NEW SOFTWARE COMPOSITION TOOLS

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ABSTRACT

This paper briefly discusses a number of software tools developed at the author's studio through the course of research work into algorithmic composition. Most of the tools developed are directly related to recursive techniques; some, however, arise from more general techniques of algorithmic composition first described by Joseph Schillinger. Examples of recursive techniques include:

- META-FRACTALS- separating musical content from recursive structure
- the Lorenz attractor and Koch snowflake as musical generators
- Iterated Function Systems as musical generator
- dynamic values in the logistic equation and the Mandelbrot set.

Non-recursive tools include:

- the Intelligent Interval Tool- a form of limited contrapuntal intelligence
- the Harmonic Activator - Schillinger arpeggiation tool
- the Arbitrary Pattern Generator
- the smart duration operator
- the Granulator - applying a granular synthesis process at the note-level

It is hoped that the brief descriptions of these functions will stimulate the imagination of other composers.

RECURSIVE TECHNIQUES

Most of the software tools developed during the past year have resulted from the author's continuing research into methods of algorithmic composition using recursive techniques, generally known as fractals. What follows are brief descriptions of several of these tools.

META-FRACTALS

In past experiments with classic fractals such as the Mandelbrot set and its real number counterpart the logistic equation, I have used the output of the equation, suitably scaled, as a direct index to MIDI note number (i.e. pitch), MIDI note velocity, or some other MIDI parameter such as continuous controller values. The notion of ***meta-fractals*** is simply this: to replace this simple 1:1 relationship with a more musically meaningful one. Thus, the output value becomes an index into a set of musical components, which are arranged by the recursive process into a self-similar structure. This separation of the algorithm from the musical content allows scope for several types of musical activity not previously possible with fractals.

Such a strategy also has a relation to the concept of *moment form* as defined by composers such as Stockhausen and Messiaen: "a succession of self-contained sections which do not relate to each other in any functionally implicative manner." (Kramer, *Moment Form in Twentieth Century Music)*. Kramer continues:

> The crisis for the listener is extreme; it is no surprise that discontinuous contemporary music is often not understood by its audience. *To remove continuity is to question the very meaning of time in our culture and hence of human existence.* This questioning is going all around us, and its strongest statement is found in contemporary art. By dealing with the resulting apparent chaos of this art, we are forced to understand our culture and hence to grow. (Kramer, p.55, italics mine)

It is interesting to not that dynamical systems, which arise from the need to rationally comprehend change in time, can in this way themselves become the means by which the perception of time is destroyed.

Several variations of implementation of meta-fractals are possible. Some of those that I've cataloged are:

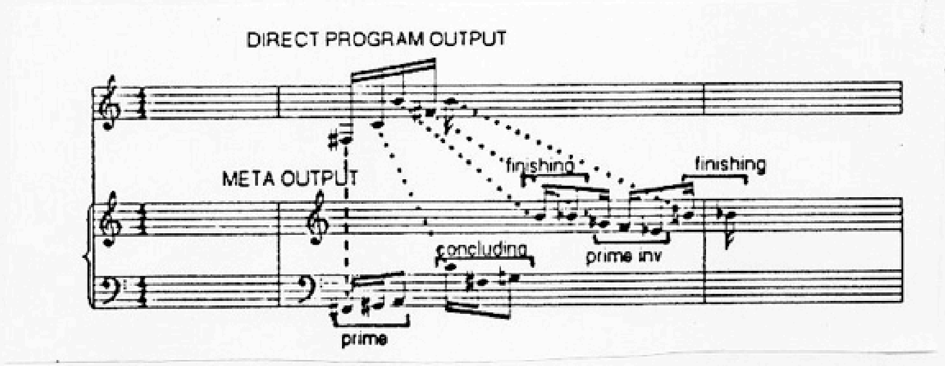
i) The simplest type is similar to a 1:1 mapping, but with a single layer of indirection through a lookup table. For example, an output value of, say, 48 (corresponding to MIDI note number 48 - cello 'c') could result instead in 99, or any other MIDI note number. The principle use of this method is to restrict the continuous real number output of the recursive process to a more musically meaningful set, for example, the notes of a particular pitch mode or instrumental range.

ii) The next level of complexity is a big step forward. A single output value can be made to produce a *motive:* a small (typically two to four note) musical gesture. Motivic composition is a method typical of the European masters of the 19th century

(fig. 1 - Rudolf Reti, analysis of motives from Beethoven, *Pathetique Sonata*, from Cook, p.99)

iii) Complete musical events can also be specified, for example, an arpeggiated chord across several instruments, with independent control of pitch bend and velocity for each note. This amounts to a method of algorithmically determining the *orchestration* and the *dynamics*, two musical parameters that in the past have eluded meaningful attempts at fractal control. In effect, the recursive process can be used to create a *moment form:* a set of phrases, pieces, or musical gestures unrelated by functional implications.

iv) The musical elements can consist of components of an existing composition, e.g. phrases from a Mozart symphony, or pianistic gestures from a Chopin sonata.



(fig. 2 - musical example showing indirect output generated from Reti's motivic analysis, above)

v) The musical elements can consist of short musical phrases themselves produced by a fractal process, thus extending the self-similarity of structure to another level.

(fig. 3 - details of Reti's analysis of Beethoven *Pathetique*)

Meta-Fractals directly address the discontinuity of perceptual levels in applying recursive processes to music that I have noted (Degazio, 1986). They do this by allowing different processes to dominate at different levels.

THE LORENZ ATTRACTOR

Historically, the Lorenz attractor was one of the first dynamical systems shown to exhibit complex and unpredictable (chaotic) behavior. It arose in connection with weather prediction in a paper by Edward N. Lorenz in 1963. The three inter-related equations are:

$$x' = a*(y-x)$$
$$y' = b*x-y-x*z$$
$$z' = x*y-c*z$$

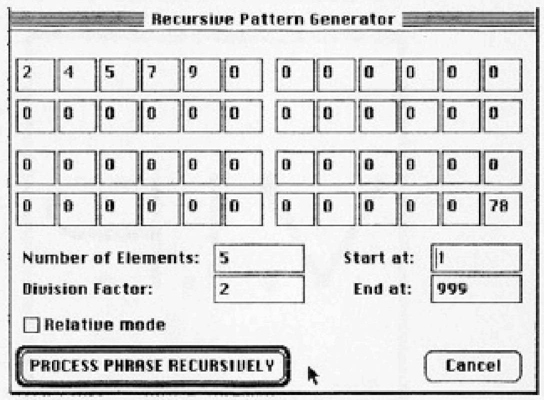
Whether by suggestion or purpose, this model proves, when mapped to a continuously variable parameter such as pitch, volume, or timbre (e.g. FM modulator index) to be extremely suggestive of the ebb and flow of such natural phenomena as wind and waves. The quality that seems to account for this is its near-predictability combined with its chaotic behavior. The equations in fact trace out a simple series of quasi sine waves - the element of predictability. The waves are, however, broken at unpredictable intervals by sudden changes of direction and amplitude - the element of chaos.

When used to directly generate sample data for reproduction as audio through a commercial sampling device, the Lorenz attractor creates an unusual low frequency oscillation. Perhaps because of its historical connection with weather prediction, this result is again extremely suggestive of natural phenomena, this time of an earthquake rumble. I used this sound for the San Francisco earthquake sequence in the IMAX film *Blue Planet*.

Mapped to MIDI data, another application was to herald the approaching storm in the media opera *Tesla: The Man Who Invented the Twentieth Century*. In this instance the attractor's outputs were applied to pitch bend (detuning) across three channels of synthesizers, producing the aural equivalent of Tesla's interference waves within the Earth. A third application was to simulate a natural choral vibrato when applied as pitch bend to six channels of sampled vocal sounds. The result was for more attractive to the ear than a regular LFO induced vibrato. The multiple outputs are correlated in such a way that they *never* meet at a common point.

RECURSIVE PATTERN GENERATOR

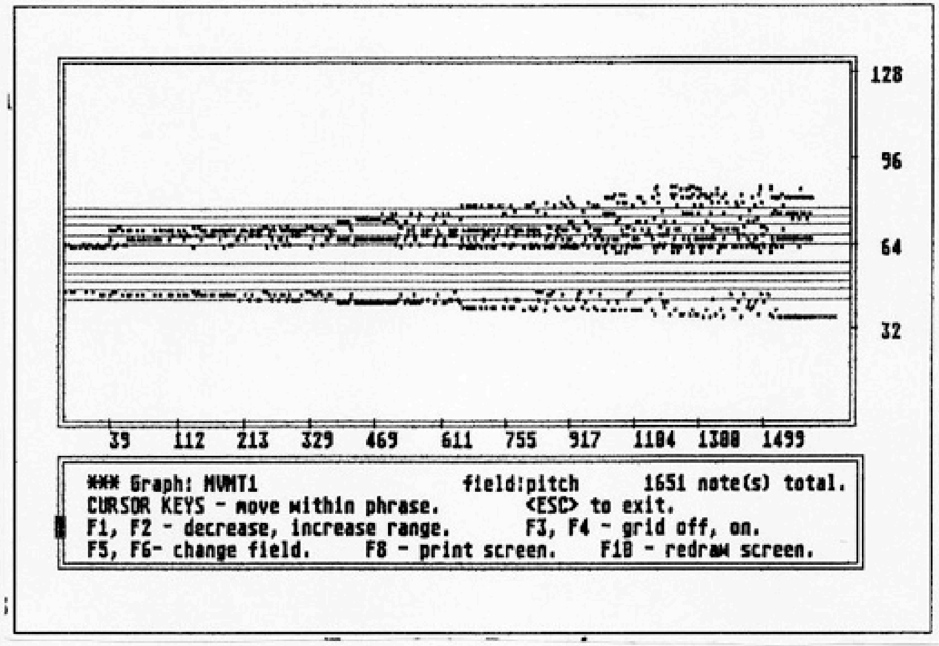
MIDIFORTH's *Recursive Pattern Generator* allows the creation of musical analogs of the Koch snowflake, a classic fractal described by Mandelbrot in *The Fractal Geometry of Nature*. It works by recursively layering a short musical motif (up to 64 notes long, but typically only three or four) specified by the composer in the form of semitone transpositions from a root.



(fig. 4 - Recursive Pattern Generator (von Koch curve) dialog box)

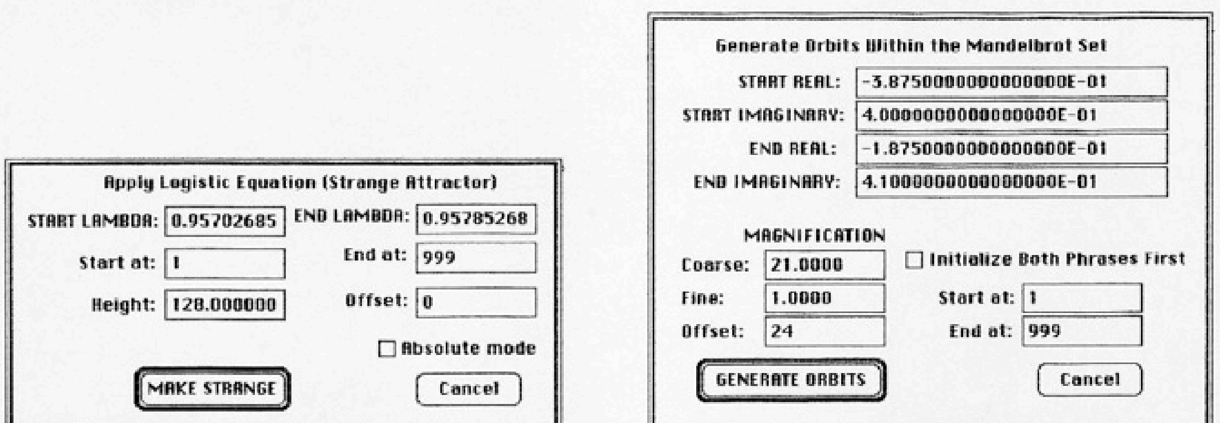
DYNAMIC VALUES IN THE LOGISTIC EQUATION AND MANDELBROT SET

Choosing a single value for *lambda* or *C* is the simplest way of composing with these equations. It has the disadvantage, however, that for many settings the output is simple or periodic, i.e. it consists of some small number of recurring values. In order to maintain the unity provided by such periodicity but also gain the variety of continual variation it is possible to vary *lambda* or *C* across a small range through the course of the composition. This generates a more interesting variety of musical material, the behaviour of which depends on the starting point and range across which it is varied. Because the variation is continous and in one direction thoughout an entire work, the changes produced are often of a fundamental or structural nature. For example, the first movement of *Digital Rituals* is clearly outlined by the gradually increasing pitch range as *lambda* varies from .895 to .92698. This is most evident in the bass line which moves gradually from pitch areas centred on B-flat-2 down to C-2.



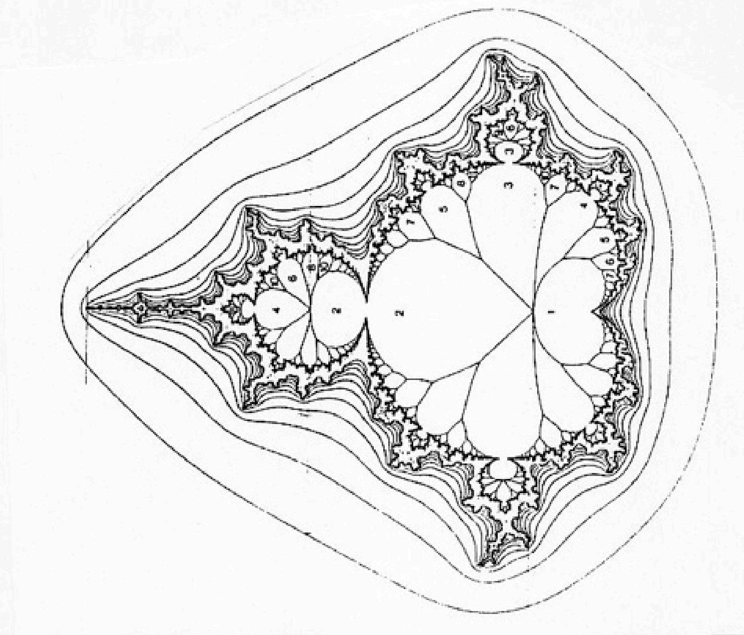
(fig.5 - pitch outline of *Digital Rituals 1 - Procession)*

The orbits produced by the equation, the cause of the musical patterning that is the main interest of the process, can be made, by careful selection of the start and end points, to cross several cyclical and chaotic boundaries through its path. This produces a variety of "textures" that can be exploited to define the structure of the composition. For example, in *HETEROPHONY 4875*, alternating periodic and chaotic regimes produce the algorithmic equivalent of a rondo.



(fig. 6 - Logistic Equation dialog box, with time varying lambda,
and Mandelbrot Set dialog box, with time varying 'X' and 'Y')

A similar logic prevails within the Mandelbrot set, with the additional complication that the paths are two dimensional. The interior of the set has fortunately been well mapped in terms of its orbital structure (fig. 7). Note the unusual additive relationship, as in a Fibonacci series, between adjacent cyclical regions in the interior of the set.



(fig. 7 - map of orbital behavior of interior of Mandelbrot set, from Peitgen)

QUATERNIONS AS MUSICAL GENERATORS

Quaternions are a four dimensional extension of previous work with the logistic equation (one dimensional, real numbers) and the Mandelbrot set (two dimensional, complex numbers). The extension of these recursive processes into a four dimensional space allows simultaneous coordinated control of up to four parameters, or of four simultaneously occurring musical elements. For example, pitch, duration, dynamics and timbre are arguably the four most important musical parameters. A recursive process employing quaternions would allow simultaneous control of all four. Alternatively, the four dimensional output could be mapped to pitch for the four instruments of a string quartet or similar ensemble. Such a recursive process is specified by the equation:

$$(x,y,w,z) \rightarrow (x^2-y^2-z^2+c,\ 2xy+c_i,\ 2xw+c_j,\ 2xz+c_k)$$

Preliminary experiments with this equation have been promising. The principal problem of exploring a four dimensional parameter space is the lack of any sort of built-in sense of 'direction'. Additionally, the quaternion parameter space has been much less explored and the system itself much less studied than the logistic equation or the Mandelbrot set, for both of which exist detailed parameter maps.

ITERATED FUNCTION SYSTEMS AS MUSICAL GENERATORS

A method of computing many of the classic fractals has been developed by Michael Barnsley of the Georgia Institute of Technology. Known as *iterated function systems*, this method bears promise as a general system for computing any desired fractal pattern, as opposed to the *ad hoc* system of many different techniques in use at present. One feature of Barnsley's method is that a continuous gradation of types is possible. This leads to the concept of *fractal interpolation* - the ability to generate fractally consistent data (i.e. of equal fractal dimension) from a small set of given data. Thus, a structural outline can be specified by a small number of pitches, the details of which are filled in by the process in a fractally consistent manner.

NON-RECURSIVE TECHNIQUES

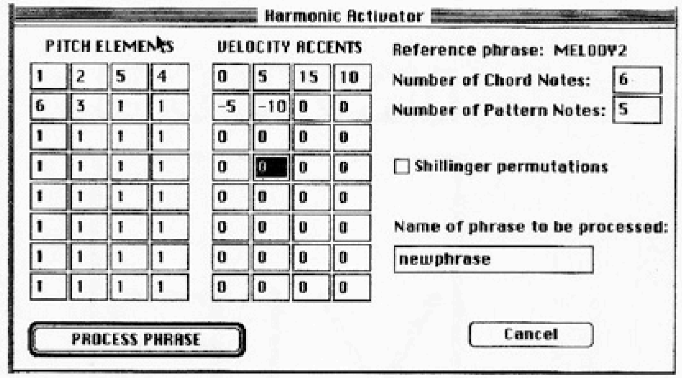
Certain other software tools have arisen out of musical needs in the past year, which do not, however, pertain to any specific recursive technique. Two are:

HARMONIC ACTIVATOR (SCHILLINGER ARPEGGIATION TOOL)

This tool implements the Schillingerian notion of harmonic activation. By specifying a pre-defined chord series and a rhythmic skeleton, the harmonic structure is "activated" through arpeggiation. It takes as its parameters: a set of chords, an arpeggiation pattern, a rhythmic value, and a total duration. Continual variation can be added through Schillinger's 'cyclical permutations'. For example, given a series of 5-voice chords, an arpeggiation pattern (spelled from the lowest voice) of *a b c d e*, and a total duration of 15 notes, the arpeggiation tool would generate this accompaniment:

a b c d e b c d e a c d e a b

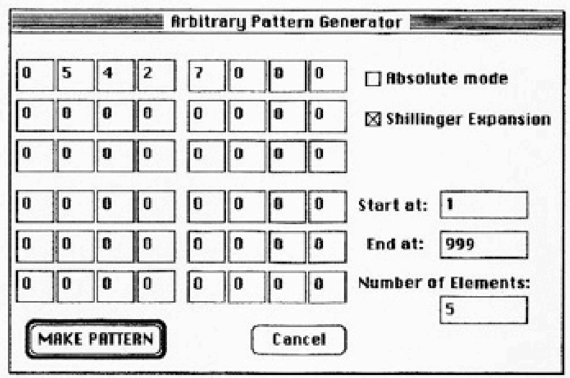
The pitch pattern is specified as chord elements, numbered from the lowest voice. An independent velocity pattern can also be applied.



(fig. 8 - Harmonic Activator dialog box)

ARBITRARY PATTERN GENERATOR

The arbitrary Pattern Generator is a simple and useful tool. It is used whenever a simple repeating pattern is required, such as a sequence of repeating melodic shapes, or dynamic accents. These are often useful starting points for other algorithmic process. The simple nature of the repetition can be made somewhat more complex by the application of Schillinger's cyclical permutations, as in the Harmonic Activator.



(fig. 9 - Arbitrary Pattern Generator dialog box)

SMART DURATION OPERATOR

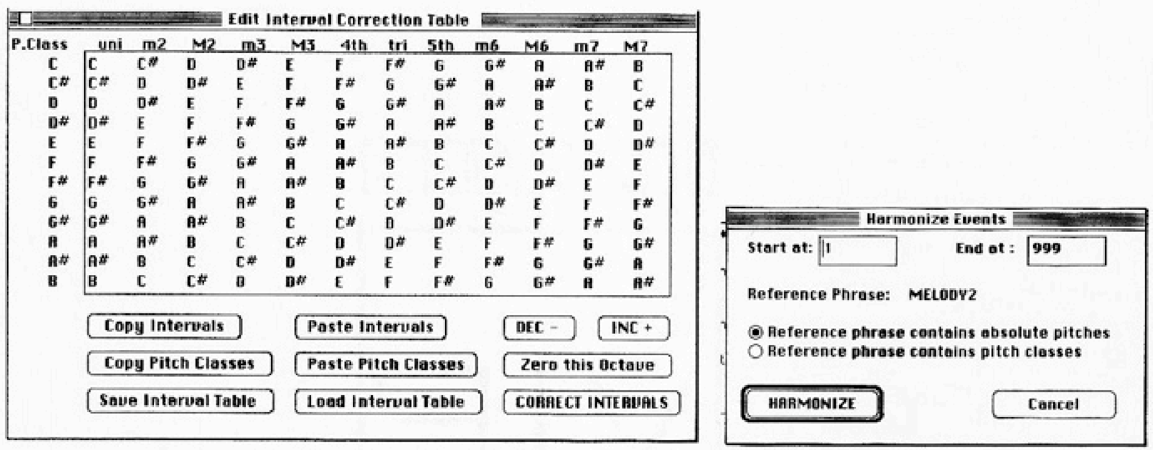
When any of the above processes is applied to rhythm or duration the results can be less than satisfactory because of the way a continuous value (e.g. the output of a recursive function) maps into a discontinuous parameter space (musical durations). For this reason a means of restricting operations involving rhythmic aspects of music (durations, positions within the measure) to a musically relevant set of values was developed. Three such sets of values, as defined by Schillinger, are:

the 2 power series -	1/4	1/2	**1**	2	4	8 etc
the 3 power series -	1/9	1/3	**1**	3	9	27 etc
the 5 power series -	1/25	1/5	**1**	5	25	125 etc

The smart duration operator automatically maps operations applied to durations and rhythms to members of one of these series, or of some other limited set of rhythmically meaningful values.

THE INTELLIGENT INTERVAL TOOL

The Intelligent Interval Tool is a simple method of providing any generator with a limited contrapuntal/harmonic intelligence. It can modify an existing musical line by reference to a second line (the cantus firmus) and a table of "allowed" intervals. The 'allowed' and 'disallowed' pitch intervals can vary through the composition and are specified on a pitch-class-against-pitch-class basis in the form of a table:

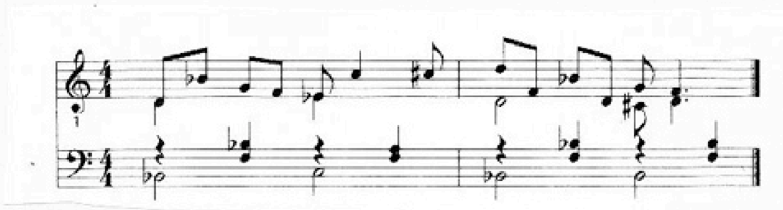


(fig. 10 - Interval Correction Table and Harmonization dialog box)

Modifications of this interval list allow the simulation of styles as varied as organum (only fourths, fifths and octaves allowed) to dodecophony (fourths, fifths and octaves disallowed). Simple extensions to this tool allow an alternate set of intervals to be specified for metrical context sensitivity. Thus, there can exist allowed intervals for both 'strong' and 'weak' beats allowing the specification of traditional forms of consonance-dissonance relationships such as passing tones and appogiaturae. Editing functions used with the interval correction table allow the copying of interval structures (i.e. chords) from one root to another (transposition), and copying pitch classes from one root to another (inversion).

GRANULATED MUSIC

This tool consists of the application to MIDI data of an audio synthesis technique known as granular synthesis. The basic procedure is to take a MIDI file consisting possibly of some well known piece of music, and stretching it out through the repetition of small blocks of musical material. A "window size" of, say, two bars, is decided upon. The computer then progresses through the source MIDI file performing the first two bars, then repeats starting, say an eighth note later, again playing two bars form that point, advances another eighth note and performs two bars from that point and so on, until the end of the file is reached. With suitable selection of window size and advancement rate, stretch factors of several thousand times may achieved while still retaining recognizable musical features in the source material. The idea is a direct application of a technique used by others, notably Barry Truax, at the audio level to achieve vastly time-stretched sounds while keeping frequency components within the human audio range.



(fig. 11 - measures 5-6 of Joplin's *Magnetic Rag*)

(fig. 12 - above measures stretched out to 12)

ACKNOWLEDGEMENTS

The work described in this paper was funded with the assistance of the Ontario Arts Council, Electronic Media Program and the Canada Council, Computer Integrated Media Program. I am also grateful to Gustav Ciamaga and to John Free for discussion of details regarding musical uses and software implementation.

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