EXTENDING GENDYN

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ABSTRACT

This paper reports on a project that integrates the Matlab algorithmic development environment and Iannis Xenakis' Gendyn sound and composition synthesis engine as implemented by Peter Hoffmann in The New GENDYN Program. This integration has provided a framework for exploring and extending the capabilities of The New GENDYN Program, and thereby the GENDYN algorithm itself. Specifically, we investigate the possibilities of the GENDYN algorithm to define many simultaneous synthesis tracks, sound event distribution in time, and sound event parameters in time. We explore granular sound synthesis and the continuity of sound and compositional structure between the bouncing digital sample vertices within elastic barriers of the GENDYN algorithm and the large-scale form of a work's sound mass. We discuss a representation of the GENDYN algorithm based on a geometric organization of digital samples and sound entities, and make extrapolations and correspondences that may prove fruitful for further investigation.

1. INTRODUCTION

Here we report on a project exploring The New GENDYN Program by Peter Hoffmann (Hoffmann 2000), a rich and multi-layered tool for the generation of, and the investigating into, granular synthesis through dynamic stochastic synthesis, as well as very interesting extensions into other territories of sound. It permits the investigation of sonic structures and forms from the fundamental sample level, through to the higher level mass distribution of sonic structures in time. The New GENDYN Program has facilitated the uncovering of a perspective on sound that bridges the span between the representation of sonic quanta as grains and the representation of particles of information, combining them in a sort of dualistic model of sound. Iannis Xenakis' approach to algorithmic composition within the GENDYN framework was fundamental, drilling down to the most abstract representation of events through atomistic particles – in the case of GENDYN, not particles or quanta of sound as in his discussions and applications of granular synthesis, but particles of information represented as points in a space undergoing the stress of external forces within bounded limits.

With the New GENDYN Program it is possible to implement many multiple parallel sound synthesis tracks (up to 50), as well as many multiple individual sections (up to 50), that would contain those parallel tracks. This approach contrasts with Iannis Xenakis' implementation of his algorithm in Gendy3 and S.709. In the case of Gendy3, linear striations of sound were synthesized across 16 tracks (and in some cases, less than

16 tracks), and distributed among 11 sections. I highlight the differences in approach only to indicate the breadth, generality and flexibility of Xenakis' approach to nonstandard synthesis in the GENDYN algorithm itself. We present here an implementation of the GENDYN algorithm to sound and composition synthesis that stretches across the range of time scales with respect to the definition of the characteristics of a sonic entity, and the distribution of that sonic entity within a field of sound. Textures of sound mass were generated through various arrangements of synthesis parameters and events along the time axis: it was possible to develop granular synthesis, with sonic events randomly distributed, according to the probability distributions within Gendyn, where those same probability distributions also defined the timbre of the sound.

GENDYN sound mass and structures can vary widely. In some cases, sound distribution was quite sparse with long gaps of silence. However when many multiple layers of these sparsely distributed sonic events were produced, the resulting mass of sound had interesting qualities. One way to describe these large masses of interacting sonic events might be to suggest that they resemble clouds of swarming atomic sound particles streaming through space with an internal life and energy that radiates outward, is sometimes static and in-place, is sometimes linear in its development, or may be wildly erratic. The surface texture of this technique resembles an undulating mass with an internal life, where the whole is not equal to the sum of the separate parts but is perhaps emergent. This has been a common thread in the Gendyn experiments that have been explored and reported here.

The attempts to quantify and describe the organizational structure of the multiple tracks and sections of sound synthesis with the GENDYN algorithm have led to a way to represent the GENDYN algorithm itself that is geometric in nature and that appear to provide fertile ground for further investigation and implementation.

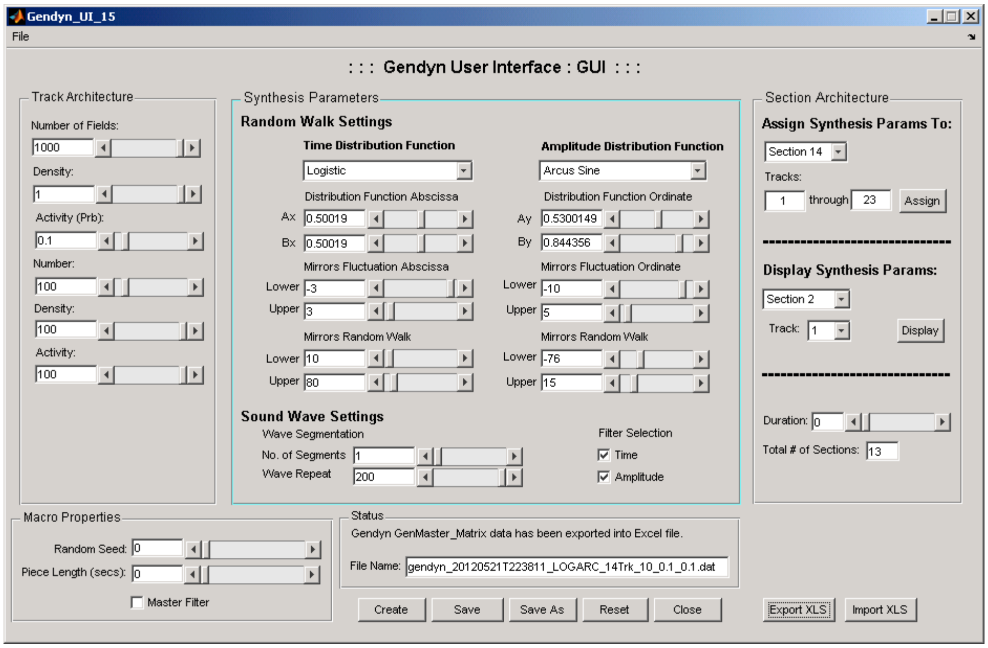
2. DISCUSSION

Figures 1 displays the Matlab implementation of the GENDYN user interface. The parameter controls of the New Gendyn Program have been translated into Matlab user interface controls. The specific parameters that motivated the initiation of this project were the "Tracks <Lo Val> through <Hi Val>" and "Total # of Sections" parameters in the Section Architecture parameter group. This permitted experimentation with respect to the distribution of sound events among a large number of tracks and a large number of sections. Roughly speaking, GENDYN tracks correspond to a vertical distribution of sound structure, and GENDYN sections correspond to a horizontal distribution of sound structure – each section contains a multitude of sonic events aggregated into masses of sound.

The Matlab implementation of the GENDYN user interface essentially creates a data file based on the parameters defined in the GUI itself. The data file contains the parameters and information that defines the probability distributions to be used for a given synthesis track, the distributions of sonic events in time, the number of tracks per section, and the total number of sections in a piece. This data file is then imported into the New GENDYN Program, where the computation of the sound takes place. To briefly describe a bit of background, the Matlab implementation progressed through iterations, wherein the first iteration managed to implement the same synthesis parameters imposed on all 50 possible tracks, where those 50 tracks were considered a single group. This configuration, although a limitation, did yield interesting sound mass and structures. However, flexibility with respect to the distribution of synthesis parameters across all 50 tracks became an obvious next step. So, in later iterations (described below), the 50 tracks were divisible into separate subgroups, each subgroup having varying numbers of tracks defined as needed. A means to vary the synthesis parameters within a given subgroup of tracks was then possible, creating the possibility for mixing different timbres within a large group of 50 tracks, in a given section. These differences could be subtle in nature, slightly adjusting a single parameter across several groups to create a specific graduated affect in the overall characteristic of the resulting sound mass. Or the differences could be dramatic, where entirely different and distinct timbre characteristics result.

It then became evident that a means to represent the number of subgroups within a given sequence (the terms sequence and section are used interchangeably here to mean an individual organizational structure of tracks; there are a maximum of 50 sections/sequences per piece, and 50 tracks per section), as well as the total number of sequences in a given piece, would be needed to manage the large number of events, and the organizational structures of those events. In the end, a maximum of 50 times 50 or 2500 total tracks could be created. A first attempt at representing these track groups/sections is depicted in figure 2. In this figure, we see a 50 by 50 grid, with each cell of the grid representing one track per section. A column of tracks could be 50 cells high, representing the 50 tracks of events. The two colours within each cell indicate a specific probability distribution has been selected for the synthesis parameters of the corresponding track, one distribution for the amplitude and one distribution for the time component. These distributions determine the ultimate positions of the polygon vertices that define the time-pressure curve of the sound.

By adjusting the three parameters of “Number of fields”, “Density” and “Activity”, it is possible to vary the distribution of events along the time-line of a track. One can specify that the distribution be sparse and open, or a dense amalgamation of events can be created. It is at this point where much experimentation and heuristic iterations can develop, resulting in many different combinations of sparseness and denseness, undulating characteristics and rich fields of sound.



: : : Gendyn User Interface : GUI : : :

Track Architecture

Number of Fields: 1000

Density: 1

Activity (Prb): 0.1

Number: 100

Density: 100

Activity: 100

Synthesis Parameters

Random Walk Settings

Time Distribution Function: Logistic

Amplitude Distribution Function: Arcus Sine

Distribution Function Abscissa: Ax 0.50019, Bx 0.50019

Distribution Function Ordinate: Ay 0.5300149, By 0.844356

Mirrors Fluctuation Abscissa: Lower -3, Upper 3

Mirrors Fluctuation Ordinate: Lower -10, Upper 5

Mirrors Random Walk: Lower 10, Upper 80

Mirrors Random Walk: Lower -76, Upper 15

Sound Wave Settings

Wave Segmentation: No. of Segments 1, Wave Repeat 200

Filter Selection: ☑ Time ☑ Amplitude

Section Architecture

Assign Synthesis Params To: Section 14

Tracks: 1 through 23 Assign

Display Synthesis Params: Section 2

Track: 1 Display

Duration: 0

Total # of Sections: 13

Macro Properties

Random Seed: 0

Piece Length (secs): 0

☐ Master Filter

Status

Gendyn GenMaster_Matrix data has been exported into Excel file.

File Name: gendyn_20120521T223811_LOGARC_14Trk_10_0.1_0.1.dat

Figure 1. Matlab GENDYN user interface.

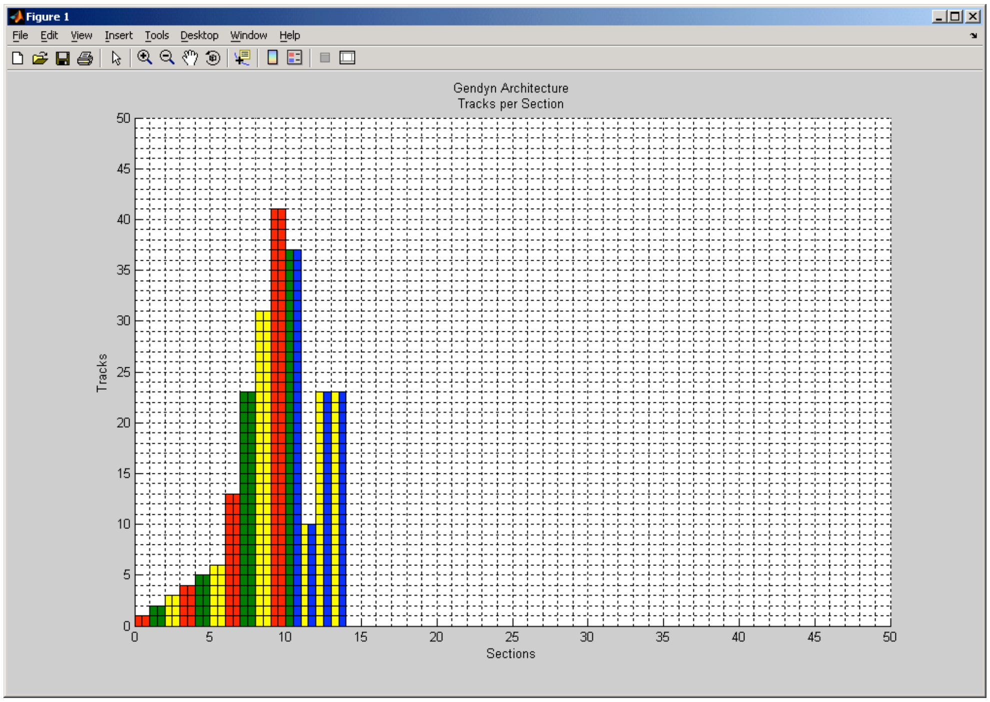


Figure 2. Gendyn section and track organizational structure as depicted via a matrix of color tiles. Each track in each section is represented by two color tiles each: the left-most half of the tile represents the time distribution function, and the right-most half of the tile represents the amplitude distribution function. This graph above reflects the settings defined in the user interface in figure 1.

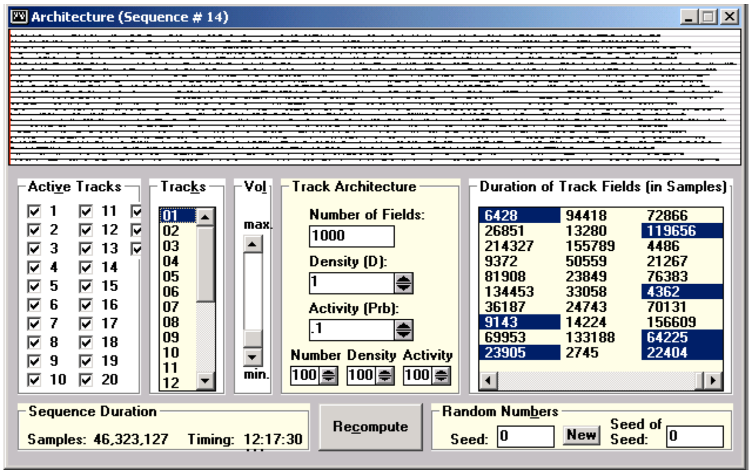
3. ANALYSIS

3.1. Granular GENDYN Timbre

Often, a particular sound synthesis parameter configuration might not be very interesting in and of itself. However if that one uninteresting sound track were multiplied by 50 and layered – with the sound events in each of those tracks randomly distributed in time – the result could be interesting. Tens or hundreds of thousands or millions of grains distributed in time with varying densities might present something interesting and stirring. A benefit of the GENDYN/Matlab program combination is that one can vary the "width" of the grain in time, within each track, randomly. In some cases, a sound field may be a very short and quick "blip" in the time line. In other cases, the sound field may be lengthened over a few seconds. And in some cases, the sound field might be tens of seconds long (this is the duration of an event that begins to approach those heard in Gendy3 or S.709). In addition, the content or timbre of the grain is defined by the synthesis engine of GENDYN, and the sound is dynamic and can change within a single "grain" or sound segment event.

The manner in which the GENDYN/Matlab implementation has been utilized starts with the definition of what may be called a sound palette – conscious heuristic decisions are made regarding an aspect of the makeup of the final work. It's an "exploratory expedition" of sorts, of computed timbres. Because it was decided to create the timbres in this way (via layers of tracks and layers of layers of tracks, etc), it was necessary to first define the structure and framework within which the machine could then also work in. Once the limits and extent of this framework is defined, it is certainly possible to let the machine carry on the process just as Iannis Xenakis had done in his implementation. But first one must define the structure of the framework, define what the possibilities are – the boundaries of a work – and then proceed. An automated process could then be initiated. In the case as presented here, the GENDYN data file is created with Matlab, the data file is loaded into the New GENDYN Program, the "Recompute" button is clicked, and the probability distribution functions through the program are set in motion. Then the New GENDYN Program would deposit a .wav sound file onto the hard drive. By extension, if one wanted to have multiple tracks for a multiple loudspeaker installation, one could define 8 or 16 Gendyn data files (for example), and load each into the New GENDYN Program, and create 8 or 16 .wav sound files for simultaneous playback performance.

Examples of computed stochastic granular GENDYN sounds are available at:
https://sites.google.com/site/abello110/.



Active Tracks: ☑ 1 ☑ 2 ☑ 3 ☑ 4 ☑ 5 ☑ 6 ☑ 7 ☑ 8 ☑ 9 ☑ 10 ☑ 11 ☑ 12 ☑ 13 ☑ 14 ☑ 15 ☑ 16 ☑ 17 ☑ 18 ☑ 19 ☑ 20

Tracks: 01 02 03 04 05 06 07 08 09 10 11 12

Number of Fields: 1000

Density (D): 1

Activity (Prb): .1

Number 100 Density 100 Activity 100

Duration of Track Fields (in Samples)

6428	94418	72866
26851	13280	119656
214327	155789	4486
9372	50559	21267
81908	23849	76383
134453	33058	4362
36187	24743	70131
9143	14224	156609
69953	133188	64225
23905	2745	22404

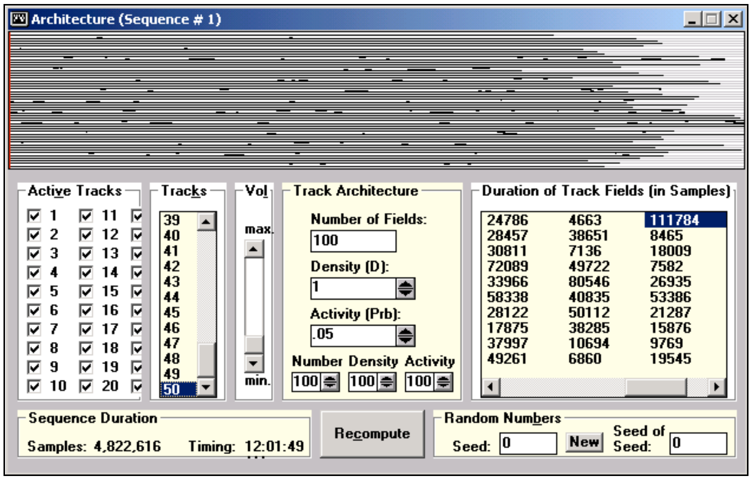
Sequence Duration

Samples: 46,323,127 Timing: 12:17:30

Random Numbers

Seed: 0 Seed of Seed: 0

(a)



Active Tracks: ☑ 1 ☑ 2 ☑ 3 ☑ 4 ☑ 5 ☑ 6 ☑ 7 ☑ 8 ☑ 9 ☑ 10 ☑ 11 ☑ 12 ☑ 13 ☑ 14 ☑ 15 ☑ 16 ☑ 17 ☑ 18 ☑ 19 ☑ 20

Tracks: 39 40 41 42 43 44 45 46 47 48 49 50

Number of Fields: 100

Density (D): 1

Activity (Prb): .05

Number 100 Density 100 Activity 100

Duration of Track Fields (in Samples)

24786	4663	111784
28457	38651	8465
30811	7136	18009
72089	49722	7582
33966	80546	26935
58338	40835	53386
28122	50112	21287
17875	38285	15876
37997	10694	9769
49261	6860	19545

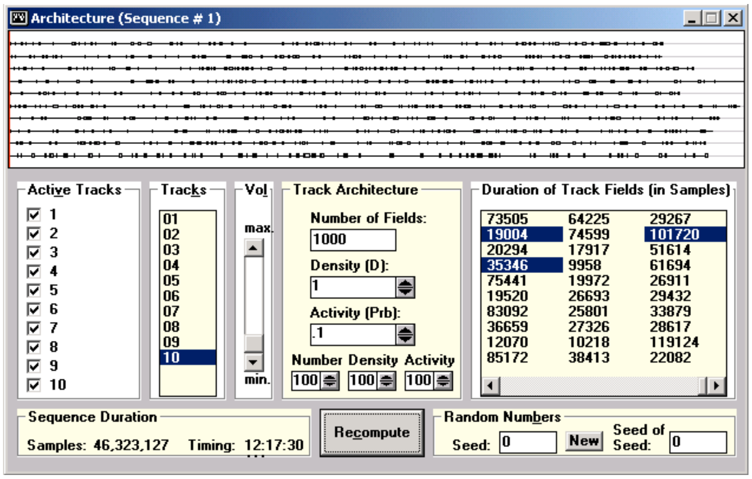
Sequence Duration

Samples: 4,822,616 Timing: 12:01:49

Random Numbers

Seed: 0 Seed of Seed: 0

(b)



Active Tracks: ☑ 1 ☑ 2 ☑ 3 ☑ 4 ☑ 5 ☑ 6 ☑ 7 ☑ 8 ☑ 9 ☑ 10

Tracks: 01 02 03 04 05 06 07 08 09 10

Number of Fields: 1000

Density (D): 1

Activity (Prb): .1

Number 100 Density 100 Activity 100

Duration of Track Fields (in Samples)

73505	64225	29267
19004	74599	101720
20294	17917	51614
35346	9958	61694
75441	19972	26911
19520	26693	29432
83092	25801	33879
36659	27326	28617
12070	10218	119124
85172	38413	22082

Sequence Duration

Samples: 46,323,127 Timing: 12:17:30

Random Numbers

Seed: 0 Seed of Seed: 0

(c)

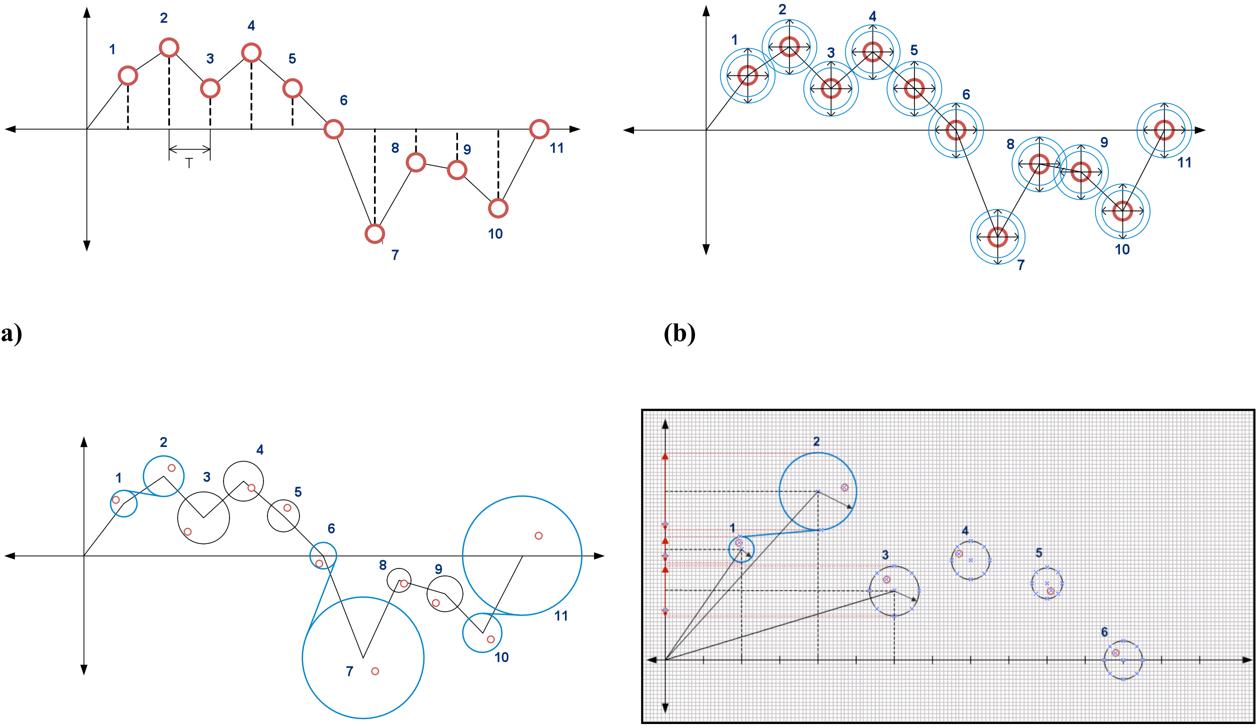
Figure 3. Three examples of stochastic granular distributions of sonic events in The New GENDYN Program, with parameters as defined using the Matlab user interface.

4. REPRESENTING GENDYN

Here we suggest ways to represent the GENDYN algorithm as relationships between and among geometric figures on a Cartesian plane. We will focus on two aspects of the GENDYN's sound characteristic, (1.) the time-pressure curve as a series of polygonal vertices and (2.) the organizational structure of the sonic events along the time-line of a GENDYN track. Further, we will touch on a discrete signal description of the GENDYN events, and then a digital logic gate representation of the GENDYN algorithm.

4. 1 THE POLGONAL TIME-PRESSURE CURVE

Following Xenakis' algorithm, consider a set of vertices of a polygon, representing discrete samples of a waveform. Figure 4 below shows 11 vertices, the 11th folds back onto the origin. The outer concentric circles of figure 4(b) represent the range of motion for that particular vertex in the horizontal and vertical directions. As in Xenakis' algorithm, there will be intervening samples inserted or removed between the red circles and depending upon the movement of the vertices, samples are interpolated or decimated. There are two separate probability distributions for each vertex, one to define movement for amplitude (y direction) and one to define movement for time (x direction). The consistent concentric radii of the 11 vertices indicate that the same set of two probability distributions are applied to all vertices.



(a) **(b)**

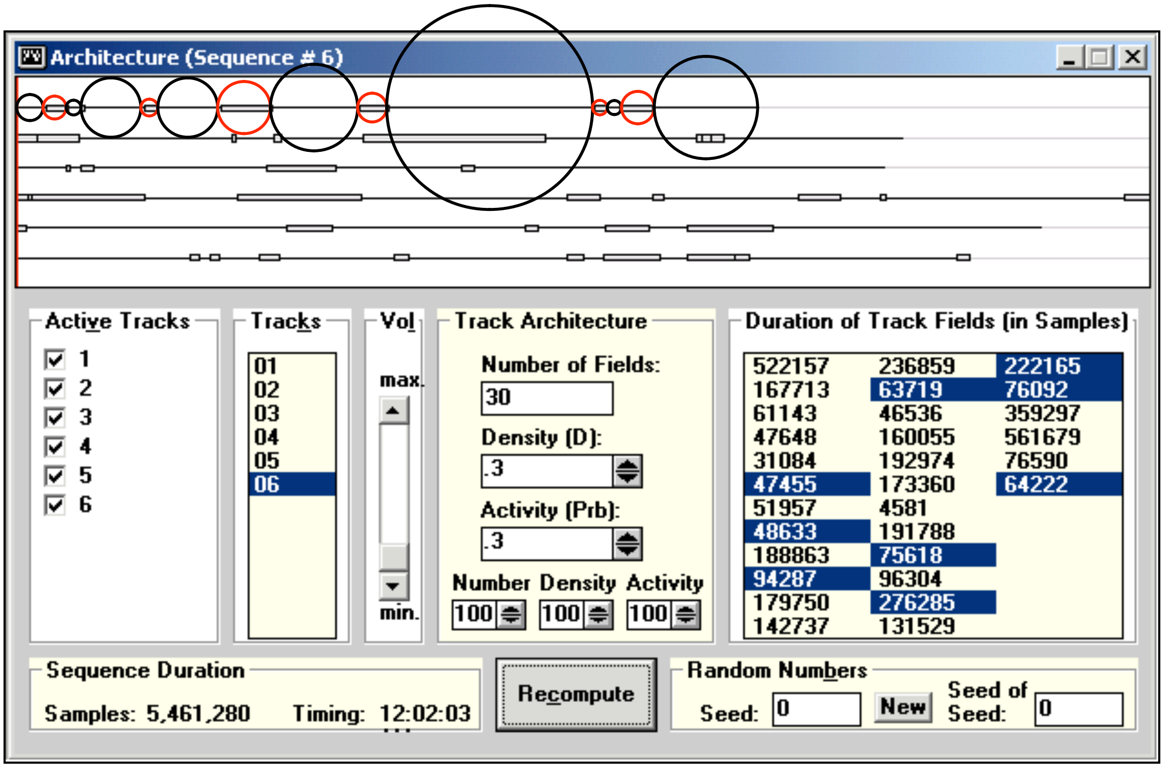
(c) **(d)**

Figure 4. The polygonal vertices with imposed boundaries of motion discussed in the text. Eleven samples considered as a subset of the totality of digital samples representing the computable sound. The intervening samples are determined via a decimation or interpolation process. According to the

GENDYN algorithm, each vertex has a range of motion in the horizontal and vertical directions where the position in each direction is dictated by two separate probability distributions. The range of motion for each vertex (i.e. the two probability distributions) is depicted by two concentric circles. In (c) the 11 vertices are shown, each having a different boundary of motion that could be defined by separate distributions for each vertex. Cross-coupling is indicated between vertices 1/2, 6/7, and 10/11. In (d), a grid is introduced onto which the vertices are arranged; the focus is on vertices 1-6. In this image, the polygon vertices are represented as vectors, with magnitudes and angles relative to the positive x-axis.

4. 2 THE EVENTS OF THE GENDYN TRACK ARCHITECTURE

Figure 5(a) is an example of a sparse distribution of sonic events along a GENDYN track time-line. Figure 5(d) is an example of a more dense stochastic distribution of events. As in the case of the polygonal vertices, our analysis dislocates the events from their GENDYN time-line, and places them in Cartesian space, isolated and floating, as in figures 5(b) and (c).



Active Tracks: ☑ 1 ☑ 2 ☑ 3 ☑ 4 ☑ 5 ☑ 6

Tracks: 01 02 03 04 05 06

Number of Fields: 30

Density (D): .3

Activity (Prb): .3

Number Density Activity: 100 100 100

522157	236859	222165
167713	63719	76092
61143	46536	359297
47648	160055	561679
31084	192974	76590
47455	173360	64222
51957	4581	
48633	191788	
188863	75618	
94287	96304	
179750	276285	
142737	131529	

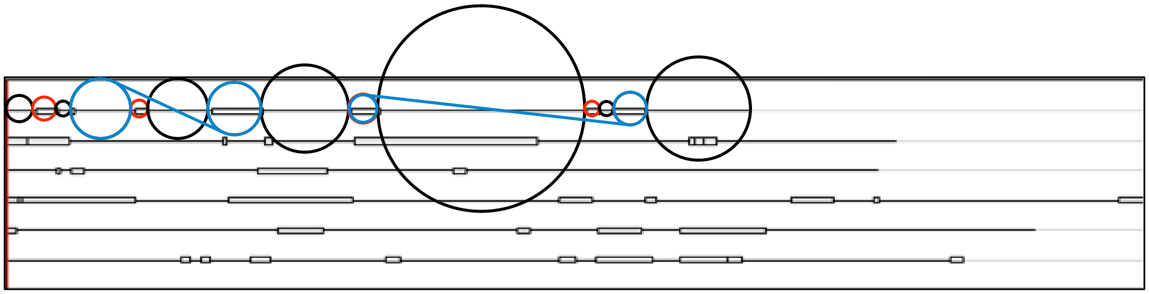
Sequence Duration

Samples: 5,461,280 Timing: 12:02:03

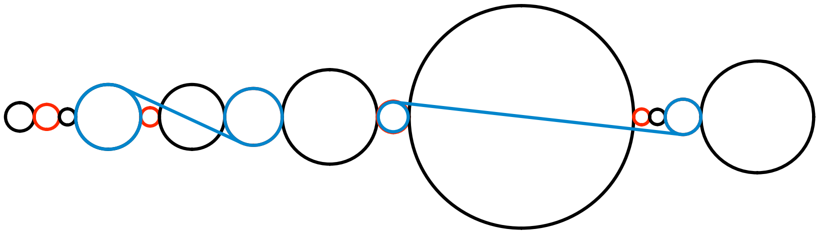
Random Numbers

Seed: 0 Seed of Seed: 0

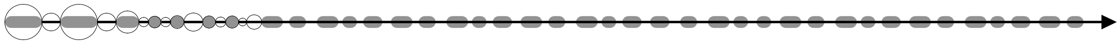
(a)



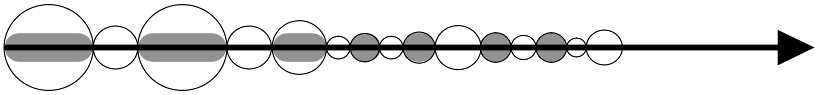
(b)



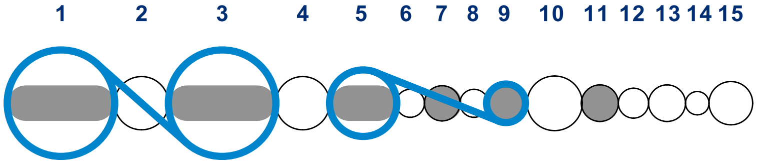
(c)



(d)



(e)



(f)

Figure 5. Geometry of GENDYN track architecture. The diameters of the circles introduced are proportional to the length of the corresponding event. (a) Broad sparse stretches of sound and silence on the track time-line displayed within the user interface of the New GENDYN Program; (b) dislocating the track architecture from the user interface and introducing cross-coupling/linkages between specific events/circles. The behaviour of one event would impose an influence on another event. Their properties would not necessarily be defined by a single probability distribution, but could be defined by an interplay among and between events within the same timeline, or coupling among and between differing probability distributions; (c) further detachment of the on/off events from the time-line; (d) short instances of sound and silence, approaching a dense granular scale and distribution; (e) focusing on the first several instances of sound and silence in the time-line; (f) further detachment of on/off representations from the time-line and re-presenting them as a geometric organization of objects, with cross-coupling linkages.

The equation of a circle is

$$(x-h)^2+(y-k)^2=r^2 \qquad (1)$$

We assume that the center of the circles in figure 5 reside on the x axis, therefore the value for *k* in equation (1) will be 0. Equation (1) then becomes

$$(x-h)^2 + y^2 = r^2 \qquad (2)$$

The radius of each circle is proportional to the duration of the associated events that the circles represent which could be either silence or sound. To establish a relationship between all individual circles/events, and the summation of those events (that represent the complete duration of an entire track), another circle is introduced whose circumference encompasses all of the other smaller circles, as in figure 6 below.

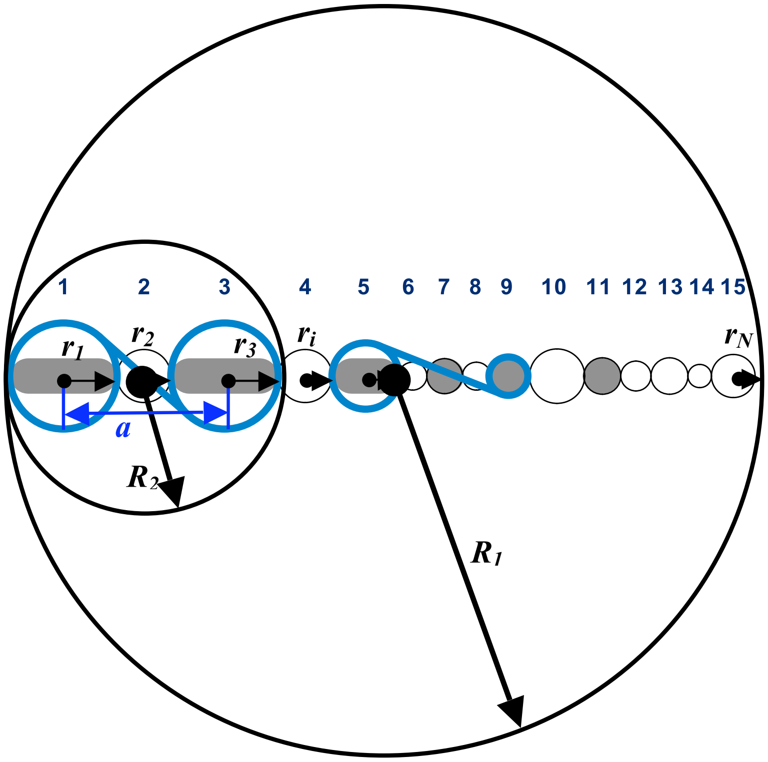


Figure 6. Representing the events of the GENDYN track architecture.

If R_1 represents the diameter of the encompassing circle, and r_i represents the individual circle diameters, the expression below could be used to describe the relation between the encompassing circle's radius and the individual events' radii.

$$R_1 = \sum_{i=1}^{N} r_i \qquad (3)$$

Focusing on the grouping of events represented by radius R_2 in the diagram, the length of the line segment *a* can be expressed in terms of the relationship between the radii of the cross-coupled circles as in equation (4) below

$$a = \sqrt{r_1^{\,2} + x^2} + \sqrt{r_3^{\,2} + y^2} \qquad (4)$$

where x and y are line segments that define the length of the hypotenuse of the two triangles that are formed by the line that connects the common tangent points of the two cross-coupled circles. The radius R_1 of the encompassing circle could be expressed as a ratio of the radius R_2, while the radii of the balance of the other circles remain constant. This relationship could provide a means to adjust specific events in the track timeline independently of other events, or provide an influence on other events. There can obviously be many more events included within the subset of circles defined by R_2 whose properties could be dictated by processes separate from the over-arching processes that define the entirety of the track architecture. Levels of distributions can be defined.

4.3 A Discrete Time Signal Representation of the GENDYN Polygonal Variation and Events

Consider a series of discrete samples, x[n], such that

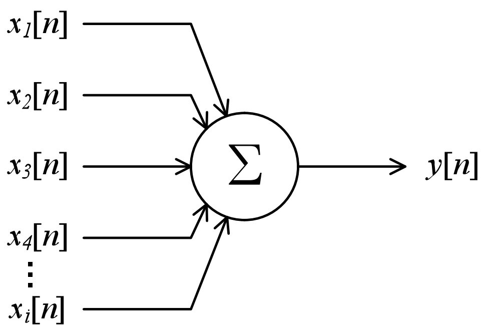
$$x[n] = \sum_{k=0}^{N} x[k]\partial[n-k] \qquad (5)$$

and

$$\partial[n] = \begin{Bmatrix} 0, n \neq 0 \\ 1, n = 0 \end{Bmatrix} \qquad (6)$$

is the unit sample sequence.

There are potentially 50 of such sample sequences in a given GENDYN section that are summed.



In the aggregate, the sum of all sequences will result in a single series representation of the sound output:

$$y[n] = \sum_{i=1}^{50} \sum_{k=0}^{N} x_i[k] \cdot \partial[n-k] \qquad (7)$$

If we introduce a random variable *a[k]* that represents a perturbation in the position of a vertex in the positive or negative amplitude direction, we can represent our sequence as

$$y[n] = \sum_{i=1}^{50} \ \sum_{k=0}^{N} a[k] \cdot x[k] \cdot \partial[n-k] \qquad (8)$$

4.4 Digital Logic Gate Representation of the GENDYN Algorithm

The GENDYN algorithm can be represented as a digital logic circuit. Figure 7 shows a part of the GENDYN algorithm utilizing primitive logic gates; we can consider this a first step towards a full digital circuit representation. Individual registers, latches, adders, and comparators are identified, and the function of each is established. In figure 7, inputs are defined as the random number generated by a probability distribution and the elastic barrier limit. Outputs are defined as the primary random walk output value, and the comparator output indicating whether the generated random walk value exceeds the elastic barrier limit or not. The diagram displays a rudimentary design of the random walk portion of the GENDYN algorithm, utilizing 16 bit digital samples in the logic gate realization. The circuit introduced here would yield the subset of points representing the polygonal vertices only, comparable to those illustrated in figure 4. An interesting project might be to implement the GENDYN algorithm as a complete digital electronic circuit.

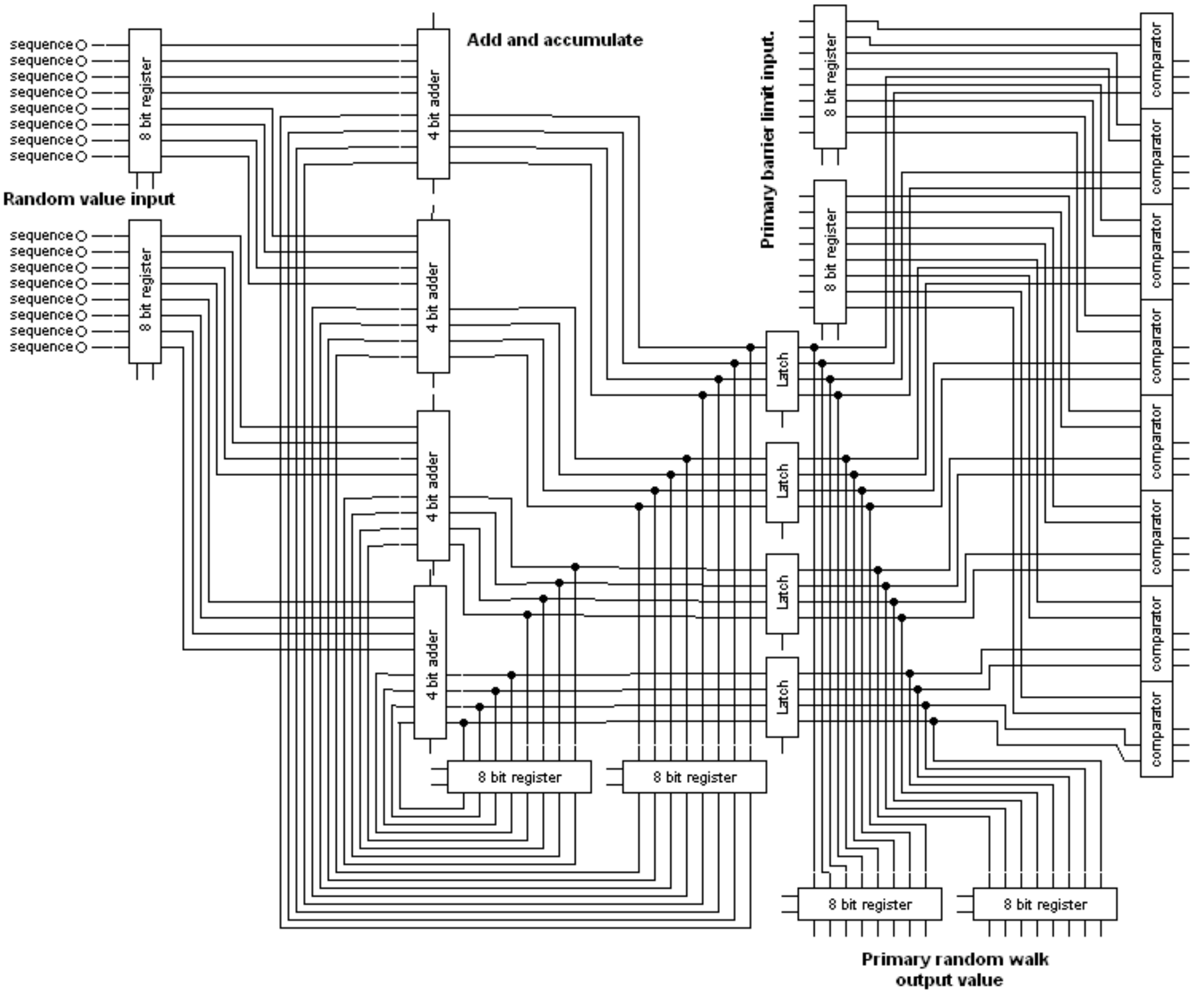
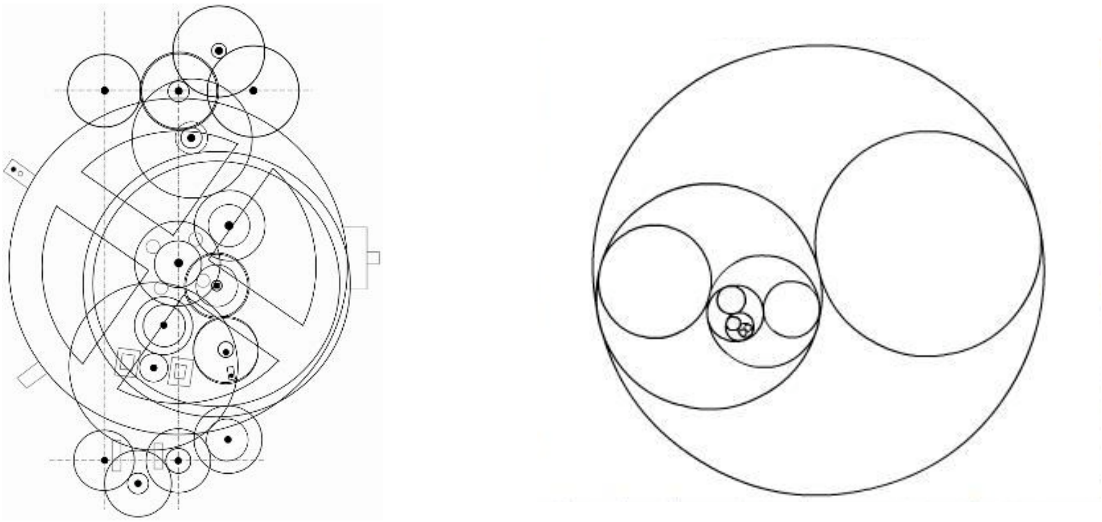


Figure 7. Logic gate implementation of the primary random walk portion of the GENDYN algorithm using a 16-bit word length. This circuit was realized using the Digital Works logic design software tool (see references).

5. Extrapolations and Parallels

The Antykithera Mechanism (Freeth 2006), (see figure 8(a) for a schematic representation; details of the device are provided in the reference), is a complex gear mechanism, thought to have been constructed in approximately 100 BC, in ancient Greece. The device is believed to have been a tool for determining the positions of the planets as well as predictions as to when lunar and solar eclipses were to take place. As a technological appliance, there has not been evidence of such technical proficiency and a realization of mathematical thought, for the following one thousand years. Whether the device can be considered a computer in the modern sense (Turing sense), has been debated. It seems apparent, however, that the methods encompassed in the device could certainly be applied or perhaps extended to implement the modern notion of computation, with appropriate care taken. A comparable (in sprit at least) clock has been developed as a "Google Plugin", by Forrest Oliphant (Oliphant 2007), see figure 8(b). We briefly discuss here these devices only to point out an interesting duality between analogue computers, of which the Antykithera Mechanism might be considered, and a modern realization of an algorithm of a digital clock, on which the Google clock is based.

One might imagine an "analogue GENDYN" that is powered by natural forces, dutifully turning the shafts and gears that dictate the multiple parameters and rules that define the positions of the vertices of the polygonal variations, and therefore the characteristics of an emergent sound. What was once a thought that had been substantiated into a tangible form, to predict the cosmos, and therefore an attempt to understand the whims of the gods over 2000 years ago, has been disrupted and then abstracted, over the intervening millennia, through mankind's attempts to understand the world and the forces that control it through reason, into the technological understanding of being that we experience in the present age. Could an analogue GENDYN be constructed to guide us to the saving power of the humble things?



(a) **(b)**

Figure 8. A schematic depiction of the Antykithera Mechanism (a), and a "Google Plugin" clock (b) developed by Forrest Oliphant (Oliphant 2007).

6. REFERENCES

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