Keynote

Dr Kevin Suffern

Kevin Suffern is a Senior Lecturer in the Faculty of Information Technology who has taught programming, computer languages, and computer graphics. He also developed electives on ray tracing and 3D computer animation that gave a cohort of talented young Australians the opportunity to be part of the emerging animation industry in the early *1990s.*

His former students are currently working in major visual effects companies world wide, and five have credits on films that won the Academy Award for Best Visual Effects. In *1998* he developed a computer graphics sub-major. With ray tracing the overriding passion of his life, Dr Suffern's aim is to teach the best ray tracing course anywhere. He is able to transfer this passion to his students, who are described as "buzzing with enthusiasm" for Dr Suffern's classes. He is regarded as an inspired and inspiring teacher, who encourages students to push the limits of their capability and to explore outside the normal boundaries of the subject.
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"My research interests are in computer graphics, in particular ray tracing and implicit surface visualisation. I have written a ray tracer to help my computer graphics teaching and research. Recent research work includes a new algorithm for ray tracing parametric surface patches that is simple enough to teach to undergraduate students. I also use ray tracing to create computer art."

Integrating computational generative processes in acoustic music composition

Kirsty Beilharz

This paper concerns applications of computer-aided aleatory and generative structures in contemporary acoustic music: integrating computer-assisted generative processes in analogue music composition practice. Generative structures are discussed in music composed by Boulez and Xenakis. The transition of these manual generative processes into specialist composition software is illustrated through constructions in OpenMusic (software) (IRCAM 2005). Finally, this paper looks at considerations for practical performance and idiomatic instrumental composition when integrating computer-generated material in acoustic practice.

This paper explores applications of computer-aided aleatory and generative structures in contemporary acoustic music: integrating computer-assisted generative processes in analogue music composition practice.

1. Introduction

With the emergence of computer-aided algorithmic and other generative processes, tools exist for the development of often increasingly complex outcomes. As a result, for composers of the 60s and 70s, like Pierre Boulez, Karlheinz Stockhausen, Iannis Xenakis, and subsequently Tristan Murail, Jonathan Harvey, Georges Aperghis, for example, a logical trend is to also use the computer for performance or recording of the music as its rhythmic, textural, timbral and microtonal complexity exceeds the capabilities of human performance on traditional physical instruments. This is obviously a successful path and there are other inherent features of computer music that set it apart from human performance, such as the creation of synthetic tone colours, inharmonic spectral overtone series, physical modelling of non-existent instruments, densities and difficulties beyond human execution. There still is, however, a continuing domain for contemporary music performance by people. Some characteristics of chamber and orchestral performance include the visual and gestural qualities brought to delivery, craftsmanship of the composer's orchestration, interpretative variation, emotional expressiveness and the perception of reality affected by physical acoustics of instruments and rooms in performance and recording. (This paper will not enter into the aesthetic arguments for and against both acoustic music and computer music).

In response, this paper looks at the challenge of integrating computer-aided composition, using the computer to assist the generative process and some necessary adaptations to utilise this material in analogue composition for acoustic instruments with all their physical and human limitations (qualities).

The structure of this paper follows the transition by historically renowned composers from manual stochastic and algorithmic generative procedures to computational practice of these processes. Examples show ways in which many of these generative techniques have become integral to current software tools for computer-aided composition. Repetitive algorithmic generation and creating "random" material within composer-determined confines are tasks well served by computational tools. Finally, an acoustic composition by the author, *Fluid Sinews* (2005), integrating elements of computer-aided composition with conventional compositional procedures for acoustic instruments and human performance is used as the vehicle for discussion of adaptations and considerations (such as registration, fingering, phrasing, articulation, rhythm, *timbre*, dynamic, repetition and microtonality) when computer-generated material is applied in practice.

2. Computer-aided composition

Generative music, in the broadest sense, includes any sort of procedural, rule-based system for generating and producing solutions, variations, procreating material. There are conventional methods employed historically for doing this such as serial and stochastic techniques and there are techniques borrowed from other disciplines and applied widely to music and other arts, such as Genetic Algorithms, Cellular Automata, Lindenmayer Systems (L-systems) and other classes of algorithmic structure. These systems are used to generate the product itself or a body of material options that are utilised selectively by the composer with varying degrees of modification.

Aleatoric, i.e. random or chance procedures, come interestingly both from the highly structural influences of stochastic composition by Xenakis (Le Corbusier in Serial architecture) at one end of the spectrum and from Deconstructivist composers aiming to disintegrate conventional structural boundaries such as John Cage and Cornelius Cardew (Jackson Pollack in painting, Marcel Duchamp, Robert Filliou, the Fluxus movement and Happenings) at the other end of the spectrum.

Digital music production is perhaps less confined by difficulty, microtonality and complexity than instrumental music because practical constraints of human-performed acoustic music and analogue

composition require special attention in order to assimilate computer-generated material that is idiomatic. This paper looks at the practice of several renowned composers and the ways in which generative and subsequently computer-generated design has been applied: in the works of Boulez, Xenakis and Murail, leading to the emergence of scientific softwares for aiding this approach circulated in the IRCAM *(Institut de Recherche et Coordination Acoustique / Musique* - Institute for music/acoustic research and coordination) compositional community (1).

The integration of computer-aided composition into analogue compositional practice presents new issues that are discussed in relation to *Fluid Sinews*, a composition for bass clarinet and piano. The generative techniques that have shaped the creation of applications like OpenMusic (IRCAM 2005) (2) and some processes in Max/MSP (Cycling 74 2005) were originally non-automated, manually calculated processes when initiated by Boulez and Xenakis. In certain situations the software can be the means and the end, i.e. it creates and performs/produces the MIDI rendering of the music that will be heard. In Max/MSP, it is often both. A characteristic of OpenMusic (OM) is the portability of material based on the Common LISP protocol. Material can be shared between OpenMusic and other applications using MIDI for porting sound, e.g. to sequencing programs, samplers, or to Max/MSP for Real Time interactive performance; LISP for values, lists and raw data, e.g. to AudioSculpt (IRCAM 2005) or Max/MSP; and ETF protocol for notation porting into Finale (MakeMusic 2004) or other score-writing programs. This paper, rather, looks at generative processes as a part of the broader, complex task of composing, that also includes selection: of pitches; pitch sets; chords. Selectivity utilising generative materials, choosing which rules to apply affects interpolation and aleatory. The composer also makes strategic choices about instrumentation and orchestration. Orchestration is concerned not merely which instrument/voice to use but with numerous intricacies arising from the realities of human performers: idiomatic or practicable fingering; registration/*tessitura;* timbral nuances; idiomatic fluency; breath/bow/voice constraints of speed, duration and intensity; peculiar shortcomings of physical instruments. A separate discussion could be given to electronic/computer music, synthesised instruments and virtual instruments using physical acoustic modelling of non-physical (non-real) instruments.

2.1. Xenakis and generative processes

When Xenakis wrote *Formalized Music: Thought and Mathematics in Music* (Xenakis 1992), originally appearing in 1971, he was trying to formalise a treatise as a visionary, a luminary, at a time when computer music was in its infancy, a time of transition from manual algorithmic calculation to computational processing. Conceptually, the methods employed by composers have not changed so much but scale, fluency, scope and complexity, as well as rendering (computer performance and now real-time processing) have changed the workflow practice and perhaps the accessibility of music-writing.

> "... Any theory or solution given on one level can be assigned to the solution of problems on another level. Thus the solutions in **macro**composition on the Families level (programmed stochastic mechanisms) can engender simpler and more powerful new perspectives in the shaping of **micro**sounds ..." (p.vii, Xenakis 1992)

One structural idea that computer-aided composition facilitates is working parallel processes on high-level and low-level design, i.e. facilitating relations between micro- and macro-structures, especially by increasing the fluency for algorithmically generating numerous micro-structures within a set of parameters. Alternatively, it is practical to apply the same function to minutiae such as individual note durations on the micro-level and to formal structures or pitch trends at the macro-level.

In practice, these relations across material can be achieved by using chordal structures as the basis for harmonic and inharmonic spectral generation – long, elaborate strings of pitches produced from selective regions of harmonics of a chord or from sequences of chords. Xenakis explains his motivation for a structural, hence generative, approach:

> "to reduce certain sound sensations, to understand their logical causes, to dominate them, and then to use them in wanted constructions ..."

His process consists of unravelling logical causes and acoustic qualities, then using them in "wanted constructions", deconstruction then reconstruction, to generate musical material from particles that are intricately connected.

In Xenakis' music, a composer and an architect, a spatial thinker, we see clearly in the scores and sketches a connection not only predictably between process and pitch, but also between curves (algorithms for generative processes) and physical attributes such as orchestration, physical spatialisation, registration and acoustic separation. **Fig. 1** shows parabolic shapes, described algorithmically in the generative process, here mapped on to a pitch/orchestration distribution graph in *Metastasis*. It is possible to observe more extreme values lying at the registral and spatial periphery of the score (orchestra).

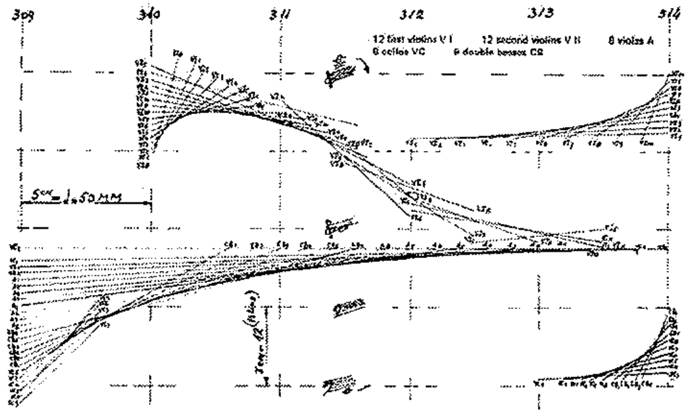


Figure 1 - Graphical representation of the *glissandi* pitches in *Metastasis* (Mâche 2001). The x-axis represents time and the y-axis represents pitch. Hence curves are pitch slides distributed over time showing duration and pitch-shift. Not only do the parabolic curves reiterate the contours of the architecture of the Philips Pavilion (Beilharz 2004), but the curves also describe generative algorithms. The abbreviations down the left side are instrumentation (celli at the bottom and violins at the top).

Xenakis used stochastic equations to generate clusters of pitches that he called "clouds" and physical variables in the equation temper intervals of intensity, pitch, 'temperature' in Gaussian distributions with clear metaphorical links between the statistical models or physical models and musical attributes. Xenakis' idea back in the 50s that "chance needs to be calculated" (p.38, Xenakis 1992) [to uphold the role of the composer and avoid banalities] provides a motivation for contemporary uses of computed random/chance procedures with controlled parameters.

Michel Philippot introduced the calculus of probabilities in 1960 and even earlier with stochastic painting. Then the composer was an "imaginary machine" (p.39, Xenakis 1992). Now it might be said, the computer performs the task for the composer, as the **imagining machine**. Xenakis used famous theorems for his generative probability, e.g. Markovian stochasticism, the Maxwell-Boltzmann Kinetic Theory of Gases in which micro-sounds or grains, like electrons, themselves insignificant, contribute to the dynamic shifts of the mass that are perceptible at the macro-form level.

The matrix is another predictive and generative tool, e.g. used to offer choices to the conductor in *Strategie* who must make game-like decisions that influence the flexible structure of the work. In Max/MSP (Cycling 74 2005), this is a basic object with adjustable dimensions, which can be used for controlling an auditory parameter to which it is linked. With the orchestral work, *Atrées*, Xenakis commenced his collaboration with computer. Used to assist his generative processes, he was still composing for conventional (though massive) symphony orchestra.

3. Categories of computer-aided generative processes

Following are some examples of generative processes that can be computer-assisted. This is an indicative but not exhaustive list. Each of these processes can be handled in OpenMusic, for example.

3.1. Serial processes (and Boulez)

Serialism is founded on the idea that a series or sequence of notes (a row) provides a rich potential of pitch material through the manipulation of this series. The four essential processes for transforming rows in Serialism are transposition (modulation), retrograde, inversion and retrograde inversion. This is a simplified explanation. Serial composers went on to serialise many other parameters of music such as dynamic intensities, positive durations/onsets (rhythm), negative durations/space (rests), articulation, timbre, etc. Combined with transposition and variations of the other musical parameters, retrograde, inversion and retrograde inversion can generate an exhaustive palette of material. [In OM, these functions are handled by objects dx->x, om*, om+, x->dx]. The concept for the entire work, *Structures,* for piano by Boulez is founded on these processes (Boulez 1986; Koblyakov 1990).

In his letter to John Cage in 1951 (p.129, Boulez 1986) explaining symmetries and structural contours, e.g. in **fig. 2**, Boulez's applications of vertical, horizontal, retrograde and retrograde inversion transformations are evident, as well as compressed and augmented permutations (see section **3.2**).

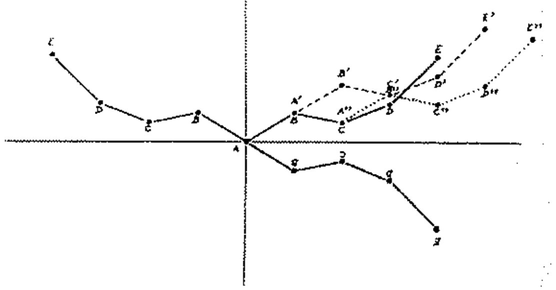


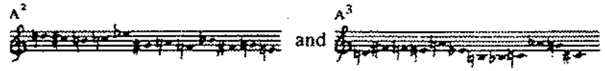
Figure 2 - From a letter to Cage describing symmetrical approaches in *Polyphonie X,* Boulez's schema shows both vertical and horizontal reflections, vertical augmentation and diminution of curves.

3.2. Changing melodic contour – vertical compression or expansion

The structures above are displacements, mirrors or symmetries. In addition, the contours of a melody (sequence) can be compressed or augmented/expanded in the vertical direction by varying ratios **(fig. 3)**. [In OM, this is the om-round function].

Series of twenty-four quarter-tones:

which divides into two series of semitones:



now take series A² and diminish the intervals by a quarter-tone –

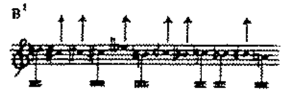


Figure 3 - The original series can be divided into two with obvious symmetries and the final transformation shows intervallic diminution (compression) reducing the vertical spread of the series. From *Polyphonie X* in *Orientations* (p.127, Boulez 1986) 'Frenzy and Organization: The System Exposed'.

3.3. Aleatory / Random

The curator of the 'Big Bang' (Destruction and Creation in 20th Century Art) exhibition at the Centre Pompidou, Catherine Grenier, describes aleatory in plastic arts:

> "Random, uncertainty and the combining of elements become the procedures of an art form open to invention, precariousness and hybridisation. Directly linked with life, forms are evolutionary and irrational".

This quotation illustrates the confusion surrounding the broad interpretation of aleatory, the gamut of implementations by artists and the struggle to interpret random procedures by the audience. By referring to the evolutionary and irrational nature of form, one assumes not systematic evolutionary/genetic processes but the inference that, perhaps out of the control of the artist, the form of the artefact is continually morphing, changing and dynamic. As mentioned earlier, the effects of random procedures in music can come from those opposing structure and those obsessed with its rigorous implementation. The effect for an audience of haphazard or highly-calculated but complex structures might be perceived similarly - impossible to understand, unpredictable, alienating, unsettling, rich, etc.

It seems logical that composers like Boulez and Xenakis, who are meticulous structure controllers and designers, architectural in their spatial conceptualisation relating meta/micro-structural procedures, employ controlled or **structured random** procedures. There are different kinds of random generative processes and, as with any computationally assisted process, the programmer/composer defines the conditions within which the random values are generated. This is rather the opposite kind of random to mushroom-hunting John Cage's controlled-by-the-environment random, Duchamp's or Beuys' Happenings, the exile of ego and governance by **chance**. Xenakis' aleatory is based on stochastic algorithms of probability used to understand trends and mass events by complex clusters of independent behaviours.

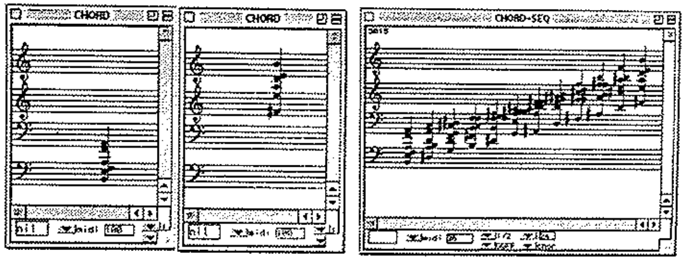
In OpenMusic, loops combined with random value generation and the computer's ability to "think randomly" provide a number of different ways to generate musical material using random processes, e.g.

1. Constructing a chord with random notes from a specified harmonic spectrum (builds a tree, lists of lists) (this can be seen later in *Fluid Sinews* in **fig. 7**)
2. Building a sequence of random notes
3. Using lists of random values to determine characteristics other than pitch, such as onsets, durations

3.4. Interpolation

Interpolation is in-between calculation (compare tweening in animation in Macromedia Director or Flash) of steps of transformation from one object to another, or a **morph**.

A computational approach is to generate a note sequence by interpolation between 2 chords with an adjustable number of interpolations and by adjusting the amount of "curve" argument for the calculation. A curve of 1 is linear, meaning that the arithmetic midpoint of the interpolation will fall exactly 50% of the way through the steps. In a non-linear interpolation specified by values smaller than 1 (but > 0) or greater than 1, the midpoint of the sequence is displaced forward or backward (see **fig. 4**).



Chord A Chord B

Figure 4 - The final frame shows the linear interpolation from chord A to chord B through 10 steps. The computer has generated the chords between the initial A and B values given by the composer.

3.5. Breakpoint Functions

A Breakpoint Function (BPF) is a simplified representation of a function curve demarcated by a number of points. For computational proposes, it is often adequate to describe a function with this contour and it requires significantly less computational processing than a curve (with a substantially greater number of points). Breakpoint functions can be used not only to describe individual note envelopes but also sequences of pitches, for scaling melodic contour.

3.6. Lists and Loops

Lists and loops of values can be used to generate non-repeating (isorhythmic) sequences of durations or to substitute some rhythmic values with rests (silences). By defining lists, rhythm can be created from arithmetic series, filled with notes from a specified chord, e.g. **fig. 5** or for creating chords based on a density contour (like Xenakis' manual Sieve procedures).

3.7. Sieves

Sieves are ordered sets of integers. Sieves can be used to produce points on a line (or curve) formed by the intersection of 2 sets. For example, $C_0^2 = 0,2,4,6,8...$ is a sieve of step 2 beginning on 0. Its intersection with $C_1^3 = 1,4,7,10,13,16...$ occurs at points 4, 16, 22, 28 and so on (which could also be used to form a Breakpoint Function). Set operations with sieves allow combination of sets to use them for filtering, elimination, or selection. In OpenMusic, for example, sieves can be used to build rhythmic grids, musically to create variation in textural density. In addition sieves can be superimposed and intersected to find common values. Boulez manually used a list-like process of replacing specific note durations with rests, using negative space to mirror space between onsets and space between sustained durations.

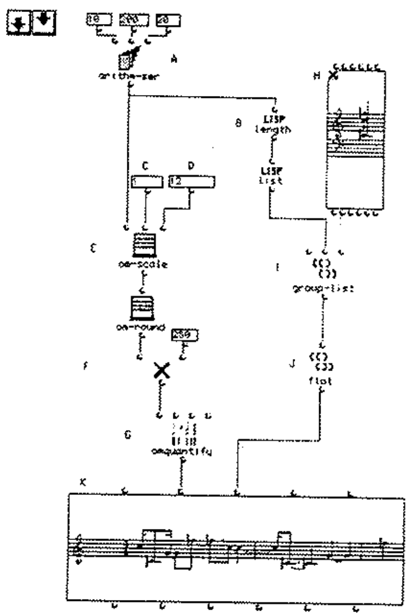


Figure 5 - Creates values of an arithmetic series from 10 to 200 by steps of 20 (A) using musical durations specified from longest to shortest (C and D) by the composer (scaled afterwards). The scaling (E and F) ensures adequate durations at a metronome speed of crotchet=60 and the 'omquantify' object quantises these numerical values into musical values represented in the final box.

3.8. Spectral Generative Processes (and Tristan Murail)

The harmonic series (overtone spectrum) of a note, or from a chord, plays an important role in our psycho-acoustic perception of the timbre/tone colour of the note. The composition and comparative strength of partials (harmonic overtones) in a note distinguishes the tone colour of a clarinet from a violin, for example. Analysis of harmonics, e.g in AudioSculpt (IRCAM 2005) sonograms allow the composer not only to understand the frequency distribution and intensity of harmonics but also to capture this data as values (spectra) that can be used for computation in OpenMusic or Max/MSP for composing new sounds, relating sequences of pitches and chords, durations, etc. Hence the compositional generative source comes from inside the spectrum of individual pitches, an introspective, or spectral approach to composition. In this way, again micro- and macro-structures are related. In many of

Murail's early spectral compositions, the structure of the piece was the same as the structure of the sound (i.e. using vertical structure to determine temporal and horizontal structure).

4. Integration of computational generative processes in *Fluid Sinews* for bass clarinet and piano

The main computer-aided generative process used in this composition is the creation of "random" sequences of monodic linear pitch material from the existing harmony in the piano part. Many permutations of the generative process were run from which the composer selected interesting solutions based on subjective choice and contextual pragmatism. The OpenMusic parameters were adjusted to vary pitch content, whether or not repeated notes were produced, quantisation and rounding to eliminate microtonal intervals of quarter- and eighth-tones in the final notation. **Section 4.1** shows the process of material generation and **section 4.2** explains orchestration/compositional considerations that affected implementation in the final score for human performance.

4.1. Generating random pitch sequences from existing harmony

The opening phrases of the piano part provided the material from which the entire piano part is derived harmonically and a chord comprising significant pitches from these bars was conflated to form the basis for aleatoric pitch generation in OpenMusic (**Fig. 6**). OpenMusic was used to generate pitch sequences or chord sequences from the original material (**Fig. 7**) and to round it to whole semitone pitches, playable easily on the bass clarinet. The random operators can be adjusted to permit or prevent repetitions of adjacent pitches (which can be awkward to articulate at a rapid tempo on the bass clarinet). The generative process can easily be run many times to "trawl" for interesting generations. The number of notes, length of phrase, is an adjustable argument in the loop (**fig. 8**).

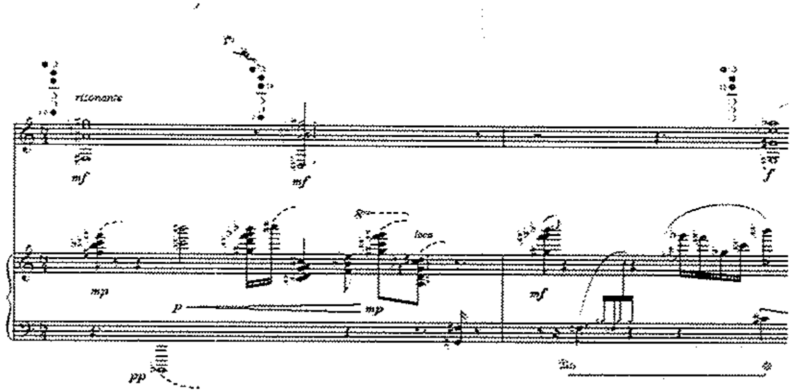


Figure 6 - The opening phrase of *Fluid Sinews* piano sonorities provide the harmonic basis for the chords used to generate the spectral "random" pitch sequences used in the bass clarinet part (3). N.B. The bass clarinet sounds a minor 9th lower than notated (conventional transposition) in all score extracts.

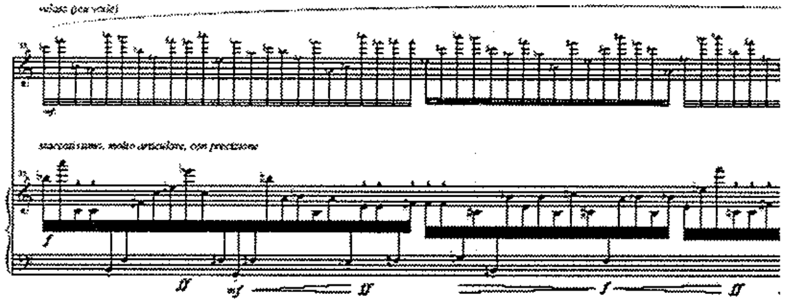


Figure 7 - To achieve this contiguous *velato* (veiled) *legato* (smooth) phrase that must match the piano in duration (number of notes), a greater number of pitches in the [OM omloop object] sequence was specified. The generation is transposed to sit just comfortably inside the top register of the bass clarinet's range.

4.2. Practical modifications for human performance

While the bass clarinet is a very versatile, dextrous, agile instrument with a huge pitch range, distinctive *tessituras* (registral voicing) and capable of producing a diverse range of dynamics, articulation and tone colours, it is also necessary to accommodate idiomatic playing, practicality and to use these colourful attributes of the instrument in conformity to the physical attributes that characterise the instrument. For example major shifts in embouchure (mouth shape) to move from one register to another or produce drastically different dynamics are impractical at rapid speeds. It is almost impossible to play very softly in the extremely high register. While fingerings do exist for microtonal quartertone intervals on many notes (but not all due to mechanics), these are non-standard, best suited for slower passages (**fig. 9**). Figure

9 shows one such example of automated output generated from a subset of a chord spectrum. Applied in composition, this passage was transposed in register and the large leaps were modified to cover a gamut within one register on the instrument. Tongued (separately articulated) notes for *staccato* are affected by speed (**fig. 10**). Hence these intervals were again transposed to reduce the number of leaps across different *tessitura* boundaries and the most impractical parts were omitted in the instrumental part.

The bass clarinet, sounding an octave lower than the regular clarinet, is physically large, slower to "speak" and it requires more breath, inter-related to register, determining phrase lengths (**fig. 11**). Thus the long phrases (of nearly unlimited speed and duration) produced in the computer program, were phrased into logical sections corresponding to human breath capacity. Across the "break" between different registers of fingering and embouchure, it is more difficult to play smoothly and consistently, while within any given register, rapid fingering is typical, so the composer must be constantly aware of the fingering. (A virtuoso contemporary piece of this nature is intended for a professional performer).

Figure 9 - Unmodified in register and microtonality, this is initial pitch sequence generated from the chord spectrum. It is very high-pitched and includes quarter- and eighth-tone intervals. The range/gamut is quite wide and many leaps between adjacent notes are large, which would constitute a register and embouchure shift on the bass clarinet, unidiomatic in a fast tempo or with *legato* (smooth) articulation.

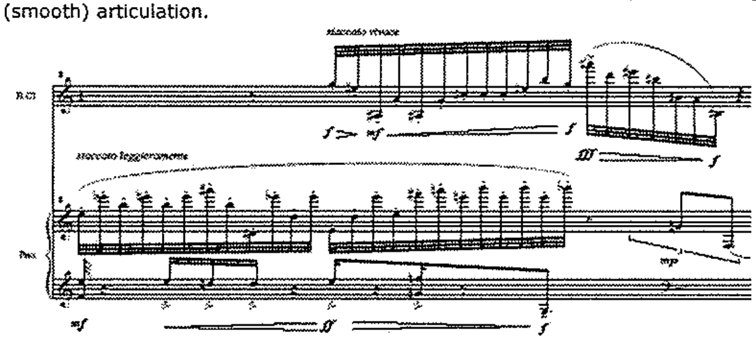


Figure 10 - Due to the *staccato* notes, which must be individually tongued/articulated, repeated notes are kept. The phrase has been transposed to sit comfortably in the bass clarinet range and the final *legato* descending gesture has individual notes transposed in register to continue the downward contour of the phrase that is required musically by the composer.

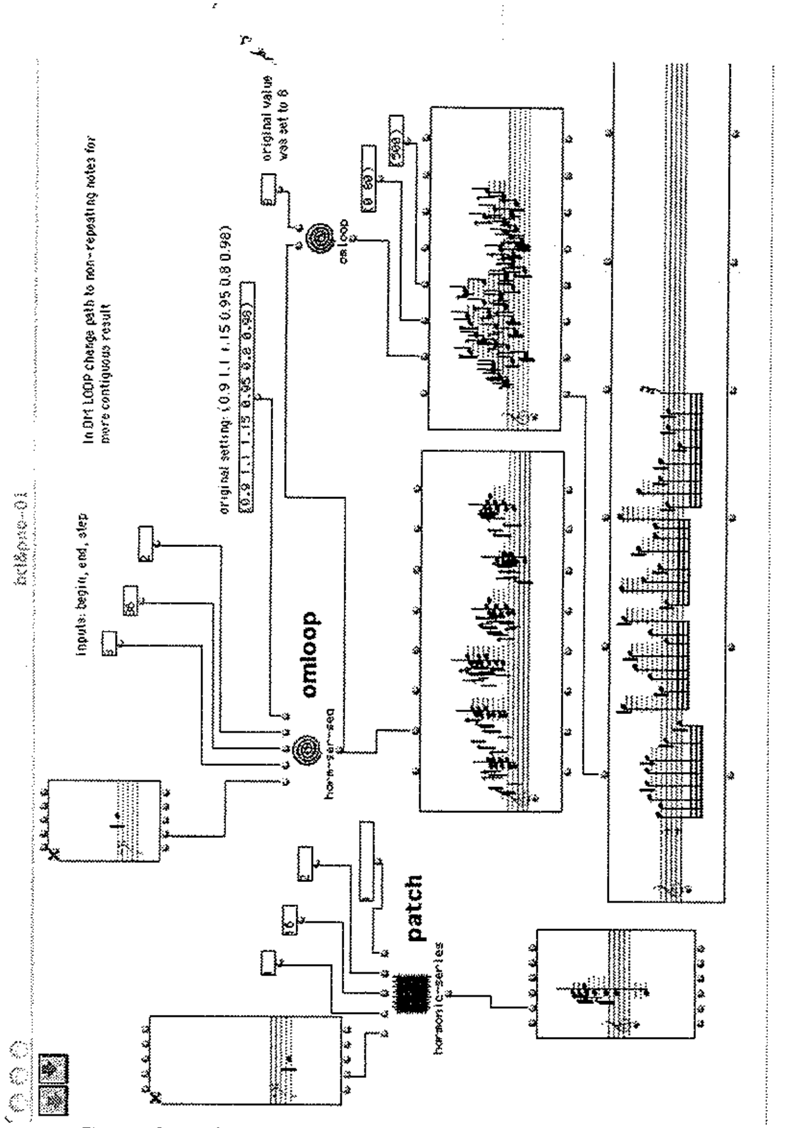


Figure 8 - The main patch is the interface for aleatoric generative processes. By connecting and running different subsets of the patch, different processes are activated to produce a) a linear microtonal sequence, b) a chordal progression, and c) a pitch-rounded (non-microtonal) phrase of notes from the spectrum of the chord, similar to techniques used by Tristan Murail.

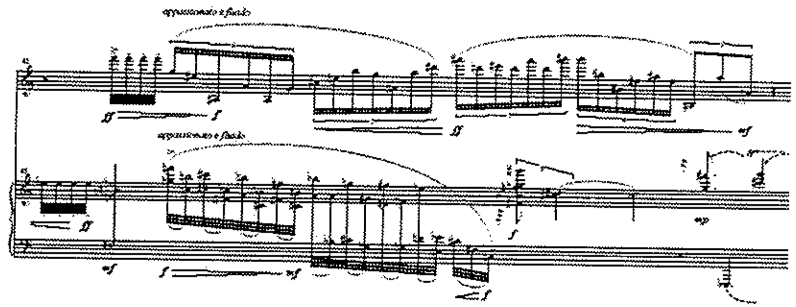


Figure 11 - In this phrase, which is both long and smooth, omitting pitches or transposing notes into a tighter vertical displacement removed excessively large leaps. Repeated notes are not permitted within beats under the one breath/phrase.

Conclusion

This paper has explored manual generative processes in musical composition by Boulez and Xenakis that have informed development of the software tools of contemporary computer-aided composition. Some different methodologies for generating musical material supported by a computational approach are presented. Finally, by analysing the application of computer-generated material in the context of a composition *(Fluid Sinews)* for analogue performance, modifications and human-centred considerations in practice are examined with the aim of integrating computer-aided generative processes in acoustic music.

Notes

1 A role of software developers at this institution has been to develop and release to the community continually evolving research software for various aspects of music composition and acoustic treatment. More of an experimental and beta-phase, code-view approach is taken than a commercial-scale stability and documentation approach. Often it is necessary to modify/adapt objects and code [bleeding edge] but simultaneously the software is directly serving the developments in its surrounding, highly specialised compositional community and hence evolves quite rapidly.

2 OpenMusic (OM) is a visual programming environment for creating computer aided composition applications on the Macintosh. It uses Digitool's Common Lisp and CLOS (Common Lisp Object System).

3 For all musical quotations, the bass clarinet part is transposed, sounding a major 9th lower than written. The fingering tablature for multiphonics and timbre trills refer to the French (Selmer or Buffet) fingering suggested by Henri Bok & Eugen Wendel in Nouvelle Techniques de la Clarinette Basse (Bok & Wendel 1989).

References

Beilharz, K. (2004). Designing Sounds and Spaces: Interdisciplinary Rules & Proportions in Generative Stochastic Music and Architecture, *Journal of Design Research* http://jdr.tudelft.nl/

Bok, H. & Wendel, E. (1989), *Nouvelle Techniques de la Clarinette Basse,* Durand-Salabert, Paris, France.

Boulez, P. (1986) *Orientations,* Harvard University Press, USA. [Originally published in 1981 in French].

Cycling 74 (1990-2005) Max/MSP (+ Jitter) (software program), current version 4.5.5 (2005), developed by M. Puckette and D. Zicarelli, Cycling 74, USA.

IRCAM (1995-2005) AudioSculpt (software program), current version 2.4.2 (2005), conception by C. Rodgers, G. Eckel, A. Richie, H. Tutschku, SuperVP engine – P. Depalle, G. Poirot, A. Roebel, realization by P. Hanappe, J. Carrive, S. Serafin, M. Koenders, A. Lefèvre, A. Ricci, D. Ralley, M. LoCascio, N. Bogaards, N. Ellis, directed by X. Rodet., IRCAM Centre Pompidou, Paris, France

IRCAM (2005) OpenMusic (software program), current version 4.9, developed jointly by G. Assayag & A. Agon with C. Rueda, O. Delarue, using Midishare and CommonLISP, IRCAM Centre Pompidou, Paris, France.

Koblyakov, L. (1990) *Pierre Boulez: A World of Harmony* Contemporary Music Studies, Volume 2, Harwood Academic Publishers, U.K.

Mâche, F.-B. (2001) *Portrait(s) de Iannis Xenakis,* Bibliotheque Nationale de France, France.

MakeMusic Inc. (2004) Finale (notation software program), current version 2005, MakeMusic Inc., USA.

Xenakis, I. (1992) *Formalized Music: Thought and Mathematics in Music,* Pendragon Revised Edition, New York, USA. [Original Edition published in 1971 by Indiana University Press].

Structuring Cellular Automata Rule Space with Attractor Basins

Dave Burraston

Complex systems such as Cellular Automata (CA) produce global behaviour based on the interactions of simple units (cells). Their evolution is specified by local interaction rules that generate some form of ordered, complex or chaotic behaviour. This wide variety of behaviour represents an important generative tool for the artist. Chaotic behaviour dominates rule space, which has serious implications for the serendipitous use of these systems in artistic endeavour. A fresh insight into a recognised key problem, the structure of rule space, is presented based on empirical evidence. This provides a method for creating groups of rules with a broad range of behaviour for application within generative arts practice and will also be of interest to scientific practitioners.

1. Introduction

> On the phono-scales a common or garden F sharp gave a reading of 93 kilogrammes. It issued from a decidedly large tenor whose weight I took. (Erik Satie 1912)

The different classes of behaviour that CA produce, whether ordered, complex or chaotic, make them interesting to artists and scientists alike. They are fascinating objects, producing more pattern than a single human is capable of observing within their own lifetime. Stephen Wolfram has proposed twenty key problems in the theory of CA (Wolfram 1985), the seventh problem asks : *How is different behaviour distributed in the space of cellular automaton rules?* The structure of the elementary rule space was examined by Li and Packard, where their aim was to show inter and intra behaviour class connections (Li and Packard 1990). The approach taken in this paper and described in section 3 is different, providing fresh insight into rule space structure.

Within the domain of generative music access to a variety of behaviour is essential. CA have played a key part in generative music for many years (Burraston, Edmonds, Livingstone and Miranda 2004) (Burraston and Edmonds 2005). Reflective practice has also been utilised to investigate and describe generative music (Burraston and Edmonds 2004) (Burraston 2005a, 2005b & 2005c), and also a precursor to the

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Forward

Paul Brown and Ernest Edmonds

To many, music is the highest art form. The purity and yet the power of these abstract structures in time seems to cross cultures and ages and are often at the centre of, or perhaps pointedly excluded from, religious worship. Not surprisingly, painters quite frequently aspire to being composers or musicians. Formally, the distinction between seeing and hearing aside, the key difference between painting and music might be seen to be the presence of time as an integral element or dimension. Vertov's characterization of his film *The man with the movie camera* as "an experiment in visual music" perhaps captures the visual artist's interest in time (Vertov 1984). However, other influences have also been afoot in the 20th century. For example, in work that uses geometric or other systems, it has been common to produce series of works that often have a natural sequence. It is only a small step to think of them as stills from a movie. Another closely related development was the early use of computer programs to generate drawings. Generative works of this kind lend themselves to the automatic generation of a series because the computer program is a kind of general structure or form that can apply to a class of works, each a variation of another. In generative time-based art, the explicitly defined part of the work is the structural element including, specifically, the rules that are to be used to determine in which order and at which pace the sequence should develop.

In the early 1970's Malcolm Hughes set up the Experimental and Computing Department in the Postgraduate School of the Slade School of Art at University College, London. By 1974 they had a Data General Nova 2 Minicomputer. At that time it was by far the most powerful computer system installed in an art school anywhere in the world. It attracted a small group of artists who, like Hughes, were interested in systems-based, conceptual and procedural art.

They included Harold Cohen, Edward Ihnatowicz, Ernest Edmonds, Chris Briscoe, Julian Sullivan, Stephen Scrivener, Darrell Viner, Stephen Bell, Dominic Boreham and Paul Brown amongst others. A few of us had pursued an interested in cellular automata after reading about John Conway's work in Scientific American in 1970 (Gardner '70). Others, like Chris Briscoe, were interested in unpredictable deterministic systems. Later a visitor, the Polish mathematician Andre Lissowski, on his way home from a residency at Harvard introduced us to the work of Benoit Mandelbrot and his concept of fractal dimensions and the field of non-linear, deterministic chaos.

Then, a decade later, the work we had pioneered was picked up by the scientific community and given a name. Chris Langton called it "artificial life" (Langton 87). I suspect that none of us would have particularly identified with that name. Mostly we were just pursuing the then-dominant system's aesthetic – that process precedes object and forms the "essence" of the artwork. It was an idea that had been pioneered by Roy Ascott amongst others in the 1960's and which was documented and contextualised by Lippard ('73). Furthermore many of the group would have been reluctant to anthropomorphise our productions, let alone claim they had anything to do with life!

Now, over 30 years down the track, our efforts have been largely forgotten by the arts mainstream – something that the recent CACHe project at London University's Birkbeck College has attempted to address (Gere '07, Brown '06). Ironically we have however been rediscovered by the science community who correctly perceive our efforts to be a part of the foundation on which a whole new scientific field was built. It's one of the few examples I can think of where a fully-fledged scientific discipline has been based, if only in part, on the work of artists who were pursuing artistic and not scientific outcomes.

In hindsight it's possible to see that we were amongst the first computational generative artists although, here again, neither adjectives would have occurred or perhaps even appealed to us at the time. And, as reassuring as it is to have been rediscovered by science, the real pleasure comes from the fact that many of us are still here, still pursuing aims that reify and build on those fumbling steps we took back in the late 1960's and 1970's.

What is particularly reassuring is that we are not alone! With the ubiquity of computer systems several new generations have been introduced to formal computational methodology in the arts. So many that we can now hold conferences to meet and network and share our work and ideas.

This Symposium is part of the Creativity and Cognition series that complements the Association for Computing Machinery Conferences of that name. The symposia are tackling specific topical questions. This one looks at the practice of generative art: where are we and where are we going next in terms of that practice?

References

Brown, Paul & Catherine Mason. (to appear 2006) A Machine that Makes Art – The origin of computer arts 1960 - 1980, ICA, Singapore.

Gardner, Martin. (1970) The fantastic combinations of John Conway's new solitaire game "life", Scientific American 223 (October) pp 120-123

Gere, Charlie; Paul Brown; Nick Lambert & Catherine Mason (Eds.). (to appear, 2007) White Heat and Cold Logic: British Computer Arts 1960 - 1980 An historical and critical analysis, MIT Press, Cambridge, MA.

Langton, Chris (Ed). (1987) Proceedings First International Conference on the Synthesis and Simulation of Living Systems (aka. Artificial Life 1), Los Alamos.

Lippard, Lucy. (1973) Six years; The Dematerialisation of the Art Object from 1966 to 1972, Berkeley: Univ of California Press.

Vertov, Dziga. (1984) *Kino-Eye: the writings of Dziga Vertov*. Ed. Michelson, A.; trans. O'Brien, K. University of California Press, Berkeley.