Azimuth

Algorithmic Score Synthesis Techniques

by Michael Rhoades

Quote: There is enough potential in anything to last a lifetime.

I. Introduction

This paper will describe the processes utilized to realize a recent composition. The primary focus will be upon the creation of formal elements through score synthesis techniques, although an overall view is necessary in order to fully explain them; therefore much of the process will be delineated.

With the proliferation of sound design software and hardware in the early years of the 21st century, there seems to be a tendency for composers to put emphasis on sound design and neglect or completely ignore considerations of form engendered by a formal score. This is indeed disturbing because these composers seem to be abandoning one of the primary means at their disposal to make musical sense of these new sounds in favor of a quick easy layering or looping of sounds. Although there are exceptions to the contrary, generally sounds do not make the composition, instead it is the composition that makes the sounds viable, as music, through formal elements. Without the use of some form of syntax, which is created by establishing score relationships, there is no meaning and so, no semantic element.

Algorithmic score synthesis is really a just way for a composer, using indirect methods, to elucidate musical combinations that would not be possible through more direct methods. Today, this means that a computer can be programmed to assist in the creation of musical possibilities through, among other methods, the use of mathematical tendency masks. This is by no means a way for the composer to remove himself from the process of composition, nor from the responsibility of making musical decisions. In fact it places the composer into an ideal position to make these creative choices because it is not necessary to be as completely absorbed by the more direct tasks that are necessary in non-algorithmic compositional approaches. The use of mathematical tendency masks is a perfect choice for algorithmic composition of music conceived in the digital realm. Since digital sound is by its very nature based on numeric values, these tendency masks integrate into the very foundation of the sound itself.

Csound, a programming language intended for musical composition, is an ideal starting point for algorithmic composition because it allows the composer to work with sound directly on a numeric level. At first this idea may seem foreign to a person who has studied and composed music in more “traditional” settings. However, consider the fact that, for centuries, music has been divided into mathematical quantities; for instance note durations, in relation to time (a quarter note at 60 bpm, in 4/4 time, is one second long) and divisions of frequency, in terms of scalar relationships (concert A vibrates at 440hz, A an octave higher vibrates at 880hz), thus establishing a musical language. A numerically unrestricted language, such as Csound, greatly expands the possibilities for precision control in these as well as countless other areas of musical creation and expression, and provides seemingly limitless new possibilities for numerical relationships, impossible to realize by traditional musical languages and instruments.

Cmask is a stochastic event generator for Csound scores. It provides a versatile array of algorithms that can be used to create tendency masks that in turn can be used to determine various pfield values in these scores. Quasi-random values are generated based on tendency masks that can be stipulated in several ways, perhaps the most interesting of which is by the use of linear and exponential envelopes.

I am extremely interested in designing score synthesis techniques to utilize in my compositional process. Through an association with Otto Laske, a pioneer in the field of algorithmic composition, I feel a unique connection to Koenig, Brun, Xenakis and Stockhausen, as well as Laske himself, all of whom have spent lifetimes developing, among other things, score synthesis techniques. These techniques need to be recognized for what they offer and therefore extended and passed on to subsequent generations of composers. This is the impetus for the documentation of the process utilized in the creation of Azimuth, a fifty five minute long composition consisting of four movements.

To understand the title of the composition, which is, in part, directly related to its formal elements, an explanation of the correlation is required. Webster defines azimuth as the "horizontal direction expressed as the angular distance between the direction of a fixed point (as the observer's heading) and the direction of the object." Commonly it is used to describe the linear path of an object originating from a starting point with relation to its degree of deviation from a path heading due north. For those who have worked with tape machines, the azimuth has to do with aligning the tape path in relation to the tape heads. The composition of Azimuth was begun with a very specific sub-score, to be explained later, as a starting point, which evolved for the creation of each of the various sections. This evolution occurs in a linear fashion in that the origin of each score can be traced back to this single sub-score that was used to generate the first sample. This method enabled the creation of relational yet time varying score data, a sense of overall formal structure as well as a general thematic direction.

II. Preliminary Considerations

A. Constraints and Considerations

The conceptual stage of the composition began with a list of constraints and guiding factors. The ideas listed here are specific criteria that were predetermined to be focused upon throughout the process. They involve decisions made with regard to previous compositions; ways to improve, extend or simply deviate from what had been done before, as well as new ideas to integrate into the process. It could be viewed as a comprehensive philosophy of composition that could take a lifetime to refine as it changes and grows to meet the specific needs of each new composition.

• Design ways to create the widest degree of contrast between the various elements of the composition. In electronic music, timbral contrast sometimes seems difficult to achieve.
• This composition will have a quasi symphonic form and will be comprised of four movements, each with unique characteristics setting it apart from the others.

• Create a wide array of density; density being defined as the value of duration in relation to start time. Shorter start times and longer the durations create a more frequent overlap in events, providing a greater density.
• Create sections that are contrapuntal in nature and others that are not and many degrees in between.
• Create sections where phrasing is a consideration. While melody in a traditional sense is not desired, an allusion to melody would be present in certain areas.
• Make tempi widely variable from section to section and in general from movement to movement.
• Write code in the orchestra to make the choice regarding which global effect is to be used, variable on an event by event basis.
• Remember to include many little nuances to give it that extra something. Use these to tie things together as well. Boulez called this "virtual orchestration".
• Include areas syntactic in nature as well as areas more soundscape in nature. A soundscape would, in this context, be defined as a composition or section of a composition, which is devoid of syntax.
• When creating base samples have each base sample morph to each of the other base samples.
• Create a detailed plan (schema) for the mixing of the samples. This is to achieve the maximum degree of variance between samples.
• Retrograde some of the scores.
• Provide for flexibility in the schema, which allows it to be altered while in the process of creating the samples; if a particularly "rich vein" is found, develop it.
• Extend previously used panning algorithms to include more waveforms to provide more variables on an event by event basis. This will disperse the stereo panorama over a greater range and create space for each event. This is especially important for areas of higher density but is beautiful in those of lower density as well.

B. The Process

The process utilized for the composition of Azimuth stems, in part, from a plan for a workshop on Algorithmic Composition developed in partnership with Otto Laske. This workshop was envisioned as a three step system, utilizing Csound in conjunction with Cmask, meant to emulate Otto's process of "score based sampling", which involved Kyma and either Cmask or Project One. The thought was that not every venue for such a workshop would have a Kyma system available but Csound and Cmask would be universally available.

The basic idea was to give the participants four samples, each approximately six seconds in length. They were then to mix these samples in various combinations, using Cmask to generate the scores, to create samples of approximately 15 seconds in length. The next step was to combine these 15 second long samples in various ways, again utilizing Cmask and adding a few effects, to make 90 second long samples. The final step was to mix any or all of these samples into a composition.

While at first this approach seemed very simple, the power and expressiveness were soon revealed. It became obvious that this was a very subtle and yet dynamic approach to algorithmic composition. By the time work began on Azimuth, several pieces had been composed, each of which began with this basic approach. Each one expanded it and took it to new and greater depths. The possibilities associated with this very basic premise are endless and extremely musical.

The extension of this approach for Azimuth was to create a schema, shown below, to precisely guide the process of the creation of the samples. Instead of four samples the intention was to begin with sixteen; four groups of four. Also, recent reading about how Koenig had formalized a mixing technique for three samples in the composition Essays sparked an interest in utilizing a variation of this approach for Azimuth. Of particular interest was the idea of morphing the samples from one to the other. Ultimately, the extension of this idea was to create four samples, considering them the base sample of each of four groups. Group One was comprised of base sample one, base sample one morphing to base sample two, base sample one morphing to base sample three and base sample one morphing to base sample four. Group Two was base sample two morphing to base sample one, base sample two morphing to base sample three and so on for all the four groups. It became evident as the planning continued that each sample group adequately represented the potential for a different movement. It was surprising that, even at this stage, the form of the piece was beginning to solidify. This initial “out of time” work, to use the vernacular of Laske and Xenakis was seriously and directly impacting the “in time” composition. After the base samples were established, as with the workshop, a set of 15 second long samples and finally a set of 90 second long samples were to be created. As the final step, all samples would be imported to and subsequently mixed in a DAW environment utilizing a multi-track editor/recording software such as DP or Sonar.

C. Base Samples

1. Selection

The selection of the samples was integral to establishing diversity and contrast. To create the base samples the program Absynth, by Native Instruments, was used. Four factory presets, each very different from the other were selected. The next step was tweaking and changing them until they were sufficiently unique, diverse and personal. Although such descriptions are quite subjective, they consisted of:

Base Sample, Group 1: A metallic cymbal-like hit (1/4 second in length).
Base Sample, Group 2: A bell/flute-like sound (one second in length).
Base Sample, Group 3: A bass sound (two seconds in length).
Base Sample, Group 4: A stretchy metallic sound (three seconds in length).

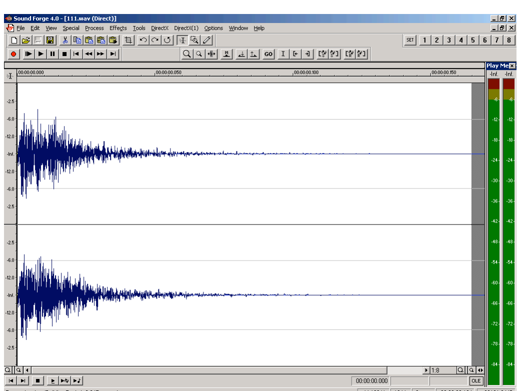
2. Morphing

The concept of morphing for this composition was comprised of simply cross-fading from one sample to another, creating a smooth transition. To morph the samples in this manner a stereo waveform editing program was used. Various sections of the secondary samples were blended with the original base samples until they sounded natural and smooth. This was not easy because of the diversity of sonic components of each. In most cases the secondary samples were cut down in size so that an exact portion fit perfectly with the primary sample and could be utilized to make an altogether new sound, which had a relationship to the original two samples but was its own entity as well. This involved removing the attack portion of the secondary sample, using only the sustain portion, inserting a smooth linear fade for its attack and laying it over the base sample which had been truncated about halfway through its sustain segment and linearly faded out. In essence this was transitioning from one timbre to another. The reasoning behind it was to provide a relational quality between some of the score events, those that used the morphed samples, which would subsequently be mixed within a single group and within other groups, thus tying the movements together timbrally.

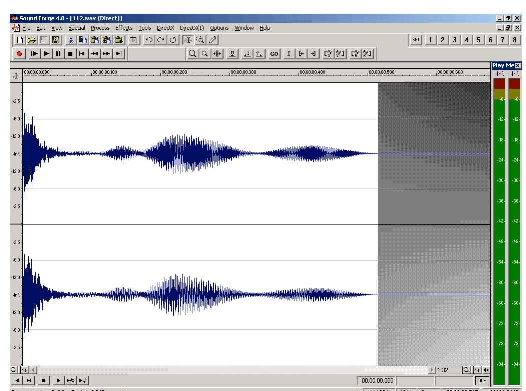
As can be observed by looking at the waveforms in the screenshots of the samples below, the beginning of each sample within a group is the same. The second portion is dependant upon the secondary sample. See Step 0 in the Schema, below, for clarification on this process.

Group 1:

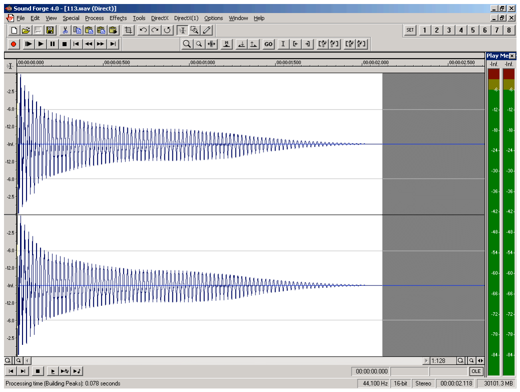
Sample 0111 – Base Sample



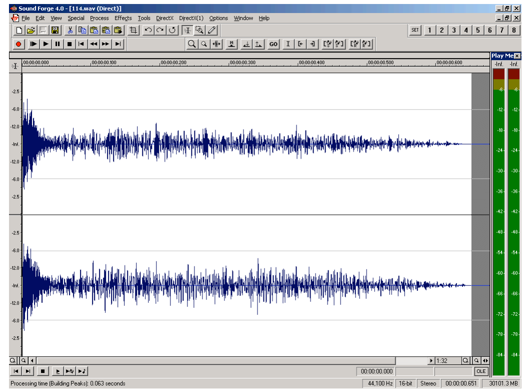
Sample 0112



Sample 0113

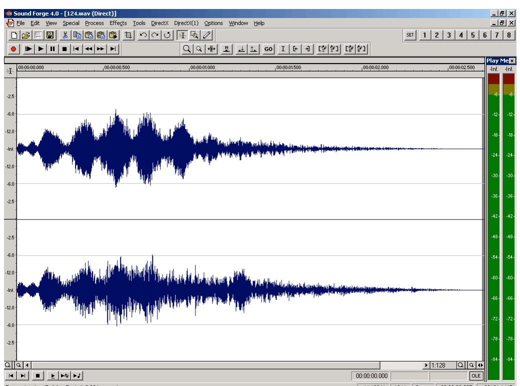


Sample 0114

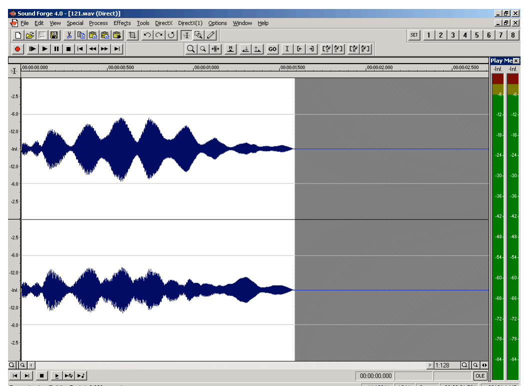


Group 2:

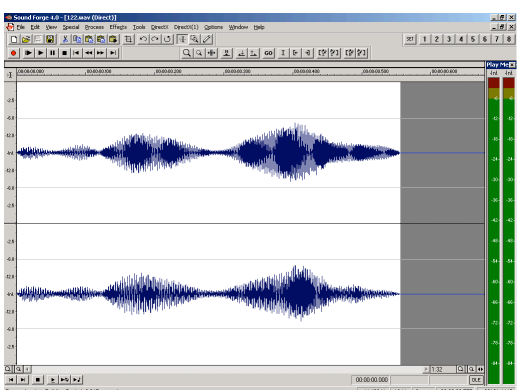
Sample 0121 – Base Sample



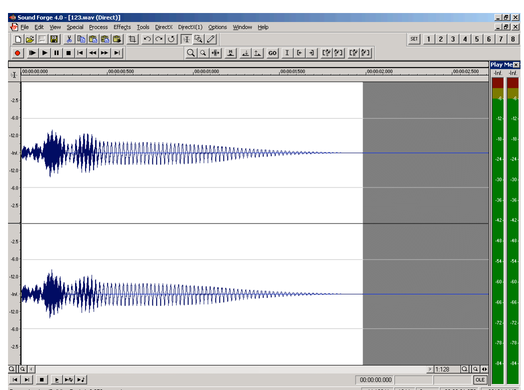
Sample 0122



Sample 0123

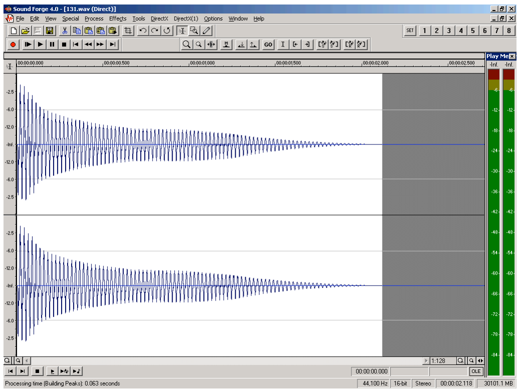


Sample 0124

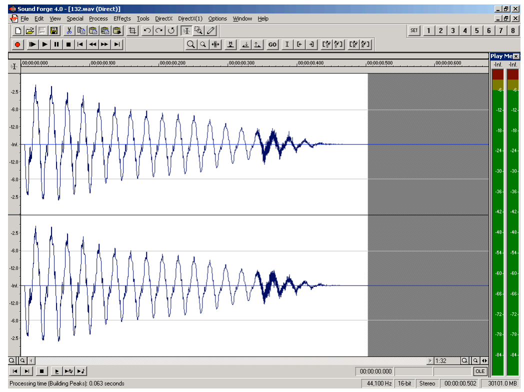


Group 3:

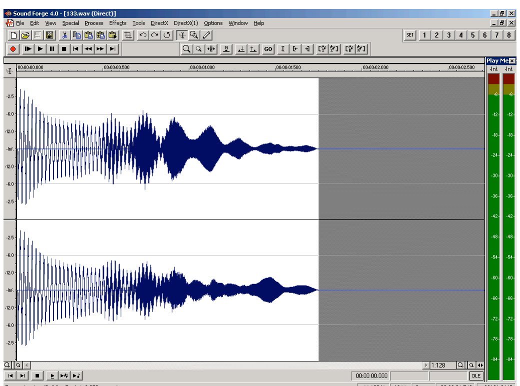
Sample 0131 – Base Sample



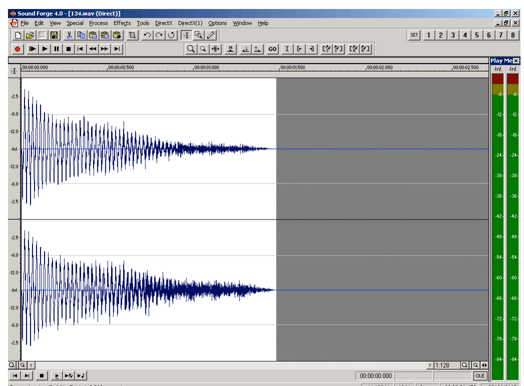
Sample 0132



Sample 0133

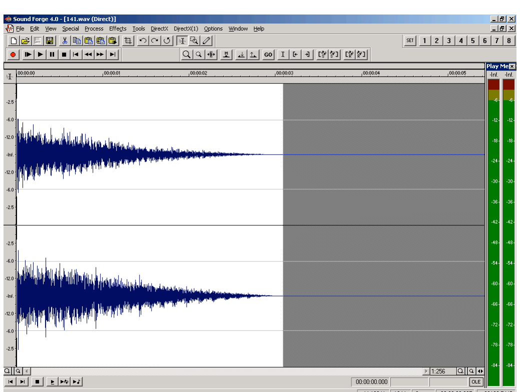


Sample 0134

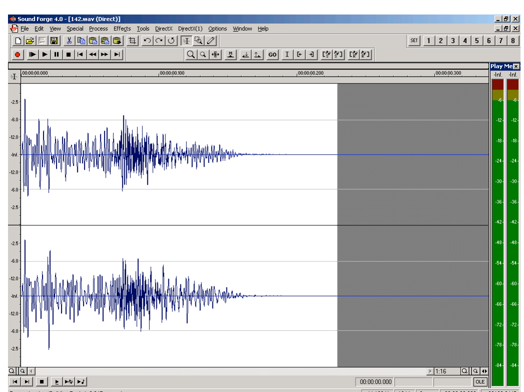


Group 4:

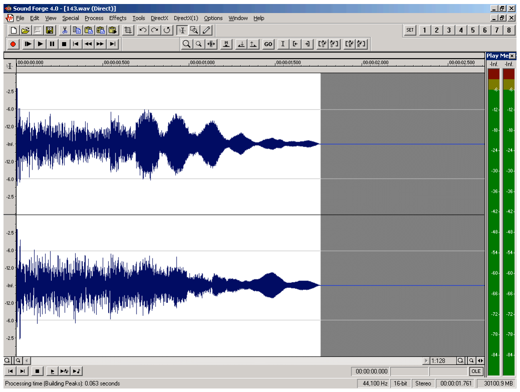
Sample 0141 – Base Sample



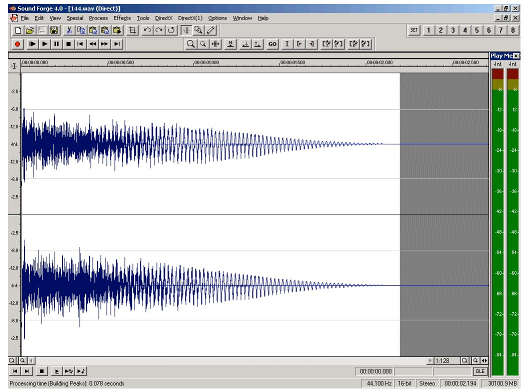
Sample 0142



Sample 0143



Sample 0144



III. The Schema

The original idea for creating a schema, meant to formally determine the various possible combinations of samples, was to create a multitude of related sample variants in order to provide the greatest diversity of sonic combinations. However, with this approach came a risk that needed to be considered; creating sounds that consist of a high degree of interrelatedness could produce homogeneity of sound that would nullify the very diversity sought. As it began to take form, the complexity of creating such a schema became apparent. About halfway through the first draft came the realization that creating this schema was in fact designing the composition as a whole on many levels, the most prominent being that of surface level structure. Each section created would ultimately consist of an individual form based on two factors: First, the Cmask sub-score used to create it and second, the selection of samples to be combined to create it (determined in the schema). The schema was crucial in determining how the piece was to move through time with regard to, first of all, formal elements such as themes and sub themes, motives, subtle nuances and etc., created by the similar yet different results of interactions between specific samples and common or related sub-scores and secondly through the ebb and flow of the timbral quality of each sample created. At this point the process was begun again, this time with a clear purpose.

Below is a representation of the spreadsheet worked from to create the schema. It was necessary to designate a naming convention that would make it easy to identify the samples, so a four digit number was used. The first digit, on the left, is the “Step” number, the second was the “Mix” number, the third the “Group” number and the fourth the “Sample” number.

Step 0:

This first section of the Schema exemplifies the original sample designations for the four groups.

Step 0 - Create 1 - 3 second samples (16 samples created)

Sample names
= Step-Mix-Group-Sample (example 1111)

Group 1

0111	Base Sample #1
0112	Morph group 1 base to group 2 base
0113	Morph group 1 base to group 3 base
0114	Morph group 1 base to group 4 base

Group 2

0121	Base Sample #2
0122	Morph group 2 base to group 1 base
0123	Morph group 2 base to group 3 base
0124	Morph group 2 base to group 4 base

Group 3

0131	Base Sample #3
0132	Morph group 3 base to group 1 base
0133	Morph group 3 base to group 2 base
0134	Morph group 3 base to group 4 base

Group 4

0141	Base Sample #4
0142	Morph group 4 base to group 1 base
0143	Morph group 4 base to group 2 base
0144	Morph group 4 base to group 3 base

Step 1:

In Step 1 the idea was to create 64 samples of 10 – 15 seconds in length. It must first be stated that a single Csound orchestra was used to create all the samples in this step. Here is an excerpt of the code:

```
instr 1

idur        =       p3
iamp        =       p4
ifreq       =       p5
kbal        =       p6
iatk        =       p3 * .1
idec        =       p3 * .2

kenv1 linseg        0, iatk,    iamp,    idur - (iatk + idec),    iamp,    idec,    0

a1, a2 diskin       1,          ifreq,   0,         1

            outs    (a1 * (kbal - 1)) * kenv1,      (a2 * kbal) * kenv1

endin
```

As can be seen this is a simple instrument. It is a stereo sample playback unit allowing for variable amplitude, frequency and static panning on a per event basis in the score. Also there is a duration dependant amplitude envelope meant to smooth any inconsistencies in the samples being used. Four of these instruments were used, all of them identical except for the sample number.

Mix 0 was begun by creating a Cmask sub-score meant to generate a Csound score that utilized sample 0111, the base sample from Group 1, to create 4 new samples. Here is an excerpt of the Cmask code (sub-score) used to create the first score:

```
f  0  30                                  ; Field start time and duration

p1 const 1                                ;instrument number constant

p2                                        ;start time
rnd uni                                   ;random uniform distribution
mask (0 0 10 5) (0 8 10 10)               ;Time Value Time Value ...
prec 0                                    ; no decimal places

p3                                        ;idur
rnd exp 1                                 ;random exponential distribution
mask (0 11 10 20) (0 20 10 30)            ;Time Value Time Value …
prec 2                                    ; two decimal places

p4                                        ;iamp ( Range 0 - 1)
rnd uni                                   ;random uniform distribution
mask .30 .76                              ;range .30 - .76
prec 2                                    ; two decimal places

p5                                        ;ifreq (Range -10 - 10)
rnd uni                                   ;random uniform distribution
mask -4.15 4.16                           ;range -4.15 – 4.16
prec 2                                    ;two decimal places

p6                                        ;kbal (Range 0 - 1)
range 0 1                                 ;uniform distribution between values
prec 2                                    ;two decimal places
```

Below, in the row marked “sample” were the names of the sample(s) that were started with and in the row marked “result” were the names of the samples created. Notice the general density designation for each row. Colors were used to make it easy to spot the origins of the results and later the origins of the reiteration process.

Step 1 - Create 10 - 15 second samples (64 samples created - approx. 16 minutes)

Mix 0 - Developing base samples

	Group 1	Group 2	Group 3	Group 4	NOTES
					Density = Start time vs. duration
Samples	0111	0121	0131	0141	
Results	**1011**	**1021**	**1031**	**1041**	Low Density
	1012	**1022**	**1032**	**1042**	Medium Low Density
	1013	**1023**	**1033**	**1043**	Medium High Density
	1014	**1024**	**1034**	**1044**	High Density

Mix 1- Mixing samples within each group

	Group 1	Group 2	Group 3	Group 4	
Samples	0111	0121	0131	0141	
	0112	0122	0132	0142	
	0113	0123	0133	0143	
	0114	0124	0134	0144	
Results	**1111**	**1121**	**1131**	**1141**	Low Density
	1112	**1122**	**1132**	**1142**	Medium Low Density
	1113	**1123**	**1133**	**1143**	Medium High Density
	1114	**1124**	**1134**	**1144**	High Density

Mix 2 - Mixing samples between groups

	Group 1	Group 2	Group 3	Group 4	
Samples	0111	0112	0113	0114	
	0121	0122	0123	0124	
	0131	0132	0133	0134	
	0141	0142	0143	0144	
Results	**1211**	**1221**	**1231**	**1241**	Low Density
	1212	**1222**	**1232**	**1242**	Medium Low Density
	1213	**1223**	**1233**	**1243**	Medium High Density
	1214	**1224**	**1234**	**1244**	High Density

Mix 3 - Morphing between groups

	Group 1	Group 2	Group 3	Group 4	
Samples	0111 to 0121, 0131 or 0141	0121 to 0111, 0131 or 0141	0131 to 0111, 0121 or 0141	0141 to 0111, 0121 or 0131	
	0112 to 0122, 0132 or 0142	0122 to 0112, 0132 or 0142	0132 to 0112, 0122 or 0142	0142 to 0112, 0122 or 0132	
	0113 to 0123, 0133 or 0143	0123 to 0113, 0133 or 0143	0133 to 0113, 0123 or 0143	0143 to 0113, 0123 or 0133	
	0114 to 0124, 0134 or 0144	0124 to 0114, 0134 or 0144	0134 to 0114, 0124 or 0144	0144 to 0114, 0124 or 0134	
Results	**1311**	**1321**	**1331**	**1341**	Low Density
	1312	**1322**	**1332**	**1342**	Medium Low Density
	1313	**1323**	**1333**	**1343**	Medium High Density
	1314	**1324**	**1334**	**1344**	High Density

Step 2:

In Step 2 the orchestra becomes both more complex and more versatile. Four global effects units were added; reverb, delay, comb filter and chorus. As noted in the list of constraints, above, it was desirable to make these variable on an event by event basis for each instrument. The imodsel variable in instrument 1 allows for a number between 1 and 4 in pfield 8 of the score to determine which global variable will be activated at initialization time for each event. The kpan variable determines the panning for each event at the control rate. Values between 0 and 1, to one decimal place, determine a static panning position while a value above 1 up to 9 would determine a dynamic panning position depending on the envelope controlling it. (Panning modulation is a very powerful tool for creating space in a composition. With it an envelope determines the position of the source sound, which moves through the stereo panorama in time.) Also the sample number is a variable in the score at pfield 7, isfile. This allows for a set of "possible" samples being available according to a weighted distribution. The possible samples are determined in the sub-score as stipulated by the schema. Below is one of four identical instruments utilized for this step.

```
;Global Variables (Modifiers)

garvb    init 0
gadelay  init 0
gacomb   init 0
gachorus init 0


instr 1

idur        =       p3
iamp        =       p4
ifreq       =       p5
kpan        =       p6
isfile      =       p7
imodsel     =       p8

iatk        =       p3 * .1
idec        =       p3 * .2

;pan envelopes
kenv1 linseg        0,      idur * .5,  1,      idur * .5,  0
kenv2 linseg        1,      idur * .5,  0,      idur * .5,  1
kenv3 linseg        0,      idur,       1
kenv4 linseg        1,      idur,       0
kenv5 linseg        0,      idur * .5,  .5,     idur * .5,  0
kenv6 linseg        1,      idur * .5,  .5,     idur * .5,  1
kenv7 linseg        0,      idur * .5,  .75,    idur * .5,  0
kenv8 linseg        1,      idur * .5,  .25,    idur * .5,  1

;amplitude envelopes
kenv11 linseg       0, iatk,    iamp,   idur - (iatk + idec),   iamp,   idec,   0

a1, a2 diskin       isfile,     ifreq,      0,      1

a3          =       a1 * kenv11
a4          =       a2 * kenv11

kenv20      =       (kpan <3  ? kenv1:kenv2)
kenv21      =       (kpan =4  ? kenv3:kenv20)
kenv22      =       (kpan =5  ? kenv4:kenv21)
kenv23      =       (kpan =6  ? kenv5:kenv22)
kenv24      =       (kpan =7  ? kenv6:kenv23)
kenv25      =       (kpan =8  ? kenv7:kenv24)
kenv26      =       (kpan =9  ? kenv8:kenv25)
kbal        =       (kpan <=1 ? kpan:kenv26)

;modulator select
if imodsel = 4 goto out4
if imodsel = 3 goto out3
if imodsel = 2 goto out2

            outs    a3 * (kbal - 1),        a4 * kbal
garvb               =       garvb + ((a3 + a4) * .25)
if imodsel = 1 goto end

out2:
            outs    a3 * (kbal - 1),        a4 * kbal
```

```
gadelay     =           gadelay + ((a3 + a4) * .5)
if imodsel = 2 goto end

out3:
            outs        a3 * (kbal - 1),        a4 * kbal
gacomb                  =           gacomb + ((a3 + a4) * .5)
if imodsel = 3 goto end

out4:
            outs        a3 * (kbal - 1),        a4 * kbal
gachorus    =           gachorus + ((a3 + a4) * .5)

end:
endin
```

Below is an excerpt of a sub-score (Cmask file) that was used in conjunction with the Step 2 instruments to create the sample results for Step 2:

```
;init global instruments
{

i5  0  110                                          ;global variable and associated start times
i6  0  110
i7  0  110
i8  0  110

}

;instr1                                             ;instrument number

f 7  75                                             ; Field start time and duration
p1 const 1                                          ;instrument number constant

p2                                                  ;start time
rnd uni                                             ;random uniform distribution
mask (0 10 60 10) (0 27.5 60 25)                    ;Time Value Time Value ...
prec 2                                              ;two decimal places

p3                                                  ;idur
rnd uni                                             ;random uniform distribution
mask (0 10 20 15 45 12) (0 17 40 15 45 18)          ;Time Value Time Value ...
prec 2                                              ;two decimal places

p4                                                  ;amp
rnd uni                                             ;random uniform distribution
mask (0 .35 75 .40) (0 .45 75 .60)                  ;mask .35 .75
prec 2                                              ;two decimal places

p5                                                  ;ifreq
rnd uni                                             ;random uniform distribution
range -.25 4.25                                     ;range of values
prec 2                                              ;two decimal places


p6                                                  ;kpan (0 - 8)
item swing (0 .1 .2 .3 .4 .5 .5 .6 .7 .8 .9 1 2 3 4 5 6 7 8 9)      ;swing distribution of values listed
prec 1                                              ;one decimal point

p7                                                  ;isfile select sample file
item random (1311 1312 1311 1314)                   ;random distribution of values listed

p8                                                  ;imodsel
item heap (1 2 3 4)                                 ;heap distribution of values listed
prec 0                                              ;no decimal place
```

The following is the section of the Schema for Step 2.

Step 2 - Create 60 - 90 second samples (18 samples created - approx. 22.5 minutes)

Mix 4 - Mixing Step 1 intergroup results

	Group 1	Group 2	Group 3	Group 4	
Samples	1011 .. 1014	1021 .. 1024	1031 .. 1034	1041 .. 1044	
	1111 .. 1114	1121 .. 1124	1131 .. 1134	1141 .. 1144	
	1211 .. 1214	1221 .. 1224	1231 .. 1234	1241 .. 1244	
	1311 .. 1314	1321 .. 1324	1331 .. 1334	1341 .. 1344	
Results	2411	2421	2431	2441	Low Density
	2412	2422	2432	2442	High Density

Mix 5 - Mixing Step 1 intermix results

	Group 1	Group 2	Group 3	Group 4	
Samples	1011 .. 1014	1111 .. 1114	1211 .. 1214	1311 .. 1314	
	1021 .. 1024	1121 .. 1124	1221 .. 1224	1311 .. 1324	
	1031 .. 1034	1131 .. 1134	1231 .. 1234	1331 .. 1334	
	1041 .. 1044	1141 .. 1144	1241 .. 1244	1341 .. 1344	
Results	2511	2521	2531	2541	Low Density
	2512	2522	2532	2542	High Density

IV. Evolution of the Sub-score

Some mention of the approach utilized in manipulating the sub-scores is pertinent. An initial sub-score was utilized to create the first sample in Step 1, Mix 0, Sample 1011. This sub-score was compiled and recompiled, with regard to the density factor designated for it in the notes section of the Schema, until it started yielding desirable results. When the final version of the sample had been produced, the sub-score that generated it was used as a starting point to create the next sample, 1012. It was manipulated and massaged until it yielded desirable results. This process continued through Group 1 to the first sample of Group 2 and so forth through all the samples in Step 1. This progression continued for the creation of the samples in Step 2 as well, although the score required additional p-fields, due to the expanded orchestra, that had to be integrated into the sub-score. This procedure engendered a linear progression of sample development and provided a cohesive structural element for the overall form of the piece.

V. Score Manipulation

Final score manipulation was accomplished with the use of a spreadsheet program. After the sub-score had produced an accepted score, there were times when it was desirable to further manipulate it. When this happened the score file was opened as a tab delimited file in a spreadsheet program and the data massaged into the ideal form. The reason for the use of a spreadsheet for this is that data can not only be edited in horizontal rows as with any text editor, but also in vertical rows. This allows the composer to transpose sections of concurrent pfields with ease. Another benefit is that a formula can be easily applied to a set of cells to aid in this transposition. One example of this is retrogression of events in a given score to produce another score, thus playing events in reverse order. Also, if there happened to be one area of the score that was especially attractive, the data could be analyzed and then emphasized to extend these areas to create more of the desirable results.

VI. Final Mixing

When all the samples were created the last step was to import them into a multi-track editor/recording software for final assembly. At first this seemed like an overwhelming task but due to the planning in the beginning, this went very smoothly. The samples were lined up so that Group 1 samples were for the 1st movement, Group 2 the 2nd and so on. They were lined up in the order in which they were created and little else was required other than to align them properly. Sometimes they were overlapped to varying degrees and sometimes there were breaks between them. Some samples were eliminated and some were duplicated. Some were truncated and some stretched. The base samples and several of the Step 1 samples were used here and there as accents or compliments to what was occurring. There were also a few serendipitous “mistakes” that were made during the sample creation process that were just too good to pass by and so they were kept and then ultimately fitted into position as well.

VII. Conclusions

This dynamic approach to algorithmic composition, an extension of those developed by the pioneers in the field, is a powerful way to create a very musical composition. The computer plays a unique role in the process, assuming many of the computational functions in which, traditionally, the composer would be required to engage, allowing more freedom to oversee the project as a whole and maintain a more creative focus in the situation in general. By feeding it pre-determined constraints, the computer can come up with the specific instances that can be chosen from and further manipulated as required. This process resembles sculpting in that the composer is given, by the computer, a mass amount of data to work with and is given the opportunity to see and release the David that ultimately lives within it.

It is hoped that the delineation of the process utilized in the creation of Azimuth can be of benefit to others who are searching for ever improving ways to release the music that is within. Embracing the limitless possibilities afforded the composer through the development of a formal score in addition to the fine art of sound creation, whether it is through sample manipulation or other digital synthesis techniques, is extremely powerful and rewarding. Musical sense can indeed be made of sounds that are comprised of relational characteristics, even if such sounds are new and heretofore unheard of in the ears of men.

Many thanks and credit should be extended to Otto Laske and Sylvia Pengilly for their faith, conversation and encouragement, without which this paper would not exist.

Appendix: This is the schema shown as a whole.

Step 0 - Create 1 - 3 second samples (16 samples created)

Results = Step-Mix-Group-Sample (example 1111)

Group 1	
111	Base Sample #1
112	Morph group 1 base to group 2 base
113	Morph group 1 base to group 3 base
114	Morph group 1 base to group 4 base
Group 2	
121	Base Sample #2
122	Morph group 2 base to group 1 base
123	Morph group 2 base to group 3 base
124	Morph group 2 base to group 4 base
Group 3	
131	Base Sample #3
132	Morph group 3 base to group 1 base
133	Morph group 3 base to group 2 base
134	Morph group 3 base to group 4 base
Group 4	
141	Base Sample #4
142	Morph group 4 base to group 1 base
143	Morph group 4 base to group 2 base
144	Morph group 4 base to group 3 base

Step 1 - Create 10 - 15 second samples (64 samples created - approx. 16 minutes)

	Group 1	Group 2	Group 3	Group 4	NOTES
Mix 0 - Developing base samples					Density = Start time vs duration
Samples	111	121	131	141	
Results	**1011**	**1021**	**1031**	**1041**	Low Density
	1012	**1022**	**1032**	**1042**	Medium Low Density
	1013	**1023**	**1033**	**1043**	Medium High Density
	1014	**1024**	**1034**	**1044**	High Density
Mix 1- Mixing samples within each group	**Group 1**	**Group 2**	**Group 3**	**Group 4**	
Samples	111	121	131	141	
	112	122	132	142	
	113	123	133	143	
	114	124	134	144	
Results	**1111**	**1121**	**1131**	**1141**	Low Density
	1112	**1122**	**1132**	**1142**	Medium Low Density
	1113	**1123**	**1133**	**1143**	Medium High Density
	1114	**1124**	**1134**	**1144**	High Density
Mix 2 - Mixing samples between groups	**Group 1**	**Group 2**	**Group 3**	**Group 4**	
Samples	111	112	113	114	
	121	122	123	124	
	131	132	133	134	
	141	142	143	144	
Results	**1211**	**1221**	**1231**	**1241**	Low Density
	1212	**1222**	**1232**	**1242**	Medium Low Density
	1213	**1223**	**1233**	**1243**	Medium High Density
	1214	**1224**	**1234**	**1244**	High Density
Mix 3 - Morphing between groups	**Group 1**	**Group 2**	**Group 3**	**Group 4**	
Samples	111 to 121, 131 or 141	121 to 111, 131 or 141	131 to 111, 121 or 141	141 to 111, 121 or 131	
	112 to 122, 132 or 142	122 to 112, 132 or 142	132 to 112, 122 or 142	142 to 112, 122 or 132	
	113 to 123, 133 or 143	123 to 113, 133 or 143	133 to 113, 123 or 143	143 to 113, 123 or 133	
	114 to 124, 134 or 144	124 to 114, 134 or 144	134 to 114, 124 or 144	144 to 114, 124 or 134	
Results	**1311**	**1321**	**1331**	**1341**	Low Density
	1312	**1322**	**1332**	**1342**	Medium Low Density
	1313	**1323**	**1333**	**1343**	Medium High Density
	1314	**1324**	**1334**	**1344**	High Density

Step 2 - Create 60 - 90 second samples (18 samples created - approx. 22.5 minutes)

	Group 1	Group 2	Group 3	Group 4	
Mix 4 - Mixing Step 1 intergroup results					
Samples	1011 .. 1014	1021 .. 1024	1031 .. 1034	1041 .. 1044	
	1111 .. 1114	1121 .. 1124	1131 .. 1134	1141 .. 1144	
	1211 .. 1214	1221 .. 1224	1231 .. 1234	1241 .. 1244	
	1311 .. 1314	1321 .. 1324	1331 .. 1334	1341 .. 1344	
Results	2411	2421	2431	2441	Low Density
	2412	2422	2432	2442	High Density
Mix 5 - Mixing Step 1 intermix results	**Group 1**	**Group 2**	**Group 3**	**Group 4**	
Samples	1011 .. 1014	1111 .. 1114	1211 .. 1214	1311 .. 1314	
	1021 .. 1024	1121 .. 1124	1221 .. 1224	1311 .. 1324	
	1031 .. 1034	1131 .. 1134	1231 .. 1234	1331 .. 1334	
	1041 .. 1044	1141 .. 1144	1241 .. 1244	1341 .. 1344	
Results	2511	2521	2531	2541	Low Density
	2512	2522	2532	2542	High Density