Notes on Dynamic Stochastic Synthesis and The New GENDYN Program

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ABSTRACT

The New GENDYN Program by Peter Hoffmann is a faithful re-implementation of Iannis Xenakis' dynamic stochastic synthesis algorithm that was used to create his landmark piece Gendy3. The program also broadens the algorithm's capabilities by providing a real-time synthesis and graphical user interface environment, while serving as a platform for research in non-standard stochastic sound synthesis techniques and explorations in compositional form. We present a user report and survey of an ongoing project that is focused on understanding more thoroughly Xenakis' GENDYN algorithm via Hoffmann's program, as well as exploring algorithmic computer music composition in general, by taking advantage of the extended capabilities that are offered in Hoffmann's implementation, towards the creation of an original work with the program. Specifically, we investigate two domains not likely intended by the original algorithm or its realization in Hoffmann's program, that have none-the-less yielded interesting results: (1.) dynamic stochastic granular synthesis, and (2.) the application of a type of temperament – or tuning – of the GENDYN, that enables a kind of score synthesis with its own form of stochastically distributed counterpoint. We also explore aspects of algorithmic composition – and composition in general – that were illuminated during the development of the various workflow while using the New GENDYN Program for the development of a new work.

1. INTRODUCTION

Iannis Xenakis' dynamic stochastic synthesis algorithm (also interchangeably referred to as the GENDYN algorithm, for GÉNération DYNamique Stochastique), is a radical example of non-standard synthesis that emerged in the early 1990s with Xenakis' compositions *Gendy3* and *S.709* [1], [2]. The New GENDYN Program by Peter Hoffmann [3] extends Xenakis' original algorithm by essentially making it possible to replicate sound synthesis and architectural features on a much larger scale. For example, although Xenakis' own treatment of the algorithm was applied to sixteen simultaneous tracks of sound (Figure 1), Hoffmann's implementation permits as many as fifty simultaneous tracks. This paper describes an ongoing project into this feature of the program, and the opportunities that this approach to algorithmic composition and digital sound synthesis presents.

In [5] Hoffmann provides a description of the New GENDYN Program and its genesis, as well as a thorough investigation into the GENDYN algorithm itself and his research project of an analysis by resynthesis of Xenakis' landmark work *Gendy3*. In this paper, I will focus on that specific aspect of the New GENDYN Program that permits a multiplicity of sound synthesis events across a wide range of time scales, and, as we will also show, across ambitus scales. Along the way, I will also touch on the processes and workflow that were implemented, as well as thoughts on the implications of the methods undertaken within the framework of algorithmic computer music.

The New GENDYN Program was originally developed as an aid to assist with the musicological analysis (as well as forensics), of Xenakis' landmark work *Gendy3*, an analysis by resynthesis [3]. The application also has features that enabled the program to become a composition tool in and of itself. The author is familiar with at least one other instance where the New GENDYN Program was used for the creation of an original work [9].

I was first introduced to the application during its development in 1995-96, while attending the eight-month cursus at Les Ateliers UPIC in Alfortville. The eight month cursus eventually became a three year stay. Peter was gracious enough to provide me with a copy of the GENDYN application to experiment with. I immediately installed it on my Windows NT computer at the time. Initially, I found that the application was tricky to navigate due to my own inexperience with this new non-standard synthesis technique. In retrospect, I had spent most of my time in the late 1990s focusing on Xenakis' UPIC system at Les Ateliers UPIC, exploring its graphical interface and chaotic sound synthesis possibilities via its built-in FM capabilities. As will be explained later in this article, the experience of establishing a relationship with the New GENDYN Program, and therefore the dynamic stochastic synthesis algorithm itself, in retrospect, turned out to be a different undertaking altogether, from the similar experience when confronting the UPIC system some years earlier. A comparative study of the two platforms from an end-user's perspective would require, in the least, a separate paper altogether, to properly characterize the activities involved and work-flow necessary, and their implications, for realizing a framed result.

The composition tools (equipment) conceived by Iannis Xenakis present a unique and perhaps new type of challenge to composers wishing to incorporate them into their body of working methods. These systems are (perhaps intentionally) created to be broad blank canvases on which one does not only create a framed artifact, but one also creates an entire method, a creative ecosystem, a musical thinking space or sound world in which to inhabit, one that provides the latitude and flexibility for experimentation and pedagogy simultaneously.

This notion of constructing the rules and parameters within which to self-regulate is of course autodidactic in nature; it is a hallmark of both the UPIC system and the New GENDYN Program. If one commits to working with the application in an earnest way, how does one prevent the situation where the user may appear to simply mimic Xenakis' own efforts? How does one prevent what might ultimately become a redundant exercise? It is an almost forgone logical conclusion that, should you choose to use Xenakis' composition tools, you are forced to subvert the tool itself in hopes that you achieve an originality. You are *forced* into a position of heretical (ab)use of the given technology[1]. In my own experiences with these platforms, in the case of the UPIC system, it was transformed to become an algorithmic composition development environment. Graphical images and arcs on the UPIC page did not represent the imagined sound's properties along a timeline, indeed I utilized no UPIC arcs as intended by the system (see Figure 1).

Figure 1. The UPIC page for the piece *Maya (1997)*, by the author, showing a subset of the total of graphic arcs that make up the elements of the composition algorithm. In this case, the FM synthesis capabilities of the system were radically exploited. For the piece *Maya*, The UPIC system was performed in real-time, and captured to a DAT (digital audio tape) recording device.

[1] DiScipio discusses this here [13], Hoffmann addresses this aspect of a "heretical use of technology" here [14], p 36.

With the New GENDYN Program, the system – quite ironically – was transformed from a sound and composition synthesis system based on random walks and probability distributions, into one that was exploited to facilitate representing an array of pitched events within a time span in common practice notation. These systems, due to their open and fundamental nature, in the end, may say more about the individual who works with them than they do about the underlying technology used to realize a work.[2]

This project with the New GENDYN Program, some aspects of which are summarized in this paper, is described from a user's perspective, with the experiences encountered along the way towards creating my own works with this new technique. I've experimented extensively with the application endeavoring to understand its various capabilities, while taking advantage of its real-time sound synthesis features.[3] Over time, a catalogue of executions was compiled, where the parameter settings for each was noted and saved; the associated recordings for each parameter set were captured and archived as digital audio files. To date, over 1500 individual executions have been logged, of varying timbres, architectures, and combinations of distributions, and is growing. This catalogue acts as a reference while developing new compositions and constructions of new works. A methodical and analytical approach is what was necessary to establish a cohesive framework for such an open-ended tool and undertaking.

2. THE NEW GENDYN PROGRAM

2.1 Summary

In his original GENDYN algorithm, Xenakis had abstracted and organized tracks of sound across horizontal channels of time, that were aligned vertically (Figure 2). These multiple tracks of digital data were then summed, forming a single aggregated data stream whose values represented a time-pressure curve. This stream of data fed a digital-to-analog converter for the aural realization of a work. In this model, care was needed to prevent the amplitudes of the digitized sound from exceeding a threshold that would result in distortion.

[2] These platforms would have had to be designed in such a way to enable a personal style to ultimately emerge through persistent and systematic exploration by the user. And, of course, this is not limited to the tools devised by Xenakis. I have had similar experiences with other applications, one example is a software called *Cloud Generator* by Roads and Alexander [18], that facilitated another workflow altogether (introduced at Les Ateliers UPIC in 1995/96), resulting in a wide-ranging catalog of results that was part of a separate project on convolution methods.

[3] The New GENDYN Program is a 16 bit application. To continue using it while new operating systems and CPUs were introduced over the years, meant having to maintain a few Windows XP machines for the sole purpose of hosting the New GENDYN Program.

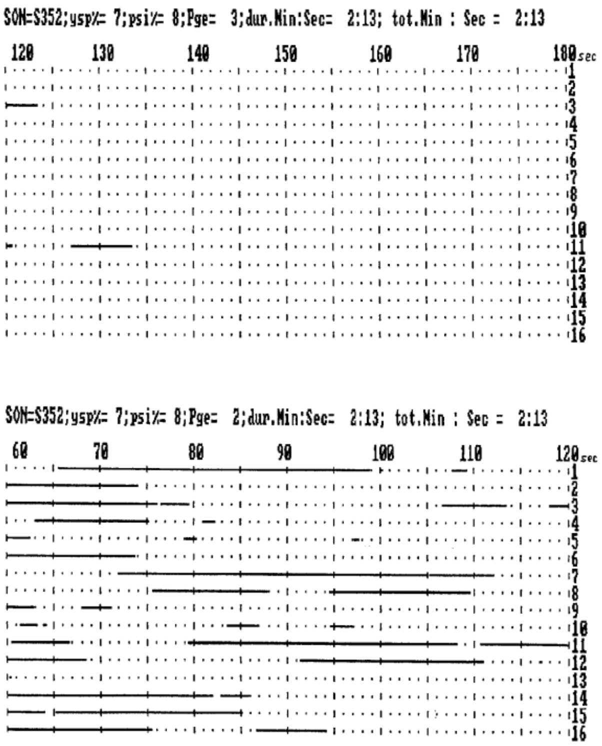

Figure 2. Two pages of a GENDYN score as presented in Xenakis' classic text Formalized Music.

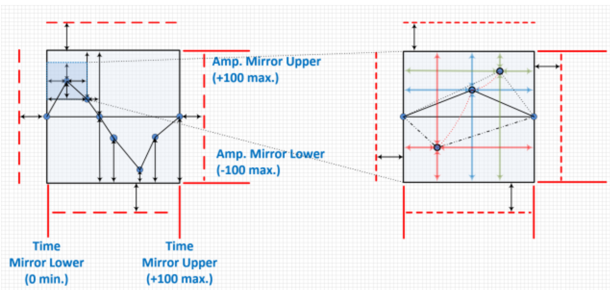

Figure 3. A schematic representation of GENDYN timbre synthesis geometry showing one cycle of a wave-form within boundary limits, followed by a single magnified vertex with an imagined displacement. The movement of this vertex (indeed all vertices of the waveform), follows a random walk that is influenced by a probability distribution function selected by the user.

Figure 3 shows a simplified model of the geometry of the dynamic stochastic sound synthesis engine, and the waveform breakpoints that are affected by the algorithm. The boundaries, or walls of the rectangle, are flexible and adjustable by the user through the interface of the program; waveform breakpoints that happen to exceed the defined boundaries are reflected into the "safe space" of the rectangle (which is presented as a square in this example, however the sides are movable based on initial conditions set by the user), thereby preventing excessive amplitude values that could result in unintended distortion. One full cycle of a waveform is contained within the boundaries, and the user can select the number of vertices for each cycle; in Figure 3 we see seven vertices for a cycle. Intervening samples between the vertices are calculated by a linear interpolation process. The positions of the vertices follow random walks that are influenced by the probability distribution function selected for that timbre. In the New GENDYN Program, each track of the total of 50 can have its own individual timbre that is unique from the other 49, or all 50 track timbres can be identical.

2.2 Algorithmic Composition Development Environment

The New GENDYN Program can be thought of as a composition development environment. Although aspects of the individual components of the application are fixed – i.e., there are only so many probability distribution functions to choose from, and a predefined range of possibilities for the initial condition parameters – there are many permutations of combinations of these various parameters, enabling a wide variety of timbral color and a range of large-scale formal architectures. Over time and through empirical heuristic iteration, a large catalog of timbres as well as macrostructure architectures was developed and documented. Patterns emerged with respect to the large-scale forms that the GENDYN algorithm generated, particularly with respect to the definition of the density of events across the multiple tracks via the *Number*, *Density* and *Activity* parameters (to be described in detail later).

Thus far, two areas emerged as being the most fertile for investigation while exploring the algorithm. The first is the ability to develop a form of dynamic stochastic granular synthesis. By judiciously adjusting the two sets of three architecture parameters – i.e., both the local and global parameters of the *Number*, *Density*, and *Activity* fields that drive the determination of events along the timeline – it is possible to sculpt densities of clouds of timbres. The New GENDYN Program extends the limits of scale with respect to the formal architecture of a given execution – an almost unlimited layering of sound on top of sound – making it possible to explore boundless distributions of events in time. This dynamic stochastic granular synthesis model that emerged proved to confirm the influence of low-level sample generation activity on the meso- and macro-level architecture of a GENDYN execution, and then of course on the emergent sound.

A second area of investigation was the algorithm's ability to generate steady-state pitched timbres, coupled with the increased scaling of the number of individual sound tracks. The GENDYN algorithm is well known for its seemingly limitless range of noise-like timbres and its arcing and curving glissandi. However, it is also possible to tune or temper the system such that a multi-octave range of pitches can be established. An entire ambitus of sustained and controlled tones, in various timbres, transforms the GENDYN into an algorithmically controlled generative pitched instrument, with an instrumental color palette, organized in such a way that is not unlike a pipe organ, with ranks and stops. An assortment of timbres has been catalogued (see Table A1), their associated parameter sets archived, enabling the possibility to arrange the instrumentation of a GENDYN execution for a desired timbral color.

Once a tempered GENDYN was established, an analysis of transcriptions of generated pitched clusters and melodies was then possible. These transcriptions of pitch distributions and accompanying melodic trajectories presented a form of stochastic counterpoint. The GENDYN would offer a cantus firmus on which additional voices of pitches could then be constructed. The stable pitched tones could be tuned to any frequency, or fraction thereof, permitting a subdivision of the modern twelve-tone equal temperament scale into a continuous spread of ambitus frequencies. Any temperament could in theory be programmed.[4]

2.3 Graphical User Interface and Real-Time Synthesis

Figure 4 shows the Track Architecture user interface window of the program, with the multiple tracks frame at the top of the figure. In the example, the same timbre was programmed across all tracks, however each track was assigned a different pitch (we will further explain this scenario in detail later).

Figure 5 shows the sound synthesis dialogue window of the New GENDYN Program. With this interface, the user can define the synthesis parameters for generating the timbres for each of the tracks of the timeline architecture in Figure 5. There is wide variability regarding tone color and sonic character that is dependent on the probability distribution function and the associated parameters selected. The combination of settings for these two dialogue interfaces work together to define an architecture at multiple levels of the synthesis engine for generating the completed result. This result can be self-contained, requiring no further adjustments: i.e., an autonomous work, executed in one go. It may be a subsection of a larger work. Further, it may form one of many layers or series of slices of synthesized sound where each slice adds a distinct layer of character to the resulting sound.

Each timbre can be previewed in real time, while synthesis parameters are adjusted, allowing the user to react to the changes. Parameters that define the distribution of events along the timeline for each track – the architecture of a work – can be adjusted with the effects witnessed in real time. For example, the density of events across all 50 tracks can be steadily increased or reduced by varying the *Number, Density and Activity* parameters during an execution.

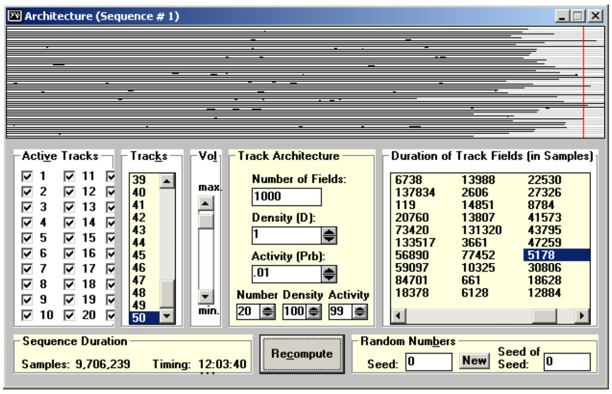

Figure 4. The track architecture dialogue of the New GENDYN Program user interface shown with the maximum number of 50 tracks of sound. This is one section of a GENDYN construction. There are potentially 50 separate sections that can be generated by the program, each with as many as 50 tracks.

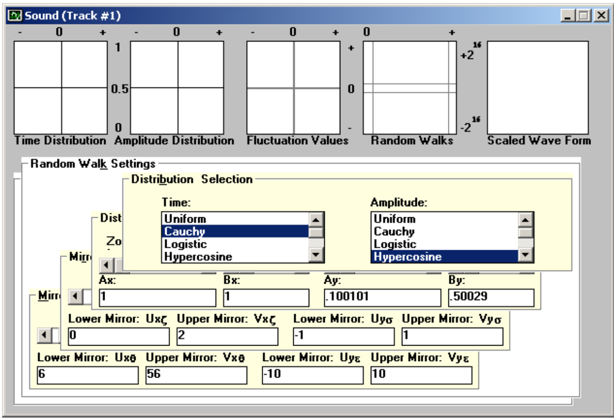

Figure 5. The timbre sound synthesis dialogue window of the New GENDYN Program.

2.4 Events and Time Scales

In figure 4, we also see the key variables that affect the distribution of events across the timeline. They are: *Number of Fields*, *Density*, and *Activity*. The combination of the *Number of Fields* and *Density* coefficient parameters are used to determine the duration of each field in each track using the exponential probability distribution. A field is nothing but a segmented section of a track along the timeline, and in this example, there are 50 tracks with 1000 fields per track. We are simply segmenting a line into constituent subunits. Once each segmented field duration is calculated, a decision must then be made to determine either the presence of sound, or of silence, for each field along the timeline. This is determined using a binary coin-tossing decision (i.e. on/off), where the toss can be biased based on the value of the *Activity* parameter.

There is a second set of *Number*, *Density*, and *Activity* parameters at the bottom of the Track Architecture section. These can be considered "Global Architecture Parameters", in that they will scale all “local” fields

[4] It is interesting to note here that, for the first time user of the UPIC system, a preprogrammed composition is available to load as an example, and is included with every installation of the software (now known as the UPIX application – a software only version of the system). This sample composition is a transcription of a J.S. Bach setting of a chorale, demonstrating the generality of the UPIC itself. The GENDYN algorithm, via Hoffmann’s realization, is in fact capable of this very demonstration. In fact, Werkmeister III tuning [19] – acknowledged as the temperament used by Bach – has been programmed into the New GENDYN Program for achieving similar tonal colors.

across all tracks in each sequence. These three parameters act as a type of scaler that are applied equally, across all events of the track architecture.

To the left of the figure, the track listings are indicated with accompanying check-boxes. In Hoffmann's implementation, it's possible to select specific tracks to be included, or not included, into the final aggregated result of digital sound data. However, one of the peculiarities of the user interface is that it is not possible to affect tracks 31 through 50 via the user interface itself, as they are hidden behind the boundary of that section of the interface. However, I considered this to be a feature, as it led to having to enter into the accompanying GENDYN data file. This data file is a container of all the parameters that make up the configuration of a given GENDYN execution. Manually editing the fields of this data file enables those parameters to be adjusted. Each execution of the GENDYN can be stored as an archive via this data file; a library of data files emerges over time.

2.5 Matlab GENDYN User Interface

However, it became apparent that as the full capabilities of the program were explored a revised user interface would be practical. One such interface was created in the Matlab development environment, shown in Figure 5. The Matlab interface was designed to permit the assignment of synthesis parameters to individual tracks, as well as to groups of tracks, within a given section, or across multiple sections. A parameter data file is the output, appropriately formatted, that is then read by Hoffmann's synthesis engine in the New GENDYN Program.

With the Matlab interface, it is possible to selectively assign the entirety of the synthesis parameters – i.e. the specification of the distribution functions, and all associated variables such as mirror boundary values, etc. – to individual tracks, as well as to large groups of tracks, copying parameters from one to another or to a group. Large collections of tracks could be programmed simultaneously, with subtle changes for each to create a desired timbral result.

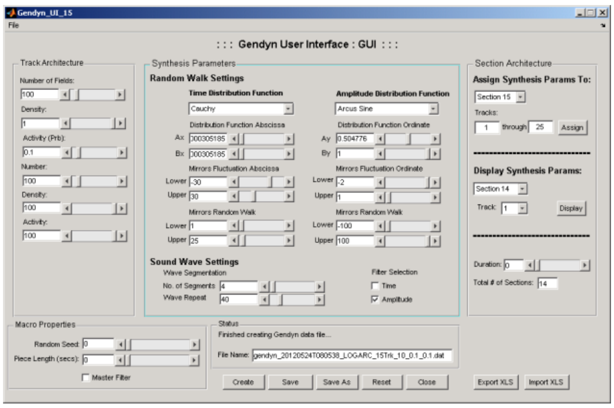

Figure 6. The GENDYN user interface as implemented in the Matlab programming environment.

3. DYNAMIC STOCHASTIC GRANULAR SYNTHESIS

3.1 High Density Synthesis Events

The New GENDYN Program provides a novel method for generating and organizing a multiplicity of events in time. This capability lends itself to granular synthesis techniques. Managing these scales of events in aggregate can become unwieldy, particularly when the events vary in duration from several microseconds and may number in the many tens or hundreds of thousands. The workflow procedures vary widely, we will briefly discuss the predominant methods that have been employed.

Layering many multiple timelines in parallel within a single execution of the sound synthesis engine yielded a variety of textures of timeline architectures. A timeline architecture is a single distribution of events in the timeline, containing up to 50 individual tracks. A given timeline architecture is defined by the *Number*, *Density* and *Activity* parameters (both local and global), to achieve the desired density of events within a timespan. Figure 4 shows an execution of the program where the initial conditions were established to deliver a sparse distribution of events across the fifty tracks, with varying durations; in this case event durations range from a fraction of a second to several seconds. Other densities are possible, including those that contain thousands of events each in the millisecond range, to those that contain events that extend for several minutes (Figure 7). Combinations of densities within the same execution deliver variations across the same span of time (Figure 8).

Timeline architectures can stand as self-contained works if the distribution of timbres is defined appropriately, or they can become part of a larger aggregation comprising of many multiple layers of separate timeline architectures. For example, aggregations that would amount to as many as 800 individual tracks (16 executions of 50 tracks each), have been generated. Of course, many more are possible, achieving yet still larger complex masses of sound.

The duration of a given execution is dependent upon the relationship between the local and global track architecture parameters (*Number*, *Density* and *Activity* field variables). Over time, as the catalog of executions began to grow, it became useful to more thoroughly understand this relationship, and its influence on the results of a given computation. Figure 9 presents event distribution curves for combinations of fixed variables, while adjusting the third parameter.

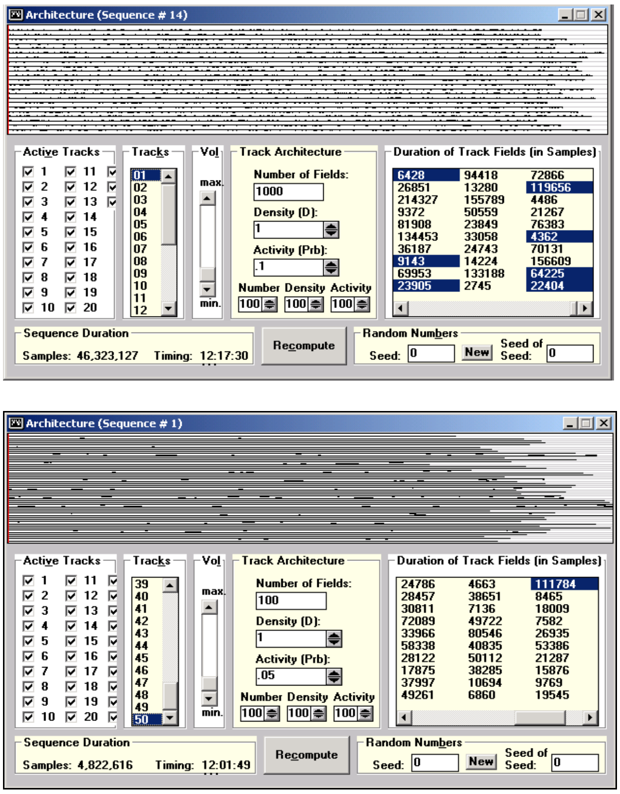

Figure 7. Two examples of stochastic granular distributions of events in The New GENDYN Program. The parameters across all tracks were defined using the Matlab user interface.

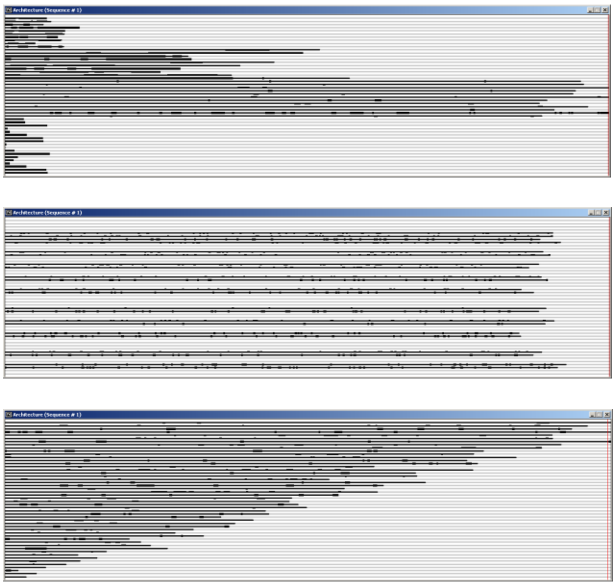

Figure 8. GENDYN architecture variations. Top: This GENDYN architecture demonstrates the effect of separately adjusting the local *Fields*, *Density* and *Activity* parameters for groupings of tracks. The duration of this architecture is 25 seconds. Center: Specific tracks can be silenced. Bottom: A tapering of the local *Density* parameter across the tracks.

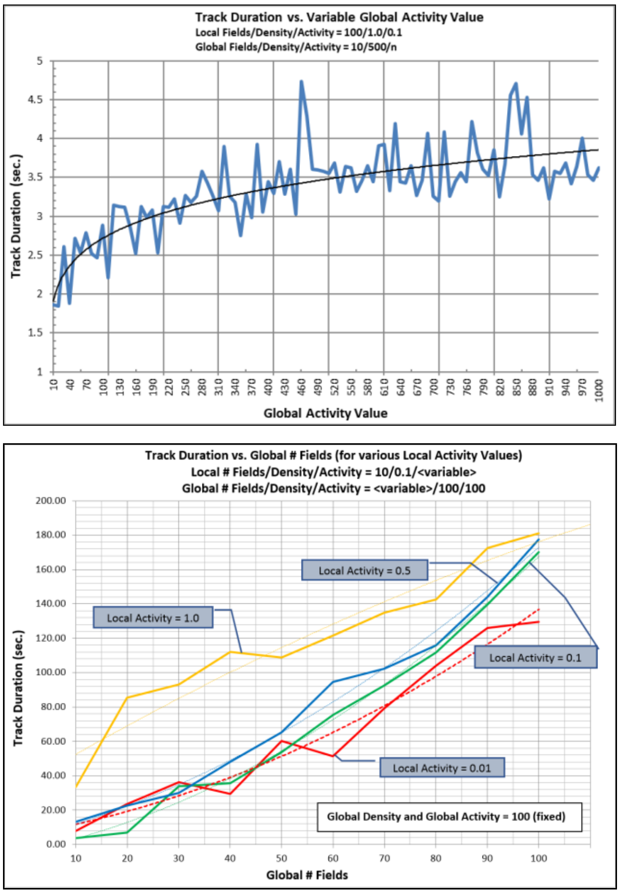

Figure 9. Two event density distribution curves for various GENDYN algorithm executions, with defined local and global architecture parameter settings. These curves provide a sense of the durations of the generated sound for particular combinations of architecure parameters.

4. A TEMPERED GENDYN ALGORITHM

4.1 Steady-State Timbres vs. Erratic Noise and Glissandi

An array of new timbres was developed and catalogued and organized with respect to the pair of probability distribution functions that characterize them. Each probability distribution function influences a pair of random walks: one distribution function influences the random walk that determines the amplitude (ordinate) value for all waveform vertices, and another distribution function influences the random walk that determines the time (abscissa) value of the vertices. For a given waveform, all amplitude values are influenced by the same probability distribution function, and likewise for the time value; it is not possible to apply different distribution functions for each vertex. As new timbres were created with their own distinctive sets of characteristic parameter definitions, it became clear that certain combinations of distribution functions created classes or groupings of timbres.

The variety of pitches that the dynamic stochastic synthesis algorithm creates could vary uncontrollably with respect to time: the characteristic glissandi undulate to and from a gravitational pitch center. Or, the jostling of the waveform breakpoints created rapidly moving melodies at such a high velocity they were received as smeared or compressed[5]. Ultimately it was discovered that certain combinations of the synthesis parameters resulted in fixed pitches, of varying timbres. Ultimately, tables of fixed pitches spanning across five octaves were defined. Consequently, the New GENDYN Program was transformed from a primarily non-standard timbre synthesis tool, into a complex tempered pitch instrument that permitted experimentation with tunings, tonalities and stochastically defined distributions of melodies and harmonies.

Eventually it became possible to define tonal centers that adhered to familiar keys or modes. Theoretically, since any steady frequency can be generated by the algorithm by adjusting the parameters accordingly, any temperament can be achieved across the fifty tracks of the architecture. In addition, it is possible to define the density and frequency of occurrence of sound events or silences along the timeline, across many multiple tracks of pitches. Executing multiple instances of these pitched constructions, and then superimposing them upon each other in a digital audio editor, permitted a layering not too unlike the layering of interlacing weaves within a tapestry or an intricate lace.

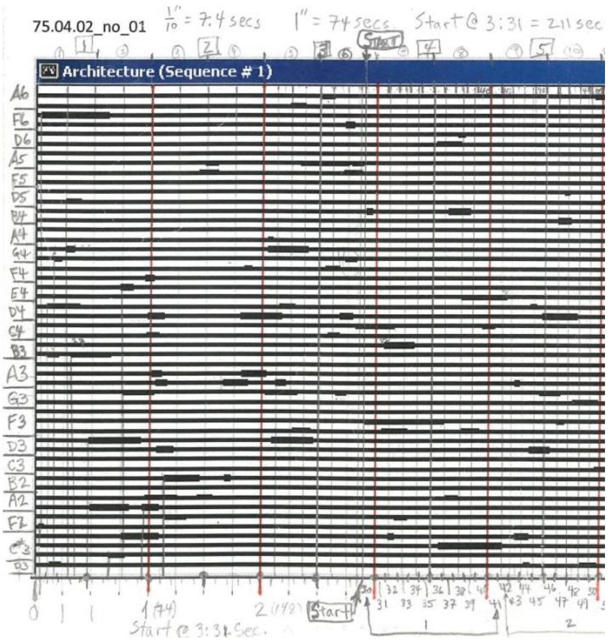

Figure 9. An early example of a tempered configuration of the New GENDYN Program, where the time-span of the resulting architecture is partitioned into measures. There are 50 tracks in this architecture, the vertical axis is partitioned into subdivisions of the ambitus range, two tracks are assigned to each of the defined pitches.

This way of representing and organizing polyphonic pitched relationships in time, spanning a continuous ambitus range, is not without precedent (Figures 10 and 11), only the means of generating the events to be represented is perhaps new. In the case of the GENDYN, machine computation yields the events. Creating a human readable format requires the organizing methods demonstrated in the example image of Figure 9, which is in fact an intermediary step towards creating the common practice notation representation as in Figure A1 (which is an example of a separate execution of the algorithm, with its own set of initial conditions).

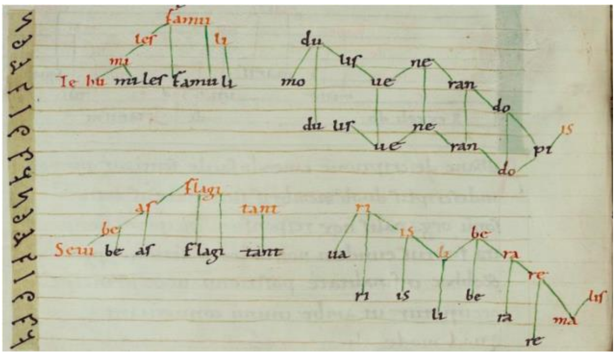

Figure 10. An example of 10th century daseian notation from the Musica Enchiriadis, demonstrating the organization of pitches in a polyphonic setting. Syllables of the sung text are placed among the horizontal spaces, each space being a pitch that is identified by the symbols on the left margin.

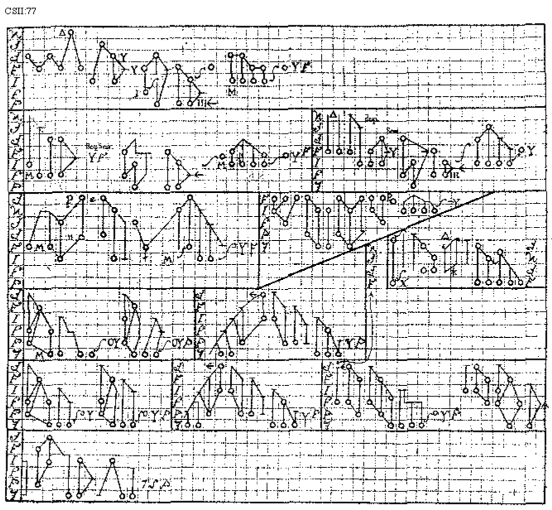

Figure 11. An example found in the 19th C text by E. de Coussemaker [18], from the section titled “Some things out of the Musica Enchiriadis, unpublished”, indicating direct linkages and transitions among and between sung pitches of organum, again with dasaeian notation on the left.

[5] It is interesting to note that this type of rapid-fire timbre melody could be slowed-down in a digital audio editor, revealing hidden melodies contained within, that were impossible to perceive otherwise.

5. COMPOSING WITH THE GENDYN

5.1 What is Composing with the New GENDYN Program?

Composing with a computer can encompass as many different procedures, techniques and approaches as there are practitioners. The GENDYN algorithm is but one of those procedures. The platform of the New GENDYN Program necessarily limits the possibilities afforded to the composer by the GENDYN algorithm, while also simultaneously widening them. What I mean by this is that the application provides a fixed number of voices and synthesis options, while at the same time, allows for a vast number of permutations of parameter and variable combinations. On other platforms such as MAX or SuperCollider, for example, one can synthesize a limitless range of timbres, depending on the processes that are programmed. In fact, the dynamic stochastic synthesis algorithm was realized on the SuperCollider platform [8]. With the New GENDYN Program, there are only so many probability distribution functions to choose from for influencing the random walks, that then determines the position of waveform vertices. The range of values that determine the boundaries within which the waveform vertices can travel is also (necessarily) limited (see Figure 1).

This is an important aspect of working with an application such as the New GENDYN Program. Early attempts to create an original work, one that would stand out as separate in character and form from the works that Xenakis had already created, led to frustration and even confusion. How does one rein in the vast number of choices in a way that takes advantage of the wide timbre and structural possibilities? Xenakis' composition tools leave no choice for a composer but to develop their own path with self-imposed rules.

Agostino DiScipio [13] has described this aspect of computer-assisted composition as a "subversive rationalization" of technology.

> Human endeavors called creative - man's *poiesis*, the bringing forth of objects which would not have come to existence without composition, without art, without desire - entail a hidden orientation towards discarding the technical code inscribed into available tools. In short: art is made by inventing the techniques of its making, which is to say by questioning established, inherited techniques and methods. Artifacts are as traces of poiesis, tangible products testifying at invented ways of acting in a medium (i.e. in the world). Artifacts are objects made by art - thus not art in itself.

Xenakis invented systems for his own compositional purposes, to achieve his own artistic ends. These systems construct and facilitate his own *poiesis* – his means towards an artifact. His own subversion of technology, the results of this appropriation of technology – those very composition systems – can be subverted as well.

Xenakis' composition tools – his equipment – allow one to make decisions with latitude and definitiveness. He intended for these tools to be used by other composers (he has stated as such in various interviews and articles), and it may not be a stretch to suggest that he may have been aware that composers might ask themselves this very question: "Why am I using the tools invented by another composer?" Another example is the UPIC system, Xenakis' graphical drawing composition system. It presents the composer with a completely blank surface waiting for the lines and curves to be associated with a bank of waveform oscillators. With the New GENDYN Program by Hoffmann, the challenge is to understand what exactly you are confronted with – which are mathematical relationships encoded in software, situated within and projected onto an abstract geometric space of configurable constraints – and to then assert, challenge and confront yourself towards the creation of an original statement. The way I understand this confrontation with technology: to be authentic and original with perhaps a minimalist set of required elements, to ultimately fill a space of time with sound. Xenakis' tools do permit this to happen, like the way a blank sheet of music staff paper confronts a composer. With the GENDYN, he invented a way of synthesizing sound from literally nothing but geometry and mathematics: relations that describe natural phenomena – if not nature herself. But further, these already abstract relationships are then encoded in binary logic in a computer program. Hoffmann's implementation of the GENDYN algorithm was itself a landmark, like the UPIC system before it, and becomes a platform for learning, as well as a platform for a disciplined approach to a formal, structured and generative craft and ultimately the art of algorithmic composition.

5.2 Workflow and Procedure

In this section we will describe the workflow and procedure that was developed over time while exploring the GENDYN algorithm and the New GENDYN Program itself.

Initial experiments with the GENDYN yielded, ironically, explorations in sound mass. They sometimes presented as variations of Xenakis' *Concret PH* piece. It was interesting to discover that a technique born of pure mathematics and geometry and realized on a general-purpose computer yielded very similar textures as those created decades earlier with magnetic tape and a splice block. These experiments with the GENDYN demonstrated how to manage masses of sound and textures. It was a unique way of thinking about sound: massive layering upon layers of sound, and enormous, sometimes unwieldly clouds of micro-events tossing and flowing between loudspeakers as it filled the air. Creating these textures required a workflow that demanded the same tasks be performed and repeated as a routine. I become an automated facilitator to the GENDYN itself that then created the forms and architectures. Andy Warhol's mantra of *"I want to be a machine"* could have described the process, except I didn't consciously want to *be a machine* the way Warhol had so gleefully acquiesced. Instead I had to *act* like a machine to facilitate the GENDYN's results. The procedure would involve a rotating and revolving cycle of steps, adjusting variables, repeating steps, readjusting more variables then repeating the algorithm. The refinement process following each of the iterations amounted to a form of empirical heuristic natural selection. Ultimately, the many iterations with varying sets of parameters, along with the cataloging, made it possible to almost predict the outcome of an execution.

The procedures described here were executed over an extended period, and continue. The hundreds upon hundreds of executions of the algorithm needed to be catalogued and archived for reference and recall, when developing new work. This was done in four ways: (1.) the parameter settings for all variables for each execution were entered into a spreadsheet which eventually grew to massive proportions (2.) each execution's data file was archived with an identifying filename that referred to the spreadsheet entry, (3.) the respective audio file of the execution was saved (a WAV file format), and (4.) a graphic of the user interface for the track architecture of the execution was captured and retained in a pair of documents, ensuring that the visual representation of the event architecture timeline was archived. This collection of data for each execution enabled a full description of the algorithm's executions – a sort of complete identity – and permitted an empirical analysis for characterizing the performance of each execution with respect to various parameters and event distributions (we present some of these empirical results in the previous section).

Cataloguing GENDYN executions in this manner almost requires an archivist's way of working, as well as a scientist's way of collecting data. Tables of data fill spreadsheets, and graphs are plotted to understand if patterns or trends are revealed. Relationships between the variables that determine the overall architecture of an execution, and the duration of these events are tabulated. Experiments are repeated to confirm or validate that an existing set of variables would generate comparable results. These working methods at first glance may not resemble a musician's way of being. There is no flow nor "in the moment" stream-of-consciousness that may characterize an instrument-based or performance-based approach to composition.[6] I did not hear sounds in my mind's ear that I wanted to replicate.

5.3 Results

Working in the manner described above has yielded three predominant modes of composing with the GENDYN algorithm. Each mode consists of its own set of rules and workflow for forming a constructed result: (1.) a tempered construction, (2.) a rigorously [strictly] computed construction, and (3.) a hybrid construction.[7]

A tempered GENDYN construction enables a form of stochastic counterpoint, to borrow a familiar term. It requires that the GENDYN algorithm (specifically the realization that is available in Hoffmann's program), be controlled and constrained in such a way that pitched steady-state timbres may be classified and organized to simultaneously generate vertical clusters as well as horizontal melodies of voicings along a timeline. Once the timbre synthesis engine is programmed to achieve steady-state tones, the vertical ambitus scale provides an almost limitless combination of steady-state pitches, ranging from a fine-tuning of microtones to wide gaps across octaves. Multiple executions of the GENDYN algorithm, while programmed in such configurations, with subtle adjustments in the parameter sets between those executions, establishes a layering of "sheets" of pitched matrices within a time frame, where each pitched matrix becomes an impression of interspersed note events.

A rigorously computed GENDYN construction is one that is completely defined prior to its execution. The GENDYN parameter set is adjusted as part of a heuristic process, and the New GENDYN Program is left to execute the instructions. This is the mode exemplified by Xenakis with his original pieces *Gendy3*, and *S.709*. This describes a closed computation, and follows the traditional paradigm of computation. With Hoffmann's implementation however, there are over three times as many tracks to work with for distributing timbre events (and of course this can be extended with further revisions to the application).

A hybrid GENDYN construction is one that has been created with a combination of the first two modes, as well as by taking advantage of the real-time capabilities built into the New GENDYN Program, and the built-in recording function of the program. While the results of the calculations are generated, they are written to local disk storage. The effects of adjustments to any of the parameters during the execution of the program are then captured in the recording. One can also change the architecture of an execution in real-time by adjusting any of the local or global event density parameters. Therefore, in a hybrid construction, the composer could then define the character of an execution as with a rigorous execution, incorporating tempered pitches, while varying a parameter that might adjust the pitch of a prominent timbre, for example, to achieve an intended result. An element of real-time interactive computation is introduced to the execution of the dynamic stochastic synthesis algorithm.

[6] One is engaged in a constant state of disruption, with regards to what might be considered the traditional idea of flow of invention or musical activity.

[7] These modes of composing with the GENDYN are exemplified on the Elli Media CD release by the author, titled *GENDYN Suite* [10].

6. COMPOSING AND ALGORITHMS

6.1 What is Composing with Algorithms

We revisit footnote 6 above where we briefly suggested that algorithmic composition can be considered a disruption to the traditional act of musical activity or composition. The immediacy of improvisation, or of in-the-moment experimentation, is absent in the algorithmic development process, when one is engaged in the iterative trial-and-error empirical process that has characterized most of the activity I was engaged in thus far with the New GENDYN Program[8]. Certainly, the New GENDYN Program allows for real-time interaction with the synthesis engine for exploring timbres; it is even possible to change the architecture of an execution in process, while the results are being delivered to the hard drive. This however, based on my own experience with the program, is different from the situation where a musical instrument can become an extension of the performer or composer. The GENDYN is not quite an instrument in this traditional sense. A rigorous algorithmic composition, one in which only a computer is used to realize and execute the step-by-step procedure of the composition algorithm, separates the composer from the instrument – it is a completely dissociative activity. Unless we are prepared to call the general-purpose computer the instrument, as was my personal experience during the performance of the UPIC system (for the work *Maya*).

6.2 Musical Thinking, Computational Thinking

The work that is described in this paper and that led to the primary forms explained in section 5 above (the tempered, rigorously computed, and hybrid constructions), has illuminated the fact that each practitioner invents their own approach and workflow for any given set of tools or methods. This is the normal way of things and is expected. The remarkably flexible setting of the New GENDYN Program can generate practically an infinite variety of timbres and textures, with architectures of an almost infinite variety of arrangements. Xenakis' work *Gendy3* presents these timbres and forms in an abrupt and very direct manner – the timbres seem at times to be controlled by valves: on/off events with no preparation for their starting or stopping. Are there other ways to employ the algorithm that could render results that are less abrupt, that are more adaptable, and in general more expressive? In this section we consider the analysis of scholar and musicologist Christoph Wolff, in his biography of J.S. Bach [14], as he explores the path Bach takes towards forming a practice of "musical thinking". Could this analysis inform a model and a way forward, or perhaps a way out of, the strong gravitational pull and influence of Xenakis?

[8] We speak here of working with the GENDYN only and the New GENDYN Program specifically, as we are aware of the numerous real-time interfaces that have been developed for interacting between computer and acoustic instruments.

Through Bach's earliest biographer, Nicholas Forkel, Wolff points out that

> Forkel elaborates on the idea of musical thinking by emphasizing that "order, coherence, and proportion" – or better, order/organization, coherence/connection/continuity, and proportion/relation/correlation (the original German terms Ordnung, Zusamenhang, and Verhältnis are not easily rendered by single words) – must be brought to bear on musical ideas.[9]

These qualities are necessary to form a cohesive and proportioned work, and are principles that enable the organization of abstract musical concepts, that could then be manifest as physical sound in air. This transformation of the abstract into the physical is facilitated primarily by melody, harmony and counterpoint in the case of J.S. Bach.

Wolff goes on and asks, "What do order, organization, connection, coherence, continuity, proportion, and relation mean in the process of musical composition?" And again, he answers with the help of Forkel, "If Forkel accurately articulated Bach's thinking, then Bach conceived of compositional method primarily in abstract functional terms, as he also defined harmony – that is, as accumulated counterpoint."[10] The resulting musical forms with their harmonic development, their interplay and interrelationships, are an emergent result of their underlying lower level properties, in this case, their adherence to the rules of counterpoint, fugal procedures, and higher level formal structures such as the various dance forms or other largescale compositional forms such as the concerto.

While illuminating the way Bach explored these compositional features, particularly in Vivaldi's concerto compositions (the *L'Estro Armonico, Op. 3* Concertos, that acted as early lessons for Bach during his development), he notes that

> the concerto as a musical genre or form was a secondary consideration, and the same was true of counterpoint, thematic invention, and other technical aspects of composition, including even word-tone relationships in vocal works. *What Bach dubbed musical thinking was, in fact, nothing less than the conscious application of generative and formative procedures – the meticulous rationalization of the creative act.*[11]

The italics are added. This sentence highlights, as well as resonates, in the context of an automated generative music founded on mathematics which Xenakis had pioneered, the parallel and equally meticulous rationalization of the creative act manifested through the GENDYN algorithm. One can comfortably substitute in this quote, Bach's name with that of Xenakis', and the statement would immediately be describing Xenakis' project[12] in the 20th century, 250 years in the future.

[9] Christoph Wolff, *Johann Sebastian Bach, The Learned Musician*, 170-171.
[10] Ibid., 171.
[11] Ibid., 171.
[12] I use the term "Xenakis' project" in the sense as Hoffmann in [5].

A generative music, whether Xenakis' dynamic stochastic synthesis algorithm, or Bach's extensive counterpoint and fugal procedures, have long raised questions about what a mechanized music or an automated composition might mean – this is not a new inquiry with the advent of computers. Such debates have been ongoing for a couple of hundred years, at least since the middle of the 18th century. David Yearsley dedicates a chapter in his book *Bach and the Meanings of Counterpoint*, titled "Bach the Machine"[13], to address this question through the prism of Bach's powers of counterpoint and the musical automata (and a mechanical duck), that were constructed in the day and would amaze those who had witnessed them.

> [C]ounterpoint itself seems to be the agent that disturbs the temporal and intervallic relationships between the voices, with several permutational possibilities available and one or another arbitrarily engaged at any moment. It is as if the contrapuntal operations are automatically generating the musical material. Like Vaucason's automata these contrapuntal constructs are products of human genius which, once fabricated, seem to run on their own, to think for themselves. The performing machine had challenged the performer; the thinking composition machine now challenged the composer to distinguish himself from "unthinking matter".[14]

The performing machine referred to in the above quote is that of a mechanized flautist created by Jacques de Vaucanson, the French inventor and maker of mechanical automata of the 18th century. The performing musical automata was at the center of a debate regarding the origin of the soul of music, and whether such a soul could be replicated with machines. Extending this argument from automated performance into the realm of composition shines a light on the formal procedures and rules that dictate strict counterpoint and fugues of Bach. And extending this metaphor still further a couple of centuries into the future, we find ourselves concerned with, and attempting to understand, the meaning of an automated art in general and a computable and generative music more specifically, as realized with the general-purpose computer.

Which brings us back to the present effort described in this paper, with its own procedures and self-imposed rules, while perhaps subverting the original intent of Xenakis' own efforts with the GENDYN along the way. Peter Hoffmann suggests, and this effort hopefully confirms, that confronting oneself through technology means to overcome it and escape it.

> Automated Art cannot be a substitute for human creativity. Its true value is only revealed when it is harnessed by human ingenuity. Its rich potential serves to stimulate and challenge artistic invention, as well as to confront the listener (and the composer himself in the first place) with a different acoustic reality. Therefore, it is not only legitimate but important to break the rules and to change the specification wherever it seems appropriate in order not to be trapped by machine logic.[15]

7. CONCLUSION

This paper has presented some results of an ongoing project that has attempted to illuminate the capabilities of the New GENDYN Program, while also describing the process towards creating an original work with the application. Peter Hoffmann's implementation of Xenakis' algorithm provides a robust platform for investigating a rigorous form of algorithmic composition, while also serving as a pedagogical tool, shining a light on potentially new approaches towards composition assisted by algorithms and the computer. The New GENDYN Program's framework and organization allows for experimentation of timbral synthesis on a large scale – of dynamic stochastic granular synthesis – while also generating formal composition architectures. The synthesis of fixed pitches coupled with the event distribution architecture presents a platform for investigating tunings and temperaments that can be exposed to the GENDYN algorithm, yielding a form of stochastic melodies and harmonies. Future investigation involves customizing the GENDYN algorithm to include alternative distributions for influencing the random walks that control the synthesis of the timbres; a more flexible and targeted allocation of the global and local event variables that define the distribution of events along a timeline track and alternative methods of varying the individual samples that comprise a GENDYN waveform.

Acknowledgments

I would like to thank Peter Hoffmann for having generously shared the New GENDYN Program, which has provided innumerable hours of happy investigation and discovery, as well as a window into a dimension of Xenakis' creativity.

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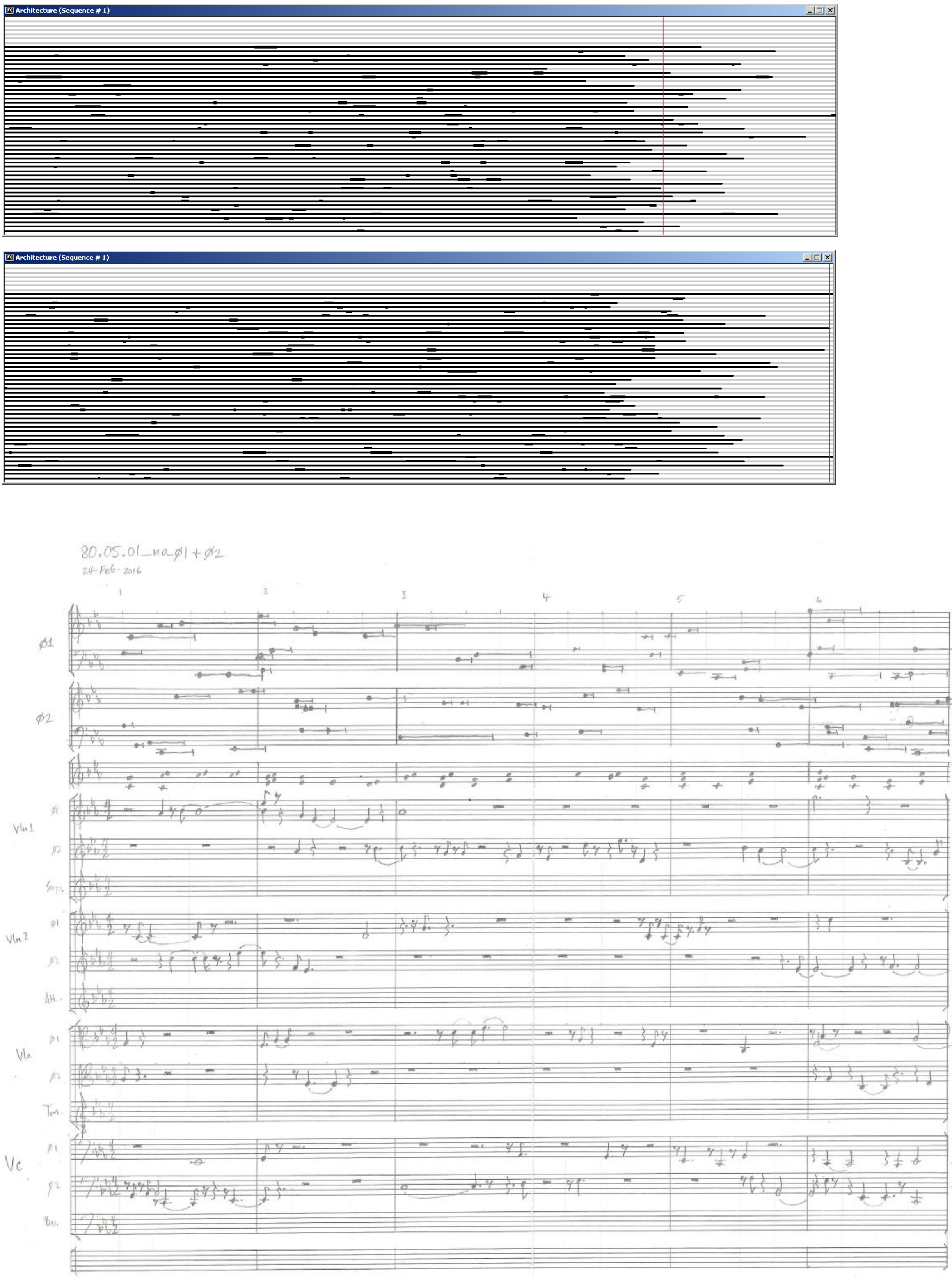

Figure A1. A pair of GENDYN executions (two top-most images), and transcription as represented on staves. φ1 and φ2 direct impression, with reduction in staves 5 and 18, and respective transcription into voices. Parameters have been defined a priori to temper the GENDYN algorithm.

			Synthesis Parameters														
			Time							Amplitude							
				Distribution Function		Mirror Flucuations		Random Walk Mirror			Distribution Function		Mirror Flucuations		Random Walk Mirror		
ID	Stop	Data File Name	Distribution	Ax	Bx	Lower	Upper	Lower	Upper	Distribution	Ay	By	Lower	Upper	Lower	Upper	
1	1	CAU_ARC1	Cauchy	1	1	-10	10	1	10	Arcus Sine	0.534257	1	-100	100	-100	100	
2	2	CAU_ARC2	Cauchy	1	1	-10	10	1	10	Arcus Sine	0.509659	0.501846	-100	100	-100	100	
3	3	CAU_ARC3	Cauchy	1	1	-10	10	1	10	Arcus Sine	0.504776	0.501846	-100	100	-100	100	
4	4	CAU_ARC4	Cauchy	1	1	-10	10	7	10	Arcus Sine	0.504776	0.501846	-100	100	-100	100	
5	5	CAU_ARC5	Cauchy	1	1	-10	10	7	10	Arcus Sine	0.50029	0.496841	-100	100	-100	100	
6	6	CAU_ARC6	Cauchy	1	1	-10	10	7	10	Arcus Sine	0.504776	0.501846	-100	100	-100	100	
7	7	CAU_ARC7	Cauchy	1	1	-10	10	7	10	Arcus Sine	0.504776	0.501846	-100	100	-100	100	
8	8	CAU_ARC8	Cauchy	1	1	-30	30	1	25	Arcus Sine	0.506851	1	-100	100	-100	100	
9	9	CAU_ARC9	Cauchy	0.000305185	0.000305185	-30	30	1	25	Arcus Sine							
10	10	CAUARC10	Cauchy	1	0	-10	10	0	5	Arcus Sine	0.499954	1	-100	100	-100	100	
11	11	CAUARC11	Cauchy	1	0	-10	10	0	5	Arcus Sine	0.499954	1	-100	100	-100	100	
12	12	CAUARC12	Cauchy	1	1	-10	10	0	5	Arcus Sine	1	0	-100	100	-100	100	
13	13	CAUARC13	Cauchy	1	1	-10	10	0	5	Arcus Sine	1	0	-100	100	-100	100	
14	14	CAUARC14	Cauchy	1	1	-10	10	0	5	Arcus Sine	1	0	-100	100	-100	100	
15	15	CAUARC15	Cauchy	1	1	-10	10	0	5	Arcus Sine	1	0	-100	100	-100	100	
16	16	CAUARC16	Cauchy	1	1	-10	10	0	20	Arcus Sine	1	0	-100	100	-100	100	
17	17	CAUARC17	Cauchy	0.00274667	0	-10	10	0	20	Arcus Sine	1	0	-100	100	-100	100	
18	18	CAUARC18	Cauchy	1	1	-10	10	0	5	Arcus Sine	0.499741	0	-100	100	-100	100	
19	19	CAUARC19	Cauchy	1	1	-10	10	0	5	Arcus Sine	0.499741	0	-100	100	-100	100	
20	20	CAUARC20	Cauchy	1	1	-10	10	0	7	Arcus Sine	0.499741	0	-100	100	-100	100	
21	21	CAUARC21	Cauchy	1	1	-10	10	0	5/7/8	Arcus Sine	0.499741	0	-100	100	-100	100	
22	22	CAUARC22	Cauchy	1	1	-10	10	0	8	Arcus Sine	0.499741	0	-100	100	-100	100	
23	23	CAUARC23	Cauchy	1	1	-10	10	0	5/7/8	Arcus Sine	0.499741	0	-100	100	-100	100	
24	24	CAUARC24	Cauchy	1	1	-10	10	0	5/7/8	Arcus Sine	0.499741	0	-100	100	-100	100	
25	25	CAUARC25	Cauchy	1	1	-10	10	0	5/7/8	Arcus Sine	0.499741	0	-100	100	-100	100	
26	26	CAUARC26	Cauchy	1	1	-10	10	0	5/7/8	Arcus Sine	0.499741	0	-100	100	-100	100	
27	27	CAUARC27	Cauchy	1	1	-10	10	0	5/7/8/9	Arcus Sine	0.499741	0	-100	100	-100	100	
28	28	CAUARC28	Cauchy	1	1	-10	10	0	5/7/8/9	Arcus Sine	0.499741	0	-100	100	-100	100	
30	30	CAUARC30	Cauchy	1	1	-10	10	0	5	Arcus Sine	0.499893	0	-100	100	-13	8	
31	31	CAUARC31	Cauchy	1	1	-10	10	0	5	Arcus Sine	0.499893	0	-100	100	-13	8	
32	32	CAUARC32	Cauchy	0.0061037	0.0061037	-10	10	0	5	Arcus Sine	0.499832	1	-100	100	-13	8	
33	33	CAUARC33	Cauchy	0.0061037	0.0061037	-10	10	0	5	Arcus Sine	0.499832	1	-100	100	-13	8	
34	34	CAUARC34	Cauchy	0.0061037	0.0061037	-10	10	0	5	Arcus Sine	0.499832	1	-100	100	-13	8	
35	35	CAUARC35	Cauchy	0.0061037	0.0061037	-10	10	0	5	Arcus Sine	0.499832	1	-100	100	-13	8	
36	36	CAUARC36	Cauchy	0.0061037	0.0061037	-10	10	0	5	Arcus Sine	0.499832	1	-100	100	-13	8	
37	37	CAUARC37	Cauchy	0.0061037	0.0061037	-10	10	0	5	Arcus Sine	0.499832	1	-100	100	-13	8	
38	38	CAUARC38	Cauchy	0.0061037	0.0061037	-10	10	0	5	Arcus Sine	0.499832	1	-100	100	-13	8	
39	39	CAUARC39 * note	Cauchy	0.000305185	0.000305185	-30	30	1	25	Arcus Sine	0.504776	1	-2	1	-100	100	
40	40	C_A_40	Cauchy	0.0061037	0.0061037	-10	10	0	5	Arcus Sine	0.499832	1	-100	100	-13	8	
41	41	C_A_41	Cauchy	0.0061037	0.0061037	-10	10	0	5	Arcus Sine	0.499832	1	-100	100	-13	8	
42	42	C_A_42	Cauchy	1	1	-10	10	0	5	Arcus Sine	0.499863	0	-100	100	-100	100	
43	43	C_A_42_A	Cauchy	1	1	-10	10	0	5	Arcus Sine	0.499863	0	-100	100	-100	100	
44	44	C_A_42_B	Cauchy	1	1	-10	10	0	5	Arcus Sine	0.499863	0	-100	100	-100	100	
45	45	CAUARC43	Cauchy	0.671224	0	-13	13	0	30	Arcus Sine	1	0	-10	10	-10	20	
46	46	CAUARC44	Cauchy							Arcus Sine							
47	47	CAUARC45	Cauchy	0.0061037	0.0061037	-10	10	0	5	Arcus Sine	0.499832	1	-100	100	-13	8	
48	48	CAUARC46	Cauchy	0.0061037	0.0061037	-10	10	0	5	Arcus Sine	0.499832	1	-100	100	-13	8	
49	49	CAUARC47	Cauchy	1	1	-10	10	7	10	Arcus Sine	0.504776	0.501846	-100	100	-100	100	
50	50	CAUARC48	Cauchy	1	1	-10	10	7	10	Arcus Sine	0.504776	0.501846	-100	100	-100	100	
51	51	CAUARC49	Cauchy	1	1	-10	10	7	10	Arcus Sine	0.504776	0.501846	-100	100	-100	100	
52	52	CAUARC50	Cauchy	1	1	-10	10	7	10	Arcus Sine	0.504776	0.501846	-100	100	-100	100	
53	53	CAUARC51	Cauchy	1	1	-10	10	20	20	Arcus Sine	1	0	-100	100	-100	100	
54	54	CAUARC52	Cauchy	0.0061037	0.0061037	-10	10	0	5	Arcus Sine	0.499832	1	-100	100	-13	8	
55	1	CAUCAU01	Cauchy	1	0	-10	10	0	10	Cauchy	1	0	-100	100	-100	100	
56	2	CAUCAU02	Cauchy	0.000305185	0.000305185	-30	30	1	25	Cauchy	0.506851	1	-2	1	-100	100	
57	3	CAUCAU03	Cauchy	0.000305185	0.000305185	-30	30	5	9	Cauchy	0.500046	1	-13	4	-100	100	
58	4	CAUCAU04	Cauchy	0.000305185	0.000305185	-30	30	5	9	Cauchy	0.500046	1	-13	4	-100	100	
59	5	CAUCAU05	Cauchy	0.000305185	0.000305185	-30	30	5	9	Cauchy	0.500046	1	-13	4	-100	100	
60	6	CAUCAU06	Cauchy	0.000305185	0.000305185	-30	30	5	9	Cauchy	0.500046	1	-13	4	-100	100	
61	7	CAUCAU07	Cauchy	0.000305185	0.000305185	-30	30	5	9	Cauchy	0.500046	1	-13	4	-100	100	
62	8	CAUCAU08	Cauchy	0.0061037	0.0061037	-10	10	0	5	Arcus Sine	0.499832	1	-100	100	-13	8	
63	9	CAUCAU09	Cauchy	0.000305185	0.000305185	-30	30	1	25	Cauchy	0.506851	1	-100	100	-100	100	
64	10	CAUCAU10	Cauchy	0.000305185	0.000305185	-30	30	1	25	Cauchy	0.506851	1	-2	1	-100	100	
65	11	CAUCAU11	Cauchy	0.000305185	0.000305185	-81	84	0	105	Cauchy	0.506851	1	-76	68	-100	100	
66	12	CAUCAU12	Cauchy	0.000305185	0.000305185	-81	84	0	105	Cauchy	0.506851	1	-76	68	-100	100	
67	13	CAUCAU13	Cauchy	0.000305185	0.000305185	-81	84	0	105	Cauchy	0.506851	1	-76	68	-100	100	
68	14	CAUCAU14	Cauchy	0.000305185	0.000305185	-81	84	0	105	Cauchy	0.506851	1	-76	68	-100	100	
69	15	CAUCAU15	Cauchy	0.000305185	0.000305185	-81	84	0	105	Cauchy	0.506851	1	-76	68	-100	100	
70	16	CAUCAU16	Cauchy	0.000305185	0.000305185	-81	84	0	105	Cauchy	0.506851	1	-76	68	-100	100	
71	17	CAUCAU16_b	Cauchy	0.000305185	0.000305185	-81	84	0	105	Cauchy	0.506851	1	-76	68	-100	100	
72	18	CAUCAU16_c	Cauchy	0.000305185	0.000305185	-81	84	0	105	Cauchy	0.506851	1	-76	68	-100	100	
73	19	CAUCAU16_d	Cauchy	0.000305185	0.000305185	-81	84	0	105	Cauchy	0.506851	1	-76	68	-100	100	
74	20	CAUCAU16_e	Cauchy	0.000305185	0.000305185	-81	84	0	10	Cauchy	0.506851	1	-76	68	-100	100	
76	22	CAUCAU17	Cauchy	0.000305185	0.000305185	-100	100	5	9	Cauchy	0.00488296	0	-11	11	-100	100	
77	23	CAUCAU18	Cauchy	0.000305185	0.000305185	-100	100	5	9	Cauchy	0.00488296	0	-11	11	-100	100	
78	24	CAUCAU19	Cauchy	0.000305185	0.000305185	-100	100	2	23	Cauchy	0.00488296	0	-11	11	-100	100	
79	25	CAUCAU20	Cauchy	0.000305185	0.000305185	-100	100	2	23	Cauchy	0.00488296	0	-11	11	-100	100	
80	26	CAUCAU21	Cauchy	0.000305185	0.000305185	-100	100	23	23	Cauchy	0.00488296	0	-11	11	-100	100	
81	27	CAUCAU22	Cauchy	0.000305185	0.000305185	-100	100	2	23	Cauchy	0.00488296	0	-11	11	-100	100	
82	28	CAUCAU23	Cauchy	0.000305185	0.000305185	-100	100	2	23	Cauchy	0.00488296	0	-11	11	-100	100	
83	29	CAUCAU24	Cauchy	0.000305185	0.000305185	-100	100	2	23	Cauchy	0.00488296	0	-11	11	-100	100	
84	30	CAUCAU25	Cauchy	0.000305185	0.000305185	-100	100	2	23	Cauchy	0.00488296	0	-11	11	-100	100	
85	1	Cau_hyp1	Cauchy	0	0	-10	10	10	10	Hypercosine	0.496292	0	-100	100	-40	0	
86	2	Cau_hyp2	Cauchy	0	0	-10	10	0	0	Hypercosine	1	1	-100	100	-40	0	
87	3	Cau_hyp2	Cauchy	0	0	-10	10	0	0	Hypercosine	1	1	-100	100	-40	0	
88	4	Cau_hyp4	Cauchy	0	1	-30	30	1	25	Hypercosine	0.506851	1	-100	100	-100	100	
89	5	CAUHYP05	Cauchy	0.001	0.1	0	3	9	9	Hypercosine	0.1	0.0001	-1	1	-7	7	
91	1	EXPARC01	Exponential	1	1	-30	30	10	10	Arcus Sine	1	1	-30	30	-50	50	
92	2	EXPARC02	Exponential	1	1	-30	30	10	10	Arcus Sine	1	1	-30	30	-50	50	
93	3	EXPARC03	Exponential	0	0	-30	30	10	10	Arcus Sine	1	1	-30	30	-50	50	
95	1	EXPLOG01	Exponential	1.0000000	1.0000000	-10	10	20	30	Logistic	0.5001370	1.0000000	-64	100	-10	20	
96	2	EXPLOG02	Exponential	1.0000000	0.0000000	-51	100	10	90	Logistic	0.0411084	0.1463360	-83	100	-30	30	
97	3	EXPLOG03	Exponential	0.0535600	0.0000000	-51	100	10	90	Logistic	0.2465900	1.0000000	-83	100	-30	30	
99	1	HYPHYP01	Hypercosine	0.6712241	1	-13	3	0	30	Hypercosine	1	0	-10	0	-10	20	
100	2	HYPHYP02	Hypercosine	0.671224	1	-13	3	0	30	Hypercosine	1	0	-10	0	-10	20	
102	1	HYPLOG01	Hypercosine	1	1	-5	5	5	600	Logistic	0.000305185	0.000305185	-1	1	-100	100	
104	1	LOGARC01	Logistic	0.6712241	1	-13	3	0	30	Arcus Sine	1	0	-10	0	-10	20	
105	2	LOGARC02	Logistic	1	1	-7	7	0	1000	Arcus Sine	0.668752	0.170721	-50	50	-100	100	
106	3	LOGARC03	Logistic	1	1	-7	7	0	1000	Arcus Sine	0.668874	0.170721	-50	50	-100	100	
107	4	LOGARC04	Logistic	1	1	-7	7	0	1000	Arcus Sine	0.672781	0.170721	-50	50	-86	56	
108	5	LOGARC05	Logistic	1	1	-100	7	0	1000	Arcus Sine	0.672781	0.170721	-50	50	-86	15	
109	6	LOGARC06	Logistic	1	1	-7	7	0	1000	Arcus Sine	0.672781	0.170721	-50	50	-86	15	
110	7	LOGARC07	Logistic	1	1	-7	7	10	1000	Arcus Sine	0.671224	0.170721	-50	50	-86	15	
111	8	LOGARC08	Logistic	1	1	-7	7	0	1000	Arcus Sine	0.671224	0.170721	-50	50	-86	15	
112	9	LOGARC09	Logistic	1	1	-7	7	10	1000	Arcus Sine	0.671224	0.170721	-50	50	-10	10	
113	10	LOGARC10	Logistic	1	1	-17	17	10	1000	Arcus Sine	0.671224	0.170721	-50	50	-10	10	
114	11	LOGARC11	Logistic	1	1	-17	17	7	11	Arcus Sine	0.671224	0.170721	-50	50	-30	10	
115	12	LOGARC12	Logistic	0.500198	0.5000153	-3	3	10	80	Arcus Sine	0.5300149	0.844356	-10	5	-76	15	
116	13	LOGARC13	Logistic	0.500198	0.500015	-3	3	10	80	Arcus Sine	0.530015	0.844356	-10	5	-76	15	
117	14	LOGARC14	Logistic	0.500198	0.500015	-3	3	10	80	Arcus Sine	0.4998322	0.844356	-10	5	-76	15	
118	15	LOGARC15	Logistic	0.500198	0.50015	-3	3	10	80	Arcus Sine	0.530015	0.844356	-10	5	-76	15	
119	16	LOGARC16	Logistic	1	1	-3	3	0	1000	Arcus Sine	1	0.880184	-10	20	-86	15	
121	1	LE_01A	Logistic	0.500259	0.500107	-7	7	0	1000	Exponential	0.671224	0.170721	-5	5	-86	15	
122	2	LOGEXP02	Logistic	0.000305185	0.000305185	-3	3	0	200	Exponential	0.00030519	0.00030519	-100	100	-90	90	
123	3	LOGEXP03	Logistic	0.000305185	0.000305185	-3	3	0	200	Exponential	0.00030519	0.00030519	-100	100	-90	90	
125	1	LOGHYP01	Logistic	1	0	-10	10	0	5	Hypercosine	0.502304	0	0	100	-10	10	
127	1	LOGLOG01	Logistic	0.547960000	0.707327000	-10	10	11	30	Logistic	0.383557000	0.487808000	-10	10	-10	10	
128	2	LOGLOG02	Logistic	1.000000000	0.731834000	-20	20	10	100	Logistic	0.068483500	0.073183400	-12	12	-10	10	
129	3	LOGLOG03	Logistic	1.000000000	0.100650000	-20	20	10	100	Logistic	0.104068000	0.100650000	-15	15	-30	30	
130	4	LOGLOG04	Logistic	1.000000000	1.000000000	-40	-30	10	100	Logistic	0.100162000	0.100253000	-15	15	-40	40	
131	5	LOGLOG05	Logistic	1.000000000	1.000000000	-100	40	5	100	Logistic	0.000305185	0.000305185	-95	95	-100	100	
132	6	LOGLOG06	Logistic	1.000000000	1.000000000	-100	40	5	100	Logistic	0.000305185	0.000305185	-95	95	-100	100	
133	7	LOGLOG07	Logistic	1.000000000	1.000000000	-20	20	10	600	Logistic	0.123295000	0.000000000	-40	70	-100	100	
134	8	LOGLOG08	Logistic	1.000000000	0.500046000	-20	20	10	600	Logistic	0.424655000	0.414625000	-40	70	-100	100	
135	9	LOGLOG09	Logistic	1.000000000	1.000000000	-5	5	5	600	Logistic	0.000305185	0.000305185	-1	1	-100	100	
136	10	LOGLOG10	Logistic	1.000000000	1.000000000	-5	5	5	600	Logistic	0.000305185	0.000305185	-1	1	-100	100	
137	11	LOGLOG11	Logistic	0.000305185	0.000305185	-50	0	0	20	Logistic	0.164342000	0.438978000	-10	10	-50	50	
138	12	LOGLOG12	Logistic	0.000305185	0.000305185	-21	21	4	20	Logistic	0.500107000	0.500150000	-1	1	-50	50	
139	13	LOGLOG13	Logistic	0.000305185	0.000305185	-50	0	2	20	Logistic	0.164373000	0.439192000	-10	10	-50	50	
140	14	LOGLOG14	Logistic	0.013702800	1.000000000	-100	100	0	1000	Logistic	0.100436000	0.100650000	-50	50	-50	5-	
142	1	LOGTRI01	Logistic	1	1	-7	7	0	1000	Triangular	1	1	-10	10	-86	15	
143	2	LOGTRI02	Logistic	1	1	-1	1	0	1000	Triangular	1	1	-100	100	-15	15	
144	3	LOGTRI03	Logistic	1	1	-7	7	0	1000	Triangular	1	1	-20	20	-86	15	
145	4	LOGTRI04	Logistic	1	1	-3	3	0	1000	Triangular	1	0.880184	-10	5	-86	15	

Table A1. A catalogue of GENDYN timbres.