

Cool Memories:
Notes on the Ligeti Viola Sonata

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“Who are we, who is each one of us, if not a combinatoria of experiences, information, books we have read, things imagined? Each life is an encyclopedia, a library, an inventory of objects, a series of styles, and everything can be constantly shuffled and reordered in every way conceivable” -italo calvino

there is nothing outside the text

the experience of hearing and interpreting a musical work cannot be isolated from the tangled web of knowledge buried within each listener. No matter how focused or

If musical compositions contain the aesthetic property of multiplicity, if they are constructed as a network of references, quotations, imitations or non-musical metaphors, what are the ramifications for the performer/interpreter?

This essay is an attempt to explore the idea of multiplicity in musical composition through Ligeti's Sonata for Solo Viola

[The act of listening to a musical composition cannot occur in isolation from the tangled web of knowledge present in each listener.] When confronted with musical material on all levels, from phraslet to symphony to concert, we cannot help but connect the dots between what is being heard and bits of information located in our personal encyclopedia of experience. It is as if our minds create an instantaneous structuralist analysis relating the notes (^being) heard to whatever it can grasp on to. This explains how a progression in Schumann can simultaneously remind us of Bach, Mahler, the Beatles and a Giraffe.

conveying referential meaning through performance

- Polystylistic Playing (play in the style of...)
- Phrasal Emphasis (segment the horizontal stream to highlight certain symbols/signifiers)
- Education (use verbal/linguistic cues to trigger connections in the audience)

In the 1970s and 80s music took a radical hermeneutic turn away from the musical absolutism of the avant-garde toward the referentialism and multiplicity associated with post-modern aesthetics. The method of transmitting meaning through a musical message expanded beyond the boundaries of the work in-itself to include the work in its cultural and performative context. Composers began looking outward, using quotation, poly-stylism, historical regression and the free play of reference to impart meaning on their musical compositions. For performers of contemporary music, this radical shift in the way meaning is transmitted through music has profound consequences on how and with what aim we approach the performative act.

In the late 1970s György Ligeti faced a hermeneutic crisis typical of composers during that period. He had exhausted himself composing an opera about the end of the world, the musical avant-garde was dead and there seemed no way to produce a musically meaningful composition without resorting to decadence, musical digression, or kitsch. As he told students in a lecture 15 years later “I am in a prison: one wall is the avant-garde, the other wall is the past, and I want to escape” (Ross 465). In the midst of this crisis he made hundreds of unfruitful attempts at writing a piano concerto (Steinitz 245) only to finally break free five years after the completion of Le Grande Macabre with his most expressive work, the horn trio of 1982. The solution that finally freed him from his aesthetic prison was the synthesis of a unique language of multiplicity referencing an entire world of ideas ranging from chaos theory and french spectral music to the musics of Africa, the caribbean and Conlon Nancarrow. For performers of Ligeti’s late music this multiplicity presents a unique set of challenges: how can references be shown in performance? What is the responsibility of the performer-interpreter when it comes to recognizing references? How do you perform an extra-musical concept? and how can we ever expect the audience to understand this language of reference?

“A method of knowledge, and above all as a network of connections between the events, the people, and the things of the world” (Calvino 105)

“novel as a vast net” (Calvino 124)

“nostalgia for a homeland that no longer exists” (NY Times obituary of Ligeti)

“I am in a prison: one wall is the avant-garde, the other wall is the past, and I want to escape” (quoted, Ross 465)

music that is no longer built around
the primacy of the individual
statement, the musical work as complete
message whose meaning is located only
inside its time frame, to music whose
meaning is buttressed on relations to
external signs

cool memories

-an open sign ambiguously interpretable as a direct referent to a pre-existing sign/concept

-this is in direct contrast to a hot memory which is a closed sign only interpretable as a pre-existing sign/concept

	cool	hot
sign?	open	closed
value?	sign+concept	recontextualization
perceived?	through knowledge + interpretation	through knowledge
reference?	vague	direct

the value of the later lies in the fact that the pre-existing sign has been recontextualized in some fashion giving it new aesthetic life. For a cool memory value lies in the openness or ambiguity of the sign itself, the sign can be interpreted in a given way as a reference as memory to a pre-existing sign. In both cases cultural knowledge of the referenced sign is essential to their perception on the part of the listener but in the case of a cool memory the reference also requires interpretation to be uncovered

taxonomy of reference

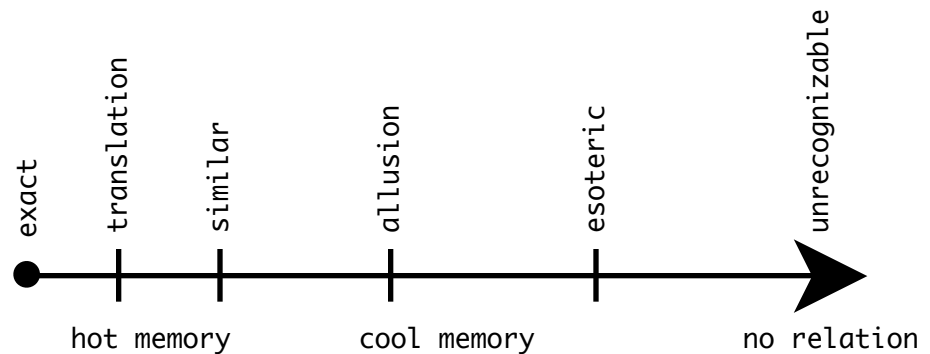
Direct -restatement of sign

Translated -same information presented in a different medium

Similar -new information that bears resemblance to previous information

Allusion -new information that suggests previous information

really a continuum



a question of the relationship between the information present in a given referencing sign and the information present in the referenced sign.

metaphor

quotation, allusion, modeling

cool memory -an open sign, (^ambiguously) interpretable as a direct referent to a pre-existing signified concept

hot memory -a closed sign only interpretable as a direct referent to a pre-existing signified concept

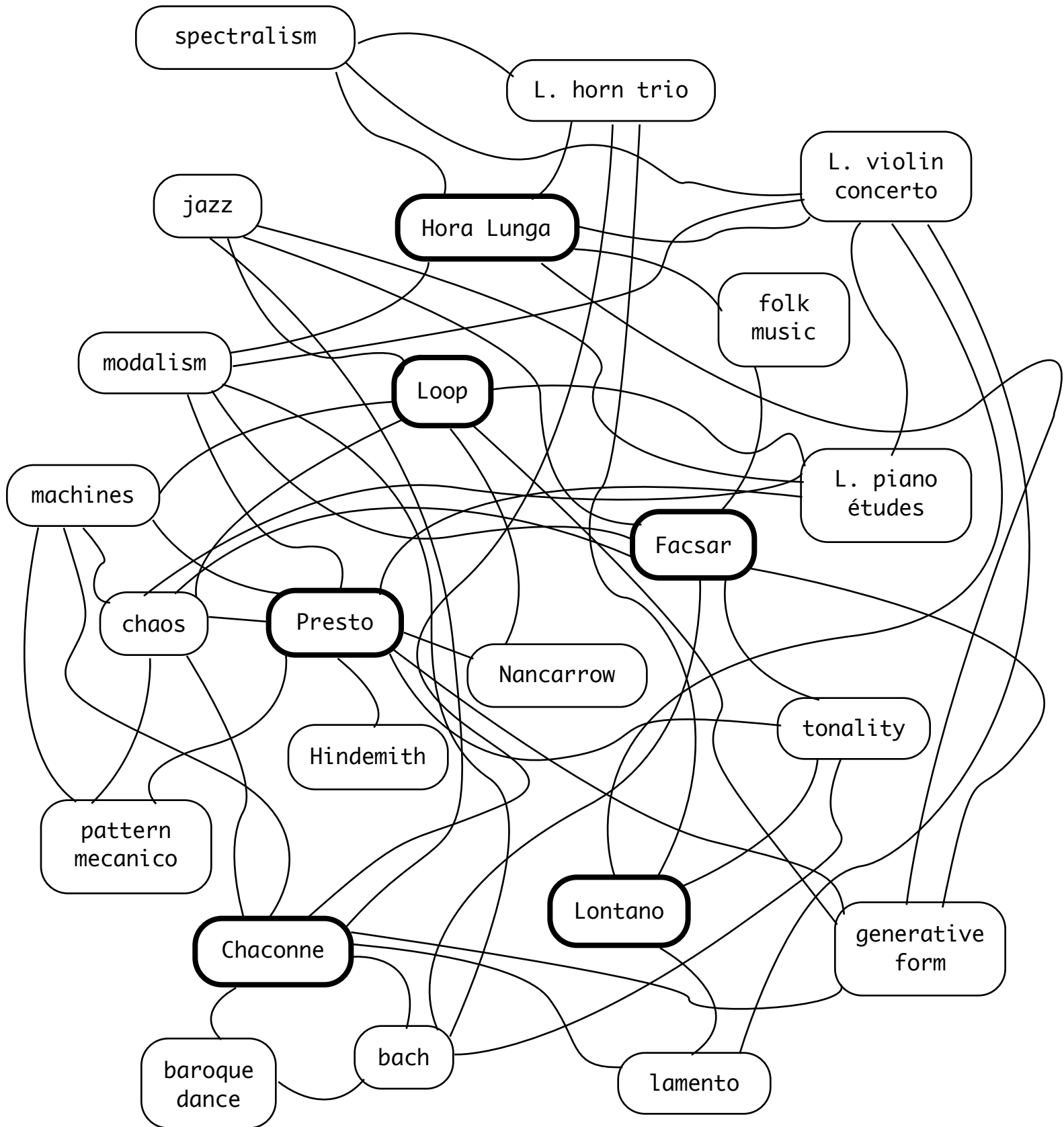
For most composers situated in the mainstream of cultural thinking, the 1960s marked the beginning of a new era in musical thought. That old fairytale of an inevitable modernist progression from Beethoven to Wagner to Schoenberg to Webern to Boulez and beyond turned out to be just that, a fairytale used to explain the necessity of unnecessary music. While the hyper-modernity of works like "Structures IA" and "Gruppen" certainly produced fascinating results for the specialist, to the ears of everyday concertgoers they were incomprehensible

For Ligeti and many composers of his generation escape was found through the free play of cool memories

Ligeti Sonata's "Cool Memories"

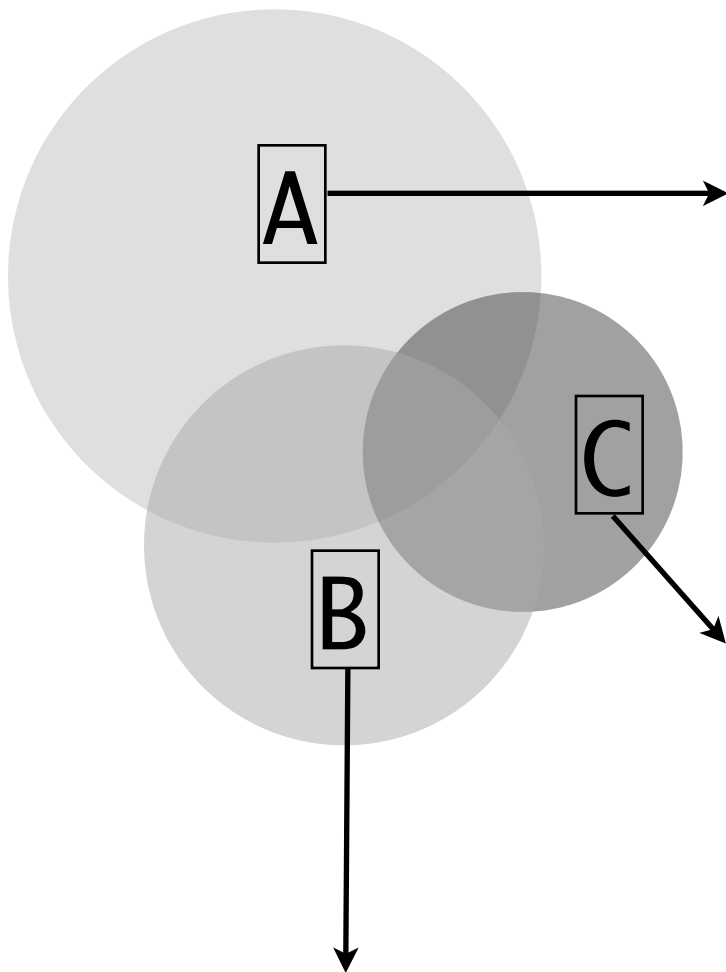
- Romanian folk song/generic folk songs (Hora Lunga/Facsar)
- Chaos (Loop/Presto)
- Harmony (Facsar)
- Baroque Dance (Chaconne)
- Lamento Motif (Lamento/Chaconne)
- Nancarrow (Loop/Presto/Chaconne)
- Jazz (Loop/Chaconne)
- Machines (Loop/Presto/Chaconne)
- Hindemith (Presto)
- Spectralism (Hora Lunga)

web of reference: ligeti viola sonata



The Wikipedia Model of Multiplicity: a sign is presented, the listener reacts by looking up a possible referential understanding (i.e. searching for the sign within their personal database), the understanding is present in a series of definitions, allusions, and related terms all hyperlinked to their own referential understanding with further definitions, allusions, and related terms. The searching is endless, a (^randomly) linked contextual multiplicity bringing variegated referential understanding to the whole. Could have resulted in any number of possible combinations of referents and is by nature incomplete.

conceptual replication of signs



Music is built of gestures, signs bent through time, acoustic phenomena with representable parametric values, sounds that are temporally and vertically segmented through perception on a variety of contextual levels, ranging in size from the quiet plucking of a ukelele to the entirety of Mahler's second symphony, with all the motives, phrases, sections and movements in between

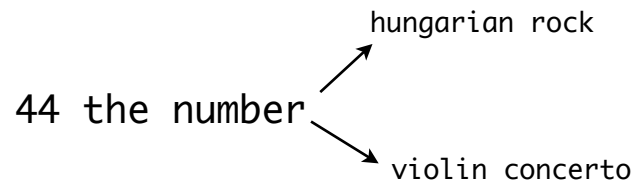
Meaning can be transmitted through referencing on every level of the work and along a continuous spectrum of vagueness. In its most clear form a composer such as John Adams in Son of Chamber Symphony will directly restate a well known musical figuration, the opening bars of Beethoven's ninth, or as in the third movement of Berio's Sinfonia, an entire musical work. Rather than direct quotation, a composer may wish to impact the reference with their own musical personality through a translation, bending the material to a new musical language as in Busoni or Stokowski's transcriptions of Bach. If the composer wants even more distance from the original referenced material they may allude to it through incorporating only certain distinctive features of a figuration or language. The art of allusion on a macrocosmic scale, that of an entire work or compositional style, was perfected by both the neo-classicists of the first half of the 20th century and the neo-romantics later in the century; however, composers as diverse as Kurtág Lachenmann and Philip Glass have all found subtle applications of allusion on the micro-levels of a phrase or sonority. [In general, the clarity of a reference is directly related to its similarity with the original referent, the more loose that relationship is the less likely the allusion is to be understood as a cogent reference.

The surprising consequence of loosening the relationship between the signifier (that which references) and the signified (that which is referenced)]

In general, the form of a reference is exactly that of a Saussurian sign: the composer uses a signifier (either a figuration, work or language) to refer to a signified concept (again, a well known figure such as the opening of Beethoven's ninth symphony, an entire piece such as the third movement of Mahler's second symphony or an entire musical style). In either case, the clarity of a reference is a direct function of the signifier's similarity to the signified and the general cultural commonality of the signified.

The surprising consequence of loosening the relationship between the signifier and the signified is that it allows for a multiplicity of references within a given signifier. Through such ambiguity a single musical sign can take on many possible interpretations, a listener hearing the double stop harmonics in Lamento may identify them as a restatement of ocarinas in Ligeti's own violin concerto, as a baroque or renaissance ground bass, or as a reference to medieval parallel organum. In each case, correctly identifying a fresh signified concept does not pit it in a dialectical argument with a previously identified reference but rather adds a new level of depth to the overall understanding of the message. Taken to its extreme, as in the novels of Carlo Emilio Gadda and James Joyce, the artwork of Hieronymus Bosch, or the "Histoire(s) du Cinema" of Jean-luc Godard, the aesthetics of multiplicity can transform an artwork into "a method of knowledge [using] a network of connections" (Calvino 105) between a vast treasury of external objects, events and concepts.

By no means must a composer limit themselves to referencing purely musical concepts. From at least the time of Monteverdi, composers have used certain musical gestures to reference non-musical sounds such as a cuckoo bird or thunder. Taking the idea further, composers routinely directly mimic poetic language with musical figurations ranging from a rising scale to represent an ascent into heaven or a tritone to represent the devil. Most interestingly, and of particular importance to Ligeti, composers have used the form of a piece itself to illustrate an extra-musical concept. Bach's infinitely rising canon from a musical offering can represent the ever rising glory of God (or his patron Frederick the Great) and the hypothetically hours long extension of color and tinea of the first movement of Messiaen's Quatour Pour le Fin du Monde can represent the eternal expansion of heaven.



Personal language and Reference

The idea that one work by a given composer can have loose references to other previously or concurrently conceived works ~~within the oeuvre~~ of that same composer is certainly suspect. Given the long held beliefs that each composer develops ~~their~~ (^his or her) own personal language, how could an interpreter possibly differentiate between the characteristics of that composer's language and (^the possibility of) somewhat vague references to other works within their oeuvre. How could one identify without a written or verbalized (^statement) by the composer, the legitimacy of an interpretation that posits a given element as a reference as opposed to a stylistic coincidence?

A clear example of reference within one's own catalogue occurs in Ligeti's fourth piano étude "Fanfares" which is built around an eight-note ostinato repeated 208 times. It's pitches are identical to those of "Hungarian Rock" (repeated 176 times) and the second movement of the horn trio (with a 3-3-2 accent grouping instead of the 3-2-3 of "Fanfares"). Given the late Ligeti's aesthetics of multiplicity and reference, it is difficult to analyze the reusing of material as the result of stylistic concerns as opposed to intentional semiological networking. In contrast (^within the critical framework of earlier musical hermeneutics), the use of similar re-used ostinati (^by) ~~within the work of earlier~~ composers such as Bach, Beethoven or ~~even~~ Bartók could rarely be considered significant. In order to generate some kind of method whereby an analyst can convincingly speak of (^a dichotomy between) personal referencing and personal style, the factors weighed must include both the way an individual composer expresses meaning through music (in gangly technical jargon the composer's hermeneutical praxis) as well as the nearness to exact repetition a given sign lies on our continuum of reference.

Given this dichotomy, clear loose references exist between the viola sonata and three other pieces from within Ligeti's work: The Violin Concerto, Piano Etudes, and Horn Trio.

$I[0]$ =Initial conditions

$I[1] = F[1]\{ I[0] \}$

$I[2] = F[2]\{ F[1]\{ I[0] \} \}$

$I[3] = F[3]\{ F[2]\{ F[1]\{ I[0] \} \} \}$

...

...

...

$I[n] = F[n]\{ F[n-1]\{ \dots F[1]\{ I[0] \} \dots \} \}$

Iterative Processing

The basic compositional device used by Ligeti throughout the viola sonata is that of the iterative process or recursion. Each moment begins within the presentation of a string of information, what I call Iteration zero of I_0 . The material is then extended by running the information contained in I_0 through some process of alteration in order to derive a new iteration I_1 . This new (^string of) information simultaneously contains both the initial material and the new material by presenting I_1 as a clear function of $I[0]$ ($I_1 = F_x\{I[0]\}$). This process is repeated again (^and again) creating $I[3]$, $I[4]$, (^all the way) to $I[n]$ when the movement finishes itself.

Mathematically, we can represent this process of nested functions in the figure below, although a simpler explanation would be to say that each iteration is created by altering the previous iteration.

Hora Lunga

The first movement of Ligeti's sonata, "Hora Lunga", is written entirely on the C-string and consists of a series of eight sections. These divide roughly into a bipartite form with sections 1-5 being mirrored in sections 6-8. The primary melodic material is a synthesis of two distinctive musical (denotative) systems (or paradigms), that of the "family of slow, stereotyped melodic formulas and figures which are strung together in Romanian folk songs from the Maramures region in the northern Carpathians" (Ligeti 17) and that of French spectralism (particularly the approach of Claude Vivier). While both are unique languages with fixed sets of signifiers and signifieds through which the composer/musician may create a musical discourse, there exists points of convergence (mainly the co-dependent use of the harmonic spectrum as the source of melodic inspiration) which Ligeti explicitly highlights (both with his verbal commentary and with stylistic technique) to create a semiological multiplicity.

AHCB: the dual nature of musical symbols

In the opening measure of "Facsar", Ligeti gives us a prime example of a musical symbol, the four-note Bach Motif re-arranged as A-B-C-Bflat (where "B" is labeled "H" in the German system). This famous motif pops up all throughout the (^literature) from the last notes of Kunst Der Fugue to the music of Webern and Boulez. It is by all means safe to assume that there is a certain class of well versed listener's who, when hearing the opening of "Facsar", will make this connection and all of the subsequent (^connections) implied by its statement (i.e. the direct links to Bach through implied harmony, four-part chordal playing technique à la the solo sonatas and partitas, and even possibly the distinctive broken double stop first found in measure 13 that harkens back directly to the andante of Bach's a-minor violin sonata). However, in order for this to be understood without prompting two requirements must be met: the listener must have a prior knowledge of the Bach motif and the listener must have enough auditory awareness to recognize the notes A-B-C-Bflat as a re-ordered statement of the Bach motif. The auditory awareness required will be different from listener to listener, ranging anywhere from perfect pitch to a hunch that just happens to be right. Either way, it is certainly safe to assume that just as there is a class of well versed listener's able to make the connection, the number of listeners in that class is small.

différance and interpretation

Once recognized as a statement of the Bach motif, the four-note phraslet described above is transformed from a purely musical signifier - whose non-linguistic meaning can only be defined through the parametric relationships present in the gesture - to a symbolic signifier with the entire network of concurrent musical, linguistic, and subjective signifiers available to each interpreter. What was once a conceptual unit "(^the parametric relations of) the opening four-note phraslet of Ligeti's Facsar" has become "a re-ordered statement of the Bach motif". Through the process of what Derrida has called Différance we have replaced one signified with (^another) signifier. A purely musical element whose meaning cannot lie outside of the parametric relations presented has become an iteration of a symbol in our personal encyclopedia of extra-musical signs. Without différance Shostakovich's ironies, Mahlerian stream of consciousness, Berlioz's tone poems and Ars Nova symbolism would all be meaningless sonic events. Even when you feel emotion or (^directly) describe the parametric features of a musical event you cannot escape the process of différance.

Example 1: Lament

Lamento

Chaconne chromatique

Ligeri facson

A H C B

BACH motif

B A C H

once the process of referential linking begins, once the auditor applies the lens of interpretation through reference, the identification of referents multiplies exponentially from both directions of decoding and applying.

The basic building block of meaning in solyptic networks is the reference, a form of sign relating its articulation to an external concept. Following the general conception of a sign as “the union of a signifier and a signified” (Barthes 38), a reference, when identified as such, is a total combine of its expression and its content, the musical event and the idea to which it is linked. It is interpretively indivisible functioning exactly as a hyperlink containing both its expression as physical fact and the code linking it to a related site. As such, references are simultaneously interpretable through either decoding its expression (“x references y”) or applying its content (“y seems related to x”), both of which are reliant on the auditor’s capacity to make the connection between expression and content. The act of interpretation becomes integral to the meaning within the message, it is an opening of the hermeneutical process whereby the traditional dichotomy of that which the artist is trying to say and that which the audience thinks he is saying is replaced by an endless network of connections between the physical events and externalized referents that are identified by the interpreter.

by definition, reference does not resort to a meta-language of interpretation, while we use the linguistic formulations “x references y” or “y is referenced by x” there is conceptually no need for language, what is heard immediately becomes a psychological unit that links directly to other psychological units (memories) that are not part of a synthetic framework of understanding.

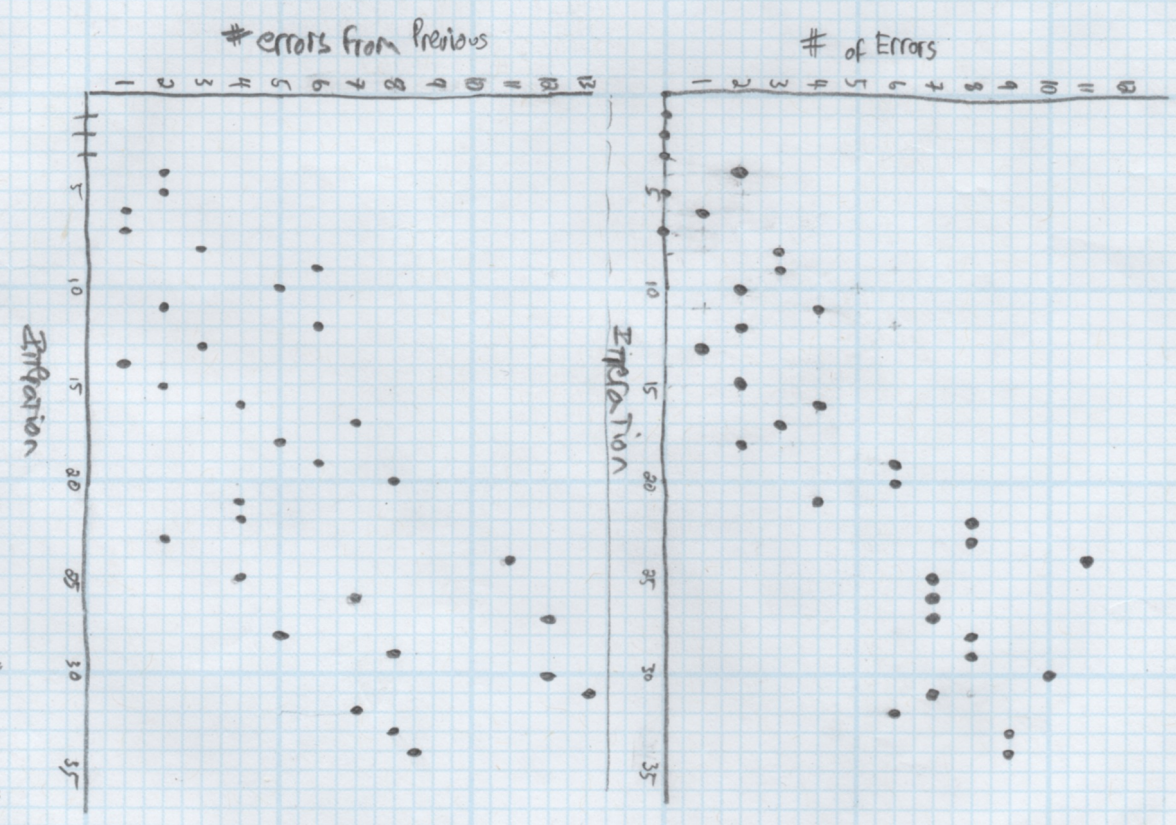
the connection between material expression and referenced concept is in Barthes the “Signification”

It is “motivated” in that a clear relation exists whereby the reference models the referent in its physical materialization

Iteration
 errors
 errors
 iterations

1	0	0
2	0	0
3	0	0
4	2	0
5	0	0
6	1	0
7	0	0
8	3	0
9	3	0
10	2	0
11	4	0
12	2	0
13	1	0
14	0	0
15	2	0
16	4	0
17	3	0
18	2	0
19	6	0
20	6	0
21	4	0
22	8	0
23	8	0
24	11	0
25	7	0
26	7	0
27	7	0
28	8	0
29	10	0
30	7	0
31	6	0
32	9	0
33	9	0
34	9	0

1 calculated by sample all ones added or deleted from 6-4-4-6-4 lattice



Both show a motion from "stability" to "instability" with the rhythmic system

“Loop” consists of a three bar introduction followed by nine complete iterations of a string of 45 dyads and one virtual iteration in which only the first three dyads are stated. Each iteration is an exact restatement of the 45 dyads, neither the order nor the pitch material changes. In order to generate an over-arching dramatic form out of the constant looping of fixed information, Ligeti subjects the rhythm of each point to irrational alteration and weights these alterations negatively in the direction of reduction. Figure 1 shows the rhythm of the first three dyads as they change with each iteration. Notice how with each iteration the rhythmic value of a given pitch could be lengthened or shortened without any compositionally logical reasoning; however, the overall trend is (^weighted) towards reduction.

Simulating Ligeti

An Algorithmic Recreation of *Loop* in OpenMusic

I Introduction

Throughout the twentieth century there was a dramatic increase in musical works created through compositional process as opposed to compositional whim. This interest clearly starts with the combinatorial methods of the second Viennese school and runs through Boulez, Cage, Xenakis, Reich, and beyond. In order for compositional theory to be of any use we must move away from analyzing the results toward analyzing the process through which those results are achieved. By studying a musical work through statistical, algorithmic, and logical analysis we can better understand both the processes through which the work itself is created and the meaning buried beneath the notes. This paper is an attempt to do just that by studying the rhythmic parameter of *Loop* from György Ligeti's *Sonata for Solo Viola*.

After a description of the general construction of *Loop*, exploring its generative form and its relationship to chaotic systems, I will take the reader through various steps to creating a method of generating algorithmic simulations of *Loop*. This method will involve a combination of Markov Analysis and programming logic using a LISP Graphical User Interface for composition called OpenMusic (OM). By properly understanding the conditions which lead to successful simulations of *Loop* we are able to clearly distinguish the limits of its compositional process and the implementation of that process by an artistically sensitive composer such as Ligeti.

II General Construction

Loop is composed of a series of nine iterations of a 45-unit long string of dyads, preceded by a two bar introduction. The overall rhythmic scheme throughout *Loop* is divisible by a common denominator of one sixteenth note, with values ranging from 1-beat units to 8-beat units. Beginning with iteration one (heretofore referred to as **I**₁) starting at bar 4, we have a rhythmically diverse presentation of the 45 dyads in a somewhat moderate rate. **I**₁ uses almost the entire gamut of rhythmic units with 2- through 8-beat units all making an appearance. As the work moves from **I**₁ to **I**₉ the rhythmic pattern morphs from moderate and varied to fast and regular, with an almost constant stream of 1-beat units occurring in **I**₉. Table II.1 shows the entire sequence of 16th note units as they move from **I**₁ to **I**₉ with their index (dyad #) in the top column.

What the data in Table II.1 show upon first inspection is the overall motion from rhythmic volatility in **I**₁ to rhythmic standardization in **I**₉. This motion is shown even more clearly when graphed as in Figure II.1, whereby each rhythmic value is plotted along the y-axis against its index in the x-axis. Graphed as such, the actual values are less interesting than the overall motion, we are able to see the trend from large variability and rhythmic value to flat, low value and almost completely even.

However, not only can we observe the data horizontally in iterative units, we can also see the transformation vertically of each dyad in the string. Thus a dyad such as number 14 occurs nine-times throughout *Loop* with the rhythmic sequence 3-3-2-2-2-1-1-1-1. When mapped individually, as in Figure II.2 for dyads 1 and 2, the generally rhythmic decay is still quite clear while the path with which that decay happens is more clearly represented. By comparing all 45 dyads mapped as such, two properties of the process become quite clear: 1) each dyad follows a *random* path of decay, and 2) each path of decay is *unique* to that dyad.

In general terms, we can say that *Loop* follows a generative process of decay whereby each atom (in our case any one of the 45 dyads) takes a *random* and *unique* path weighted towards 1-beat rhythmic units. The entire system, i.e. each iteration, moves from a *chaotic* state of high variability, entropy, and complexity to an almost totally *ordered* state of low variability, uniformity and simplicity. In nature this is the same general process of boulders becoming sand, mountains becoming plains, or snowflakes melting into water droplets.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	4	3	3	5	3	2	2	3	3	8	2	2	3	3	2
2	3	3	5	8	3	3	2	2	2	2	2	2	3	3	3
3	4	3	3	5	3	2	2	3	3	5	3	2	2	2	2
4	2	2	3	3	2	2	2	2	2	2	3	3	2	2	1
5	1	2	3	3	2	3	2	2	1	2	2	1	2	2	1
6	1	2	1	1	2	1	1	2	2	2	1	1	2	1	1
7	1	1	2	2	1	2	2	1	2	1	1	1	2	1	1
8	2	1	1	1	2	1	1	1	2	1	1	1	1	1	1
9	1	1	1	1	2	1	1	1	2	1	1	1	1	1	1

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	2	2	2	4	6	3	2	3	4	6	2	2	2	2	2
2	2	3	2	5	3	2	2	2	2	4	2	2	2	3	2
3	2	3	2	3	2	2	2	2	2	3	2	2	1	2	2
4	1	2	2	2	3	1	2	2	1	2	3	2	2	1	2
5	1	2	2	2	3	2	1	2	3	3	2	2	1	2	2
6	2	2	1	3	2	1	1	1	2	1	2	1	1	1	2
7	1	2	1	2	2	1	2	1	2	2	1	2	2	2	1
8	1	1	1	2	1	1	1	1	1	2	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
1	2	3	3	5	7	6	5	3	2	2	3	3	8	2	2
2	3	2	2	3	3	5	3	2	2	3	3	2	2	2	2
3	3	2	1	3	2	3	4	2	2	2	2	2	1	2	1
4	3	2	1	2	3	4	3	1	1	2	2	2	2	2	2
5	1	3	2	2	1	2	2	1	2	2	1	2	1	2	2
6	2	1	3	2	3	2	2	1	2	2	1	2	1	2	1
7	1	1	1	2	1	2	2	1	1	1	1	1	2	1	1
8	1	1	1	2	1	1	1	1	1	1	2	1	1	1	1
9	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1

Table II.1: Rhythmic Pattern for *Loop*

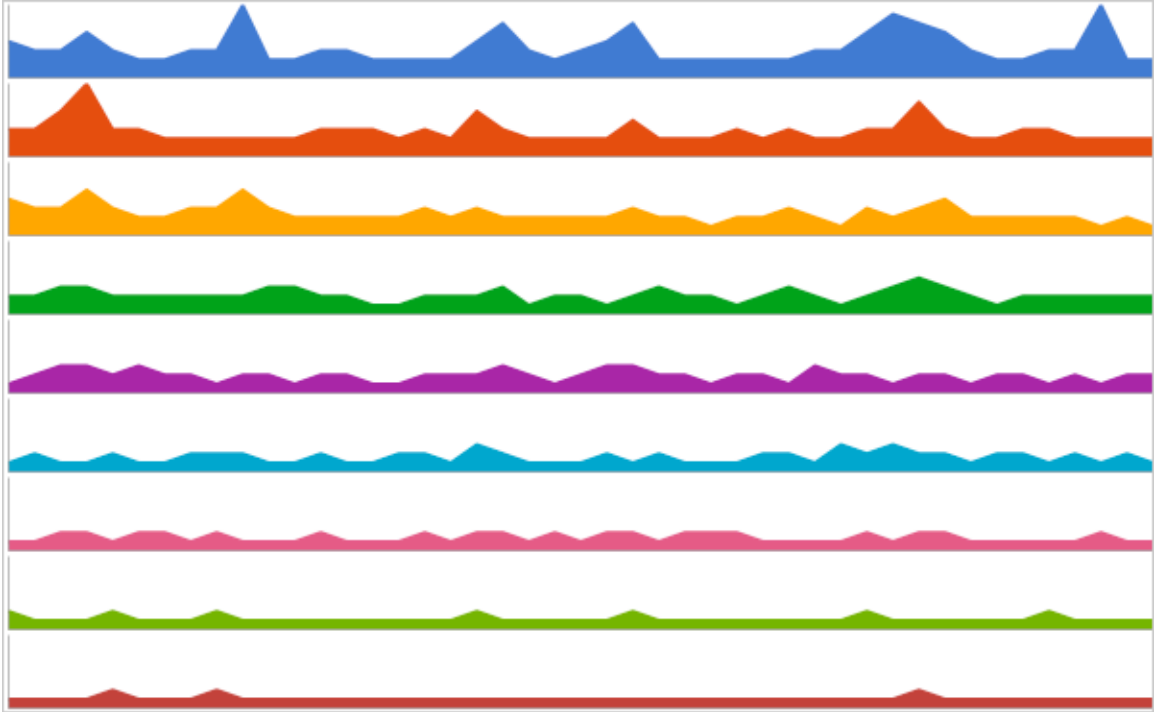


Figure II.1 General Rhythmic Transformation From I_1 to I_9

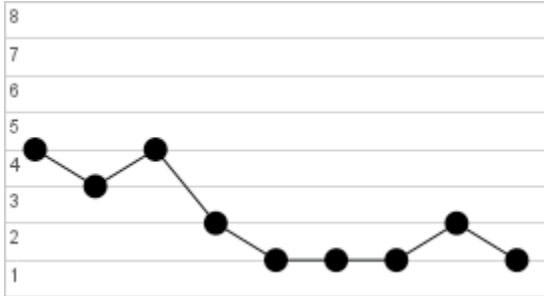


Figure II.2 A: Rhythmic Decay of Dyad 1

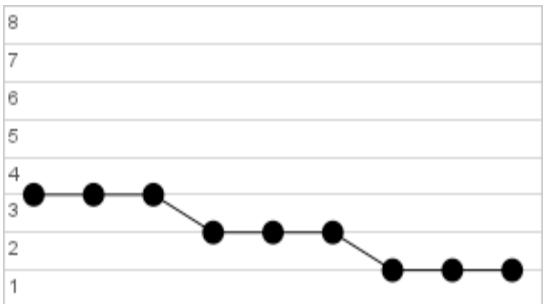


Figure II.2 B: Rhythmic Decay of Dyad 2

III General Algorithmic Process

In order to simulate the rhythmic decomposition of *Loop* we need to mechanize the derivation of each iteration. Exactly how this is done is a matter of both careful planning and taste; however, a general value that each simulation should be both varied from and similar to the original will be kept. This means that we would like to create an *algorithm*, or mechanized composition process, that can give us a variety of different solutions which all appear to be quite similar to the solution given by Ligeti. The general process of this algorithm is given in Figure III.1.

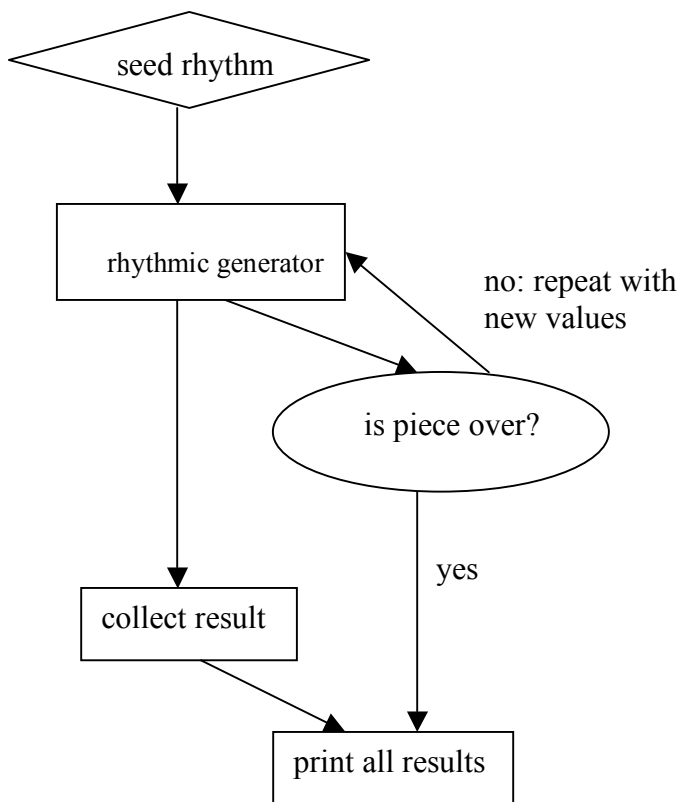


Figure III.1 General Algorithmic Process for *Loop* Simulations

In the schemata above, the seed rhythm is represented as a diamond which indicates a “fed value” – a value which the user inputs, the functions are given in rectangles and the logical operator “is piece over?” is represented in an oval. These three types of actions represent the basic building blocks of all algorithmic processes. “Fed values” can be either manually placed into the system or randomly derived; however, all algorithmic processes need some kind of data to work. Functions provide the basic transformations and/or actions taken on the data received and can range in complexity. Logical operators act by asking questions and can produce various results based on the answers to those questions. In the general algorithm presented in Figure III.1 one could set any kind of

value to answer the question “is piece over?”; however, for our purposes we will follow the model of Ligeti by stating that the work is finished after eight repetitions of “rhythmic generator”, taken with the seed value produces nine total iterations.

IV Markov Analysis

Given the rhythmic data provided by an iteration \mathbf{I}_n of *Loop* it is possible to derive a very rough imitation by creating a simple probability distribution of all possible rhythmic events occurring. This is done by counting up the occurrences of each rhythmic unit and dividing by the total. For instance, \mathbf{I}_2 has 24 occurrences of 2-beat units, 16 occurrences of 3-beat units, 1 occurrence of a 4-beat unit, 3 occurrences of 5-beat units, and one occurrence of an 8-beat unit. Using this material we can create the probability distribution of \mathbf{I}_2 found in Table II.1.

	2	3	4	5	8
P(x)	24/45	16/45	1/45	3/45	1/45

Table II.1: Probability Distribution for Rhythmic States in \mathbf{I}_2

Using the “ChoixMultiple” function in OMAlea, we can randomly select any number of events following a given probability distribution (Figure II.1). We present the function (c) with a probability vector (a) representing the distribution from Table II.1 and a list of states (b) indexed to our probability vector. The function then randomly draws a state based on the probabilities of (a).

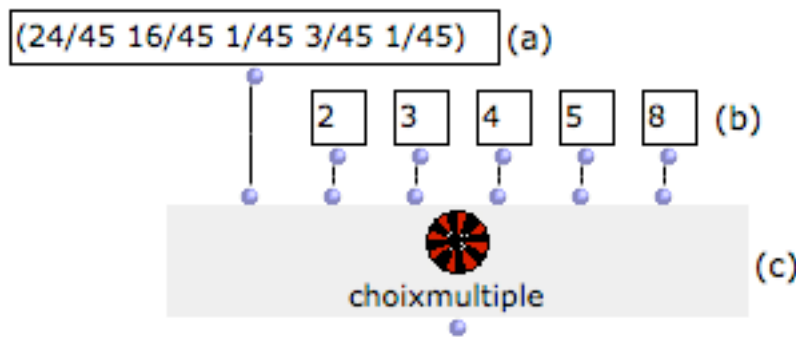


Figure II.1: Using “choixmultiple” To Generate States

By repeating this method 45 times we can create a somewhat satisfactory imitation of \mathbf{I}_2 (Figure II.2, compared with the original). However successful this method is in synthesizing an imitation of a given \mathbf{I}_n it fails miserably to produce a satisfactory imitation of the entire *Loop* process. This is because each state in a given iteration is not randomly drawn from a probability distribution but is *generated* from the equivalent state in the previous iteration. Each rhythmic state after \mathbf{I}_1 is imbued with a memory of its previous state in earlier iterations, the entire transformation from \mathbf{I}_1 to \mathbf{I}_9 is thus a *Generative Process* as opposed to a *Random Process*.

In order to deal with generative processes such as *Loop* we need a different approach to probability theory, one that takes into account the formulation “given *State A* what is the probability that *State B* will occur”. The method through which generative probability can be explored is known as “Markov Analysis”. As an analytical tool Markov analysis is similar to the method of probability distribution above; however, it

Imitation



Ligeti



Imitation (continued)



Ligeti (continued)



Figure II.2: \mathbf{I}_2 imitated with a simple probability distribution compared to original

takes the set of probabilities of all initial states becoming resultant states. For *Loop* this means measuring not the occurrences of states in an iteration \mathbf{I}_n but the transformations of states across two iterations (i.e. the probability of a X-beat unit from \mathbf{I}_{n-1} becoming a Y-beat unit in \mathbf{I}_n).

The most common method for presenting the resultant data is in what is known as a “Transition Table” whereby the initial states are listed vertically in the left-most column and the new states are listed horizontally on the top-most row. The probability of *State A* becoming *State B* is then filled in for each cell of the table. Table II.2 presents the transition table of a 1st Order Markov Analysis of \mathbf{I}_2 . By looking at an initial state from \mathbf{I}_1 we can look up the probability that a given state will occur at the same dyad in \mathbf{I}_2 .

	1	2	3	4	5	6	7	8
1	-	-	-	-	-	-	-	-
2	-	13/19	6/19	-	-	-	-	-
3	-	4/7	5/14	-	1/14	-	-	-
4	-	1/3	1/3	-	1/3	-	-	-
5	-	-	2/3	-	-	-	-	1/3

6	-	-	1/3	1/3	1/3	-	-	-
7	-	-	1/1	-	-	-	-	-
8	-	1/1	-	-	-	-	-	-

Table II.2: Transition Table \mathbf{I}_1 to \mathbf{I}_2 (1st order Markov Analysis)

This method can be expanded for all transitions \mathbf{I}_1 through \mathbf{I}_9 ddd

Another way to present the results of a Markov analysis is in a map known commonly as a Markov Chain which shows the probability that any given state will become a resultant state. This method better suits an alternative approach that focuses on the transformation of each individual dyad as opposed to the total transformation from iteration to iteration of all dyads as in the 1st order markov analysis above. Figure II.3 shows the Markov Chain of dyad 25 from \mathbf{I}_1 to \mathbf{I}_9 in *Loop*. The usefulness of this diagram lies in exposing the probability of possible paths of rhythmic decay given the information at hand and allowing the synthesizer to recreate an alternative path based on those data. Starting with an initial rhythmic value of 6 for \mathbf{I}_1 , every simulation of dyad 25 will jump down to a rhythmic value of 4 by \mathbf{I}_2 and 3 by \mathbf{I}_3 due to the 100% probability of the transitions represented in the Markov Chain. From there the possibilities using 1st order Markov Analysis double, the rhythmic value of \mathbf{I}_4 could be either 1 or 2 with equal probability. In this way, the original rhythmic value of 6 in \mathbf{I}_1 can randomly shifts until it reaches the end state (naturally, after passing through a rhythmic value of 1).

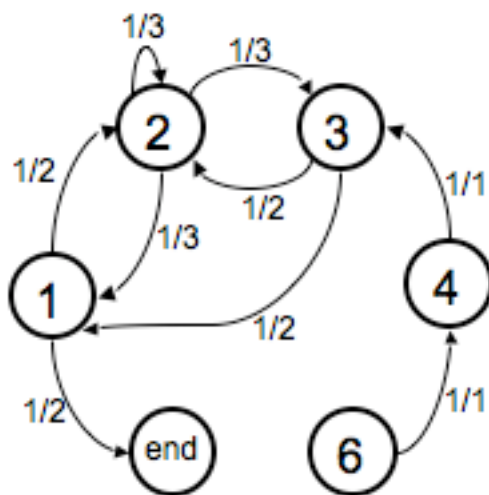


Figure II.3

	1	2	3	4	5	8	Total
1	-	-	-	-	-	-	0
2	1/6	2/3	1/8	-	1/24	-	24
3	-	9/16	5/16	1/8	-	-	16
4	-	-	1/1	-	-	-	1
5	-	-	1/1	-	-	-	3
8	-	-	-	-	1/1	-	1

Table 2: Transition Table \mathbf{I}_2 to \mathbf{I}_3 (1st order)

	1	2	3	4	5	Total
1	1/4	3/4	-	-	-	4
2	6/25	3/5	4/25	-	-	25
3	-	2/3	1/4	1/12	-	12
4	-	1/2	1/2	-	-	2
5	-	1/2	1/2	-	-	2

Table 3: Transition Table \mathbf{I}_3 to \mathbf{I}_4 (1st order)

	1	2	3	4	Total
1	2/7	4/7	1/7	-	7
2	7/28	18/28	3/28	-	28
3	1/3	1/3	1/3	-	9
4	-	1/1	-	-	1

Table 4: Transition Table \mathbf{I}_4 to \mathbf{I}_5 (1st order)

	1	2	3	Total
1	8/11	2/11	1/11	11
2	10/27	15/27	2/27	27
3	5/7	2/7	-	7

Table 5: Transition Table \mathbf{I}_5 to \mathbf{I}_6 (1st order)

	1	2	Total
1	6/11	5/11	22
2	3/5	2/5	20
3	2/3	1/3	3

Table 6: Transition Table \mathbf{I}_6 to \mathbf{I}_7 (1st order)

	1	2	Total
1	23/26	3/26	26
2	15/19	4/19	19

Table 7: Transition Table \mathbf{I}_7 to \mathbf{I}_8 (1st order)

	1	2	Total
1	37/38	1/38	38
2	5/7	2/7	7

Table 8: Transition Table \mathbf{I}_8 to \mathbf{I}_9 (1st order)

((4800 5900) (5700 6200) (5500 6600) (6400 6900) (6200 7300) (6200 7200) (5500 6800) (5500 6600) (6200 7500) (5500 7100) (4800 7000) (4800 6600) (4800 6400) (6200 8000) (6200 7800) (6200 7700) (5500 7300) (5500 7100) (6200 7600) (4800 7000) (5500 6900) (5500 6500) (6300 6900) (6200 7200) (5500 6800) (6600 6900) (6500 6900) (6100 6200) (4800 5900) (5600 6200) (5500 6600) (6400 6900) (6200 7300) (5500 7700) (6200 7000) (6200 7800) (5500 7300) (6900 7100) (6900 7000) (6600 6900) (6200 6400) (6800 6900) (5500 6600) (6500 6900) (6300 6900))

(4 3 3 5 3 2 2 3 3 8 2 2 3 3 2 2 2 2 4 6 3 2 3 4 6 2 2 2 2 2 2 3 3 5 7 6 5 3 2 2 3 3 8 2 2)
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(2 3 2 2 2 2 2 1 3 1 3 2 2 3 1 3 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2 3 2 3 1 2 3 1 3 3 3 1 3 1 1)
(3 1 2 2 2 2 2 3 1 1 1 1 2 1 1 3 2 2 3 3 2 2 3 1 1 2 1 1 2 2 2 3 1 3 3 1 2 2 3 2 2 2 2 2 2)
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