lucretius' poetic musings on Epicurean atomic principles, Carter's work establishes colourful interpretations between sound grains and Epicurean atoms – indivisible, varied particles of matter (imagined as grains) moving, colliding, and combining through void (imagined as time, frequency, and dynamic spaces) to generate everything in the universe (grains forming complete soundscapes). These metaphors integrate with the atomic synthesiser designs, enabling Lucretius' poetic atomism to be portrayed through per-grain controlled textures and gestures for granular composition.

The next section provides a brief survey of related works, focusing in on several synthesisers with digital signal processing (DSP) and interface designs that work towards sound particle separation. A conceptual outline of microsound practice will follow, elucidating the 'atomic' interpretations underpinning the first author's project. Then, the synthesiser implementations and an overview of their various technical features will be presented, highlighting the novel conceptual use of per-grain UI controls. Finally, we conclude with a discussion on the utilisation of these synthesisers in composition, noting the thematic integration of Lucretius' poetry.

2 Related Works

From the early experimental era and digital developments of Roads and Truax, granular synthesisers have since become widely popularised and available, even being built-in in certain DAWs – such as Logic Pro's 'Alchemy' [4], Ableton Live's 'Granulator III' [12] and 'Grain Delay' [2], and FL Studio's 'Granulizer' [14] – or DAW-supported as third-party granular plugins. Additionally, there are various stand-alone software and hardware implementations, and published research from institutions such as NIME [3, 6, 7, 17, 22, 24, 28] has played an important role in innovating new granular technologies.

Granular synthesisers are categorised in a couple of technical ways. Many modern granular synthesisers process grains from audio samples – so-called 'granulation' of audio files – that can radically reconstruct the original audio shape into endless new sound forms. On the other hand, some other synthesisers use synthesised waveforms for grain generation (classical granular synthesis, as in Roads' and Truax's implementations). Some granular synthesisers, as Roads et al. [20] notes, also extend grain processing through common effects chains, homogeneously applying effects to a whole grain stream. However, there are a handful of sample-granulating synthesisers that emphasise a heterogenous separation of sound grain processing.

'EmissionControl2' [20] is one such exemplary granular implementation. It features a comprehensive granulation system capable of generating up to 2,048 simultaneous grains. Each of the 15 range-adjustable grain parameters affect the collective properties of the generated grain stream. The engine then automatically assigns discrete values for envelope, waveform, amplitude, frequency, spatial position, filter frequency and resonance. Per-grain separation can be initiated with parameter modulation through six additional LFOs. This heterogenous grain processing was aesthetically motivated, enabling textures that were 'more articulated in space and animated in time, in comparison to granulators that rely on a common effects chains' [20]. Two other granular synthesisers that stand out for their per-grain heterogenous processing are 'Clouds' [8] and 'Soundgrain' [23]. The former uses a two-dimensional 'predominance' parameter that probabilistically chooses each grain waveform between four input audio sources, and the latter hosts a modulation sketch window, where 16 grain 'trajectory' textures can be mouse-drawn through the XY modulation space to generate multiple evolving streams of per-grain DSP.

This heterogeneous method is not limited to granular synthesis though. For example, 'SPEAR' [15], a quintessential spectral re-synthesis tool, provides discrete time-frequency sketching and editing of every partial in an analysed waveform. Drawing our attention yet further outwards to the conceptual domain of microsound, we can find aesthetic and technical interpretations of the 'atomic' that reflect the per-particle processing in all of these tools. Let us now examine microsound and, in doing so, introduce the conceptual foundations of the first author's synthesisers.

3 Microsound and the 'Atomic'

Curtis Roads devised microsound theory to detail the aesthetic and technical characteristics of granular synthesis and related sound particle techniques [19]. These techniques span time-domain and windowed time-frequency (spectral) representations. Described within a framework of multiple timescales, they exist on the micro-time scale 'beneath the level of the note' [19].

Some researchers have elaborated on microsound as an 'atomic' concept or identified shared 'atomic' perceptions of sound in the microsonic realm. Phil Thomson notes historical microsound technologies and artworks arising from a 'Western modernist impulse towards the atomisation of musical material and control of that material on ever-lower levels' [25]. In a recent survey [5] gathering 87 contemporary sound artist's responses to different aspects of sine wave music aesthetics, a significant number of respondents noted the sine wave for its 'atomicity' – perceived as the core element and building block of all sounds. Sonya Hofer's analysis of microsound, however, explores the 'atomic' notion most concretely [13]. Building on Roads' theory, Hofer argues for a broader description of 'microsound' practices that encompasses emergent 21st-century experimental electronica and sound art practices, including noise, glitch/'clicks and pops' aesthetics, minimalism, ambient/drone, and multi-media/sound installation art. From this perspective, a defining factor of microsound is its materialisation of 'atomic' sound. Hofer deliberates on Roads' implicit connections of the microsonic with the 'invisible' and 'unseen' world of the microscopic:

> This comparison of the microscopic to the microsonic – where sound is conceived of and represented visually and physically on a granular or 'atomic' particle level – has both theoretical grounding and ramifications. This materialisation of sound as matter not only continues to dismantle systems of pitch and harmony, but also dismantles sound itself as it is reduced to particles to be manipulated and sculpted on this perceived fundamental level. [13]

4 Designing 'Atomic' Granular Synthesisers

Microsound's atomism is core to the first author's technologies and supports his aesthetic goal of sonically imagining Epicurean atomism. The 'atomic' approach to granular synthesis describes a technical desire to create per-grain parameterisation – that is, a deconstruction of granular 'mass' parameters that are reassembled as parametric atoms of individual grain control. This takes on Hofer's characterisation of microsound as atomically 'dismantled'; sound is reduced to microscopic particles that can be metaphorically 'sculpted' like individual units of physical matter. This atomic approach necessitated new synthesiser designs that combined a per-grain DSP (as seen in EmissionControl2, Clouds, and Soundgrain) *explicitly* with per-grain UI control to let the composer manually adjust individual grain values (similar to SPEAR's spectral interfacing, but reworked into a granular synthesis context). On an artistic level, this atomic dismantling of granular parameters translates to poetic depictions of varied Epicurean atoms seamlessly, letting the composer stipulate time-varying granular sequences grain-by-grain.

The first author's collection of granular synthesisers arose out of an iterative design process and composition experimentation. At the core of each synthesiser is a 20-channel audio-sampling granulation engine, where each channel represents an individual grain voice. Using a fixed channel count streamlined the initial interface development, allowing the per-grain parameterised UI objects to remain static. This iterative design process revealed 20 grain voices to be aesthetically and technically well balanced. It fulfilled the aesthetic desire for high-information granular textures while maintaining visual readability, making it easy to interface with parameters that displayed individual grain voices.

The grain engine in every implementation – except the final 'Particle Sculptor' (which will be explained below in the Synthesiser Implementations section) – has two key particle-based signal objects from Max's MC library: 'mc.snowphasor~' and 'mc.snowfall~'. '[The] snowfall~ object controls a multidimensional particle as one or more audio ramps whose lifetime is triggered and controlled by an input phasor ramp from 0 to 1. The object will typically be used within a larger system of quasi-independent particles using the MC Wrapper as mc.snowfall~' [1]. The input phasor ramps are generated in a synchronous stream by mc.snowphasor~, cascading through the 20 channels to play each grain. This implementation (figure 1) offers expressive functions for particle motion, including multiple rate/interval controls, trigger probability, per-particle phasor ramp speed (grain size), and the vector properties of each mc.snowfall~ particle (e.g., 'direction', corresponding to pitch and waveform playback direction; 'wander probability', adding fluctuations to the pitch motion).

5 Synthesiser Implementations

Four initial prototypes established the project's atomic design motifs, forming the basis for the refined synthesiser implementations. Namely, multiple 'multislider' UI objects (figure 3) were used as the primary interfacing technique for atomic parameterisation. Set as arrays of 20 slider voices, these multisliders were used to control a per-grain delay line in 'Particle Delay', per-grain pitch control in 'Particle Aposynthesis', and per-grain resonant bandpass filtering in 'Particle Scanner'. The fourth prototype, 'Particle Compositor', explored a four-input audio buffer probability control with an XY slider ('pictslider'), based on the predominance parameter from the Clouds synthesiser.

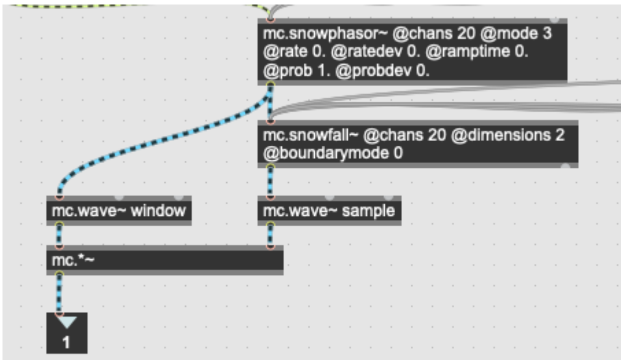

Figure 2: Grain engine driven by mc.snowphasor~ and mc.snowfall~.

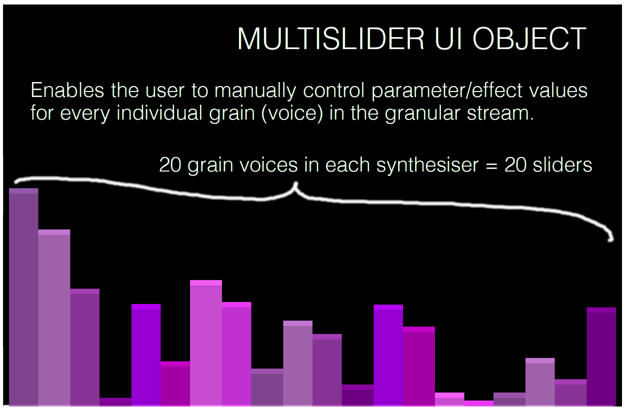

Figure 3: Multislider UI object – per-grain interface control.

Figure 4: Particle Grid and its atomic filtering controls.

'Particle Grid' (figure 4), the first refined synthesiser design, builds on these prototypes with a more powerful macro-controlled grain engine. The XY slider from Particle Compositor is repurposed as a routable matrix-modulation control for all the grain engine parameters, and the range-adjustable global grain sliders take inspiration from EmissionControl2's UI. Most importantly, this synthesiser advances parametric atomism through the reuse of Particle Scanner's multislider filtering (figure 4). Finally, a dynamic preset system (also inspired by EmissionControl2) enables banks of parameter presets to be saved, loaded, and interpolated between with time-specified ramps. This preset interpolation can usefully act on every grain voice in the multislider filtering, sometimes creating dramatic multidirectional filter trajectories in the grain stream.

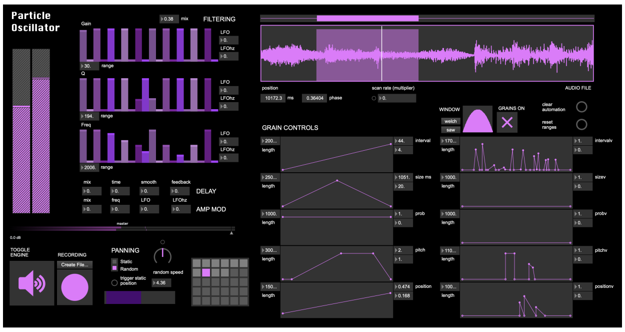

Figure 5: Particle Oscillator.

'Particle Oscillator' (figure 5) uses a near identical DSP structure to Particle Grid but applies an atomised gesture approach to the core grain parameter interfacing by using time-adjustable looping breakpoint 'function' objects in place of conventional sliders (i.e., looping envelopes with customisable shapes).

The final synthesiser implementation is 'Particle Sculptor' (figure 1). This synthesiser culminates many of the signal processing and interfacing features of the previous designs, containing the most fully realised integration of atomic parameterisation. It also hosts the most versatile array of modulation controls, with the interpolating preset system from Particle Grid, as well as six LFOs and XY macro controls routable to all the grain engine and per-grain effect parameters. The LFO and XY modulation signals apply equally across each grain voice, allowing for holistic texture movements that simultaneously maintain the relative per-grain variations in each multislider parameter.

As noted previously, it contains a different grain engine, based on Ed Roberts' synchronous, per-grain 'mc.gen~' implementation [21]. This was motivated by a desire to animate every parameter at audio rate with LFO signal modulation; some parameters from the previous grain engine design can only be controlled with slower scheduled Max messages (less responsive than audio signals). EmissionControl2 is again a key inspiration for the interface (informing the global grain parameters and six routable LFOs). Finally, the synthesiser features a large multislider grid of atomic signal processing (figure 6), controlling multiple parameters for amplitude modulation, a delay line, and bandpass filtering. These effects can be reordered in the signal chain to offer further per-grain sculpting variation. This atomic effect stacking crucially sets Particle Sculptor apart from other existing granular synthesisers in parametric control. It gives the user unparalleled access to the dismantled grain stream, allowing each grain to be manually sculpted with their own effect mix combinations – enabling extremely stratified texture sequences at an atomic level.

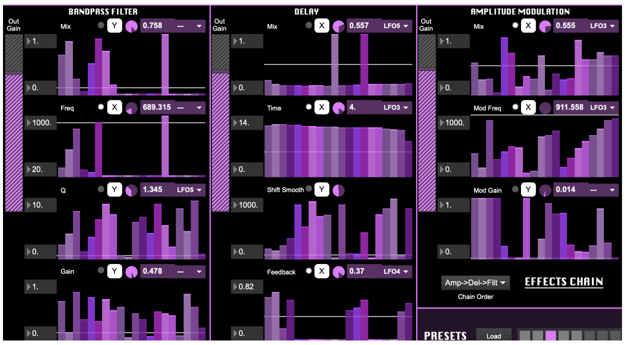

Figure 6: Atomic multislider grid – per-grain effects chain in Particle Sculptor.

6 Discussion and Conclusion

The per-grain parameterisation in these synthesisers reflects a strong compositional desire to atomically assemble environmental sound worlds, as in the case of the first author's soundscape composition, 'Matter and Void'. Elaborate expressions of environmental phenomena from 'The Nature of Things' form the thematic basis and compositional structure. The musical theme is an atomic sine-grain motif, depicting a union of elemental Epicurean atoms. To reiterate, atoms in Epicurean philosophy are indivisible units of matter, countless in number, and constantly in motion through infinite void – eternally interacting as the generative agents of the universe [16]. This constructive notion is illustrated in the composition's 'ascent' from atoms to environments, inspired by a Lucretian passage on visible, emergent motions caused by atoms (Book II, lines 115-141). Following a brief opening gesture, the piece scales through a chaotic section of primordial sine atoms, followed by organic passages and complex granular textures depicting cellular life and substances, before climaxing on granular environmental scenery supplemented with acoustic and instrumental recordings (symbolising the macro scale). The composition's granular materials were composed using the first four synthesiser prototypes, prior to the development of the refined implementations. The combined per-grain parameterisations of the prototypes were aesthetically convincing in producing atomised sound objects and spaces.

Stratifying the grain stream controls down to parametric atoms encourages textural complexity in the composition process. Defining signal processes such as delay, amplitude modulation, and filtering in every grain's mix enables crafted juxtapositions and alignments of timbre, pitch, rhythm, and textural density between grains. The delay is particularly notable for its variations; the atomised time and feedback values can create resonant tonal sequences at micro-time levels, while on the other extreme may accumulate looping textures or massive diffusions of individual grain signals, approaching reverberant atmospheres in some of the first author's experimentation. Future explorations of other grain and effect parameters at this atomic level may prove fruitful in offering even more creative sound design options. In essence, these synthesisers allow homogenous atomic streams to precisely reconfigure into various dynamic molecular unions or scatterings, richly layered substances, flowing liquid forms, and deeply layered atmospheres. Whether aiming to portray abstracted or natural subjects, the user becomes an active agent – a granular architect – in the shaping of individual sound atoms, treading between absolute chaos and harmonious order.

7 Ethical Standards

This work has no identified conflicts of interest. The master's research project by the first author (Nathan Carter) – from which this paper and the new technologies presented were realised – has been undertaken with supervision and support from the co-authors (Jim Murphy and Mo Zareei) at Victoria University of Wellington, New Zealand.

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