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GENERATIVE, EMERGENT, SELF-SIMILAR STRUCTURES: *CONSTRUCTION IN SELF*

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ABSTRACT

This paper describes the procedures and theory behind *Construction in Self*, a generative work based on the Lorenz oscillator, implemented in the programming environment Max/MSP. After a brief survey of relevant works, the following are described: properties of the Lorenz system and the exploratory, self-similar and “open” form it suggests; calculations and parameter mappings; modified nonstandard synthesis methods and the construction of a deterministic yet emergent structure aided by limited self-evaluation. In conclusion, its potential for creativity and future work are discussed.

1. INTRODUCTION

The possibility of “the composition and decomposition of timbres” materialised with the advent of electronic music: “one can either compose each sound directly in terms of its wave succession, or ... each individual sound wave ... by an ordering of the succession of pulses” (Stockhausen [13]). Later, Xenakis proposed that “sound molecules produced by ... methods [based on probability distributions] could be injected into the ST[ochastic] program ... forming the macrostructure” [14], in an attempt to compose both the pulses and waves and compose *with* the pulses and waves utilising the same process, thereby integrating material and structure. In recent times, this has been realised in works using iterated functions (Di Scipio [6]), Chua’s Circuit (Mayer-Kress *et al* [11]), stochastics (Bokesoy [2]), Lindenmayer systems (Manouskis [10]) and waveform segmentation (Chandra [4]).

In *Construction in Self*, additionally to all compositional procedures being unified by parameter mappings from the same system, the outward form of presentation of the work is also suggested by its properties.

2. FORM

The Lorenz oscillator is a three-dimensional dynamical system, derived from a model of atmospheric convection [9].

It is sensitive to initial conditions, and seemingly insignificant deviations produce widely and unpredictably differing results. This gives rise to what is popularly known as the “butterfly effect”, where a butterfly beating its wings may produce a hurricane, and also because of the attractor’s lemniscate-shape. In theory, an infinite number of possibilities exist, suggesting an expansion on Umberto Eco’s notion of a “work-in-movement”, “characteristically consist[ing] of unplanned or physically incomplete structural units”, a more restricted classification of the category of “open” works that are open to multiple interpretations [7]. *Construction in Self* takes an input prior to performance as initial conditions from which a different piece is generated each time.

Complexity ensues from its unpredictability leading to emergent behaviour. Yet it is deterministic, and in theory, the same initial conditions will always produce identical results: a possible parallel to the totality of the Einsteinian universe and its “logical simplicity of the order which we can grasp humbly and imperfectly” [8] attributed to Spinoza’s God. A diverse variety of behaviours are observable, ranging from periodicity to chaos, that yield interesting results as signal, control and meta data, suggesting a self-similar microcosm that can be replicated from the same initial input, yet is impossible to evaluate prior to calculation.

The interdependency and nonlinearity of variables and starting values that constitute the initial conditions mean that “we are left only with the possibility of a qualitative characterization of the interdependency among parameters, as opposed to a quantitative, analytical characterization” that will foster “an exploratory attitude that in the end may lead a composer or sound designer towards a fresh and renewed perspective on the nature of the sound material” [6]. This empirical exploration of the phase space of initial conditions forms the basis of the work, in the same manner as Morton Feldman or the poet Charles Olson who “engage[d] the entirety of this process [of sketching and drafting] within the very perceptible framework of [their] compositions” [5].

3. STRUCTURES

3.1. Data calculation

The Lorenz oscillator is governed by the following differential equations [9]:

$$dx/dt = \sigma (y - x) \tag{1}$$

$$dy/dt = x(r - z) - y \tag{2}$$

$$dz/dt = xy - bz \tag{3}$$

The variables, σ and b, are fixed at 10 and 8/3 respectively as per convention. r, the Raleigh number, is given twelve different values between 10 to 24, designated as set A, and a further twelve values between 28 to 350 (set B), each producing three orbits, i, ii and iii with different initial conditions explained below. The y-value (range [-1,1]) for the initial condition of orbit i is either entered manually or generated randomly prior to the performance. The x- and z-coordinates are fixed at -1 and 9 respectively. 44100 iterations are calculated using the Euler method with step size 0.001.

The following is observed in set A as r increases: an approach to a fixed point, resembling the slope of the attenuation of percussion sounds (Fig.1); the existence of a second fixed point (Fig.2); less periodic and more noise-like transients before approaching the fixed point (Fig.2); failure to converge on either of the fixed points (Fig.3).

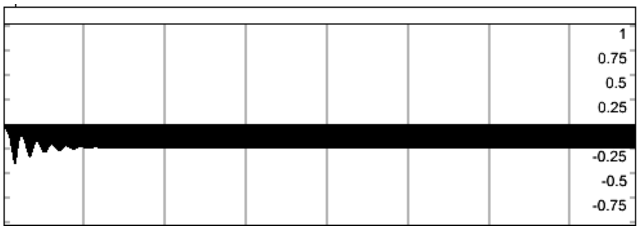

Figure 1. r =10 (i)
y [-1,1] against time (as signal [0,0.002-4secs], control [0,16-128secs], or meta [0,15-20mins] data) for all figs

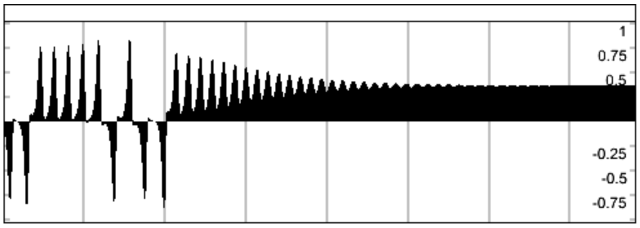

Figure 2. r =19 (i)

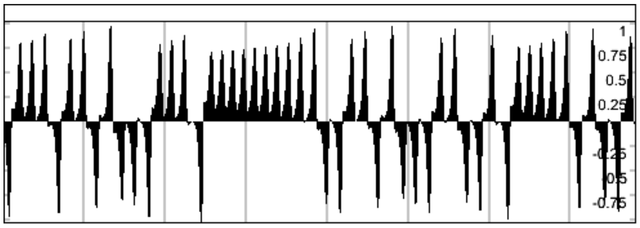

Figure 3. r =23 (i)

In set B, the Raleigh values are above the critical value of 24.74 and the two fixed points become repelling, usually resulting in chaotic orbits, though periodic behaviour can be observed for a few relatively high values of r [9].

The initial condition of orbit ii is a minute distance from that of i (the y-coordinate is moved 0.000001). The difference between i and ii are then calculated (i-ii) and scaled to the range [-1,1].

The following can be observed as r increases (with corresponding audio results when played as signal data): both i and ii approaching the same fixed point very rapidly – a burst of noise with a short decay (Fig.4); almost identical orbits for i and ii, proceeded by a sudden divergence and an extremely rapid approach to an almost coincident orbit – a fast attack (Fig.5); an almost periodic divergence and then a convergence – a slow attack and release (Fig.6); both the above in succession (Fig.8); seemingly unrelated, chaotic orbits – noise (Fig.7).

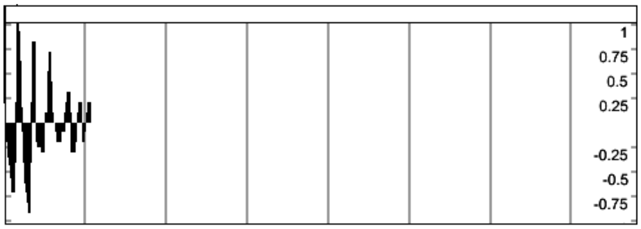

Figure 4. r =10 (i-ii)

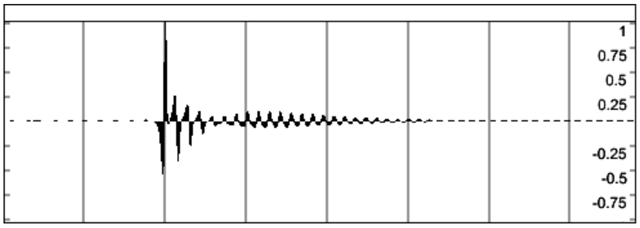

Figure 5. r =19 (i-ii)

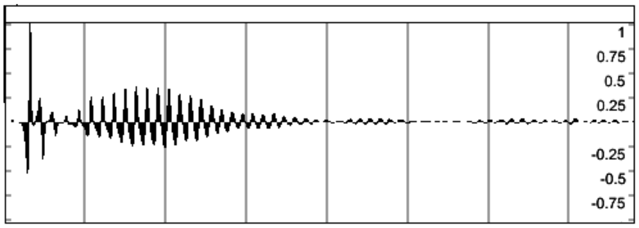

Figure 6. r =19.5 (i-ii)

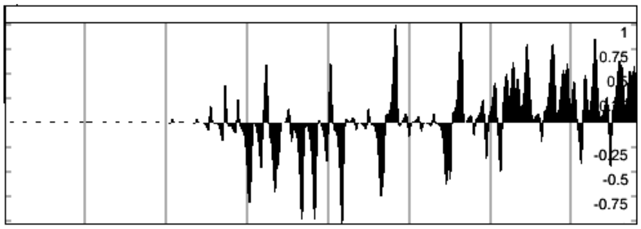

Figure 7. r =21.5 (i-ii)

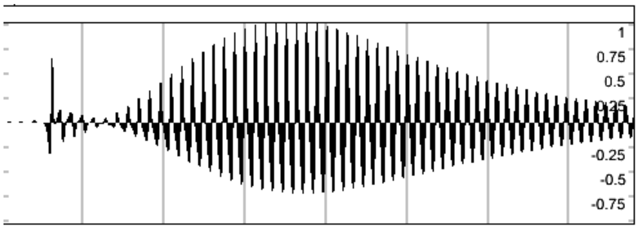

Figure 8. r =22 (i-ii)

The y-coordinate of orbit iii is assigned as the negative y-coordinate of orbit i, i.e. on the opposite side of the x-z-plane. Differences with orbit ii are also calculated (ii-iii).

3.2. Meta, Control and Signal data

The i-ii orbit of one of the Raleigh numbers from set A (similar to Fig.7 or 8) is chosen as the metadata for the structure of the entire work consisting of approximately twelve to eighteen sections. At the stationary points of x, y or z i.e. the peaks and troughs in the individual dimensions, the coordinates are used to determine the Raleigh number from set A and the orbits to be assigned as control data, the "instruments" used (interpretation as signal data, described below), the amount of reverberation and the duration of the sections (each lasting 16, 32, 64 or 128 seconds).

In each section, the relevant orbits of the same Raleigh number are played back at the speed appropriate to the assigned duration. This time, the coordinates are used as control data, either interpolated and used continuously for panning purposes, or at the points where the derivative is zero for "instruments" as was the case when determining the sequence of sections.

As signal data, there are four main types of "instruments" or sound production. In the first, the orbits are simply used as amplitude and played back as samples. They are triggered at the peaks and the troughs of the control orbit and the coordinates are scaled appropriately and mapped to r (the orbit to be played as audio, chosen from set A), playback duration (ranging from 2 ms to 4 seconds) and amplitude. The results vary from tuned percussion-like sounds (similar to those of Chua's Circuit [11]) to windowed noise.

The second uses wavetable synthesis of orbits from set B, the mapped parameters also being r, frequency and amplitude. The sounds produced vary from those reminiscent of frequency modulation to noise.

The third uses frequency modulation by a Lorenz orbit-wavetable of a sine tone, or what might be described as chaotic frequency modulation, a modification of Mayer-Kress' terminology [11]. Two control orbits are used, one for carrier frequency, modulation frequency and modulation amplitude corresponding to those of conventional FM [12], the other for fade in and fade out durations. The result varies from slow phasing to rich frequency modulated sine tone-like synths.

The final synthesis method uses Lorenz orbit-waveshaping with frequency modulation by a Lorenz orbit-wavetable (i.e. of itself), a modified combination of the above two "instruments". The parameters controlled are carrier frequency, harmonicity ratio and modulation index [12]. The result varies from frequency modulated sawtooth wave-like synths to noise.

Apart from compression and low-cut filters for the purposes of mastering, no other filtering or equalisation is included. All sounds apart from the sine tone are also derived from the Lorenz orbit and therefore inherent to the system as are most of the envelopes due to the dissipative nature of the orbit. [1]

3.3. Self Evaluation

A number of tasks are carried out in the calculation stages that involve some self evaluation. The i-ii orbits are analysed and categorised (corresponding to the five examples in Fig.4-8) in order to "quantify" their characteristics. This facilitates mapping to metadata parameters i.e. the category of the orbit and its position within it to determine the Raleigh number for each section.

The rapidity of approach to a fixed point is also analysed to determine the number of iterations to be used for a section. These algorithms were found to be necessary to reduce the possibility of over-repetition, either in meta data (a sequence of similar sections), control data (an unvarying rhythm) or signal data (a prolonged note or an unchanging timbre). Repetition is still possible, however, either within the limits set, or due to the low-level nature of the detection mechanism.

4. CONCLUSIONS

Construction in Self has been performed in various stages of development since 2009 in London. Its sound world of glitches and noise embraces and furthers what Kim Cascone describes as "the aesthetic of failure" of (post-) digital technology [3] through nonstandard synthesis. It ranges from complex to primal passages reminiscent of

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[1] However, as r becomes supercritical, "artificial" windowing is necessary in order to avoid unwanted clicks at the end of buffers.

John Cage's *Construction in Metal* to which the title alludes, often producing surprising and interesting results.

One possible development would be a less rigid distinction according to duration between signal, control and meta data analogous to "a continuous overlapping between the time sphere of "frequencies" ("sounds" and their "colors") and the sphere of "rhythms" (individually audible pulses within given time intervals)" that Stockhausen demonstrates in a passage from *Kontakte* [13]. Similar examples are present in *Construction in Self* e.g. in the first "instrument", fast successions of individual percussion-like sounds blur into a continuous sound of wavetable synthesis, which is the mechanism of the second "instrument", and vice versa: low frequency-related parameter values in the second, third and fourth "instruments" cause audible pulsating rhythms. But their occurrences are limited to extremes of parameter ranges and no further progression is possible i.e. a synthesized tone whose frequency decreases beyond the sub-audio range and becomes audible as rhythm cannot then slow down to an even greater extent to be revealed as a section of music. Perhaps not categorising the mappings as well-defined divisions of signal, control and meta data may help in obscuring these perceptual boundaries.

Margaret Boden describes the involvement of METCS – the mapping, exploration and transformation of conceptual spaces – in creativity. "Conceptual spaces are structured styles of thought... They include ways of writing prose or poetry; styles of sculpture, painting or music; theories in chemistry or biology; fashions in couture or choreography, *nouvelle cuisine* and good old meat and two veg – in short, any disciplined way of thinking that is familiar to (and valued by) a certain social group" [1]. In *Construction in Self*, the mapping of conceptual spaces i.e. the possibilities of the work, is primarily completed at the programming stage, though statistical data of the orbits generated for each performance is used for the purposes of scaling parameters in order to define the space: these could be described as "tweaks", a small change that is insufficient to be a transformation [1]. The piece takes the form of an exploration as mentioned above, and although evaluative tasks are in place that could also be classed as "tweaks" to ensure an approximate rendering that is statistically most likely, the algorithms do allow for anomalies, rewarding multiple listenings even for the composer owing to the impossibility of predicting all possible outcomes.

Musically, it has successfully managed to mirror the "deterministic emergence" of the Lorenz oscillator through its generative, exploratory form, in addition to the complex, yet partially transparent, self-similar structure perceived.

5. FUTURE WORK

With the exception of these "tweaks", however, the transformation of conceptual spaces is absent in *Construction in Self* i.e. no procedures are in place for the work to dynamically re-program itself in a radically different manner. Within the confines of an electroacoustic work, perhaps this is only possible beyond the form of a generative, concert piece. That is not to suggest that this is necessarily essential; one could argue that the transformation occurs at the compositional stage, and combine with the calculation process and performance to holistically produce creative phenomena. But this is certainly an area for further investigation, and could yield possibilities in overlapping the boundaries of the time-spheres.

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