Centenary International Symposium

XENAKIS 22

Lectures | Workshops | Concerts

May 24-29 2022
ATHENS & NAFPLIO

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Lectures Workshops Concerts

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DEPARTMENT OF PERFORMING AND DIGITAL ARTS

Preface

"There is no reason why art cannot, following the example of science, rise from the immensity of the cosmos; nor why art cannot, as a cosmic landscaper, modify the demeanor of the galaxies. This may seem utopian, and in fact it is, but only temporarily when viewed in the context of the immensity of time. On the contrary, what is not utopian but possible today is to cast luminous spiderwebs of colored laser beams like a giant polytope over cites and countrysides […] One could even willfully create artificial aurora boreales in the night skies whose movements, forms and colors would be controlled by electromagnetic fields aroused by lasers in the highest atmosphere. As for music, loudspeaker technology is still at the embryonic stage, too underdeveloped to send sound into space and have it received there, where thunder dwells."

—Iannis Xenakis,*Arts/Sciences: Alloys*

This symposium was aimed at celebrating the work of composer and architect Iannis Xenakis – 1922 (or 1921)-2001 – on the centenary of his birth. Xenakis's work has not ceased to attract the interest of a wide range of artists and researchers. A large body of related work, artistic and academic, has been developing constantly in recent decades, ranging from archival study to artistic reworking of Xenakis's original ideas. These proceedings are putting forward the idea of an interdisciplinary field of Xenakis Studies, in fruitful dialogue with other fields, including those beyond music or architecture themselves. It is our hope that such symposium as this one will foster a long-term symbiotic relationship between the arts and academic research.

Forty-five papers and eleven workshops were presented during the symposium. The papers were organized under the following themes: Music Theory and Analysis, Aesthetics, Space and Electroacoustic Music, Performance, Architecture, Archival Researches, Post-Xenakian Proposals, Computationnal Models, Polytopes, Stage works, Politics.

The symposium was organised b the National and Kapodistrian University of Athen, the Université Paris 8 (EUR ArTeC, MUSIDANSE), The Friends of Xenakis Association, The University of the Peloponnese, in collaboration with the Aristotle University of Thessaloniki, the University of Ioannina, the University of Thessaly, with the support of Lyriki Skini/Greek National Opera, ASKI (Contemporary Social History Archives, Athens), Stegi – Onassis Foundation, École française d'Athènes.

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The Use of Stochastic Distributions in the Instrumental Works of Iannis Xenakis: Between Chance and Intuition[1]

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Abstract

Relying on various examples, some of which inspired by documents or sketches found in the composer's archives, this presentation explores how Xenakis incorporates and deals with the results of his stochastic distributions in his instrumental works, discussing the degree of freedom implicit in his compositional choices. It focusses on examples taken from works where the stochastic distributions were calculated by different means: *Achorripsis* (1956-57) for chamber orchestra, *Morsima-Amorsima* (1962) for violin, violoncello double bass and piano, and *Mists* (1980) for solo piano. In *Achorripsis*, the stochastic distributions of durations and intervals were calculated by hand and expressed as tables of numbers. They appear as outside-time proportions. This is probably why Xenakis felt the need to represent them linearly, inside-time, as classes of durations and intervals as an intermediate stage in the compositional process. He then had to choose, intuitively, the intervals and durations in order to arrange them in lexicographic time. Later, at the beginning of the 60s, Xenakis designed a computer program (*ST*) that implemented the theories and ideas he had developed for *Achorripsis*. The *ST* program generates lists of data where each line corresponds to the definition of an individual note. The moment of occurrence and the pitch of each note are determined. But the program does not always take into account all the necessary parameters for the final results to be playable on the instruments. And the higher the density of the sound events, the more adjustments is needed. This is shown in *Morsima-Amorsima* by comparing the provisional results of the stochastic distributions with the final score. Finally, at the beginning of the 70s, Xenakis introduced probability theory in the field of sound synthesis when he suggested that the sound pressure be based on probability distributions. These new proposals also had an impact on his instrumental works. In *Mists*, he programmed a pocket calculator to obtain similar stochastic distributions where the occurrence and the pitch of each note were calculated separately. The input data were then modified to generate series of clouds of different densities. But the results were also altered by hand to fit different transpositions of the main sieve of the work. Whether he did his calculation by hand or resorted to technological means, Xenakis always seems to leave a gap between the output of his calculations and the traditional score. A gap that is filled manually. In the end, the composer decides, guided by his own intuition, which elements to assemble.

[1] This work was funded by national funds through the Portuguese Foundation for Science and Technology (Fundação para a Ciência e a Tecnologia), under the project UIDB/00693/2020

1. Free Stochastic Music

Iannis Xenakis is well known for having used mathematical models in his compositions. His first reference to probability theory dates from the 50s. And in his work *Pithoprakta* (1956-57) for orchestra, he already conceived masses of sounds where various musical parameters could be organised following different laws of probability. But it is in his next piece that he fully developed the ideas he had explored in *Pithoprakta*.

Achorripsis

Achorripsis (1957) is scored for 21 instruments and relies on the stochastic distribution of seven sonic events, each one associated with a group of instruments or their playing techniques: 1. flute (clarinet and bass clarinet), 2. oboe (bassoon and contrabassoon), 3. string glissando, 4. percussion, 5. pizzicato, 6. brass, 7. string arco. We know from his book *Formalized Music* that Xenakis (1992, 28-32) calculated the probability of occurrences of these sonic events using the Poisson distribution (which is the law of appearance of rare random events), and that he represented them by a matrix[2] where each line corresponds to a 'timbre' and each column to a unit of time of about 6,5 bars (Figure 1).[3]

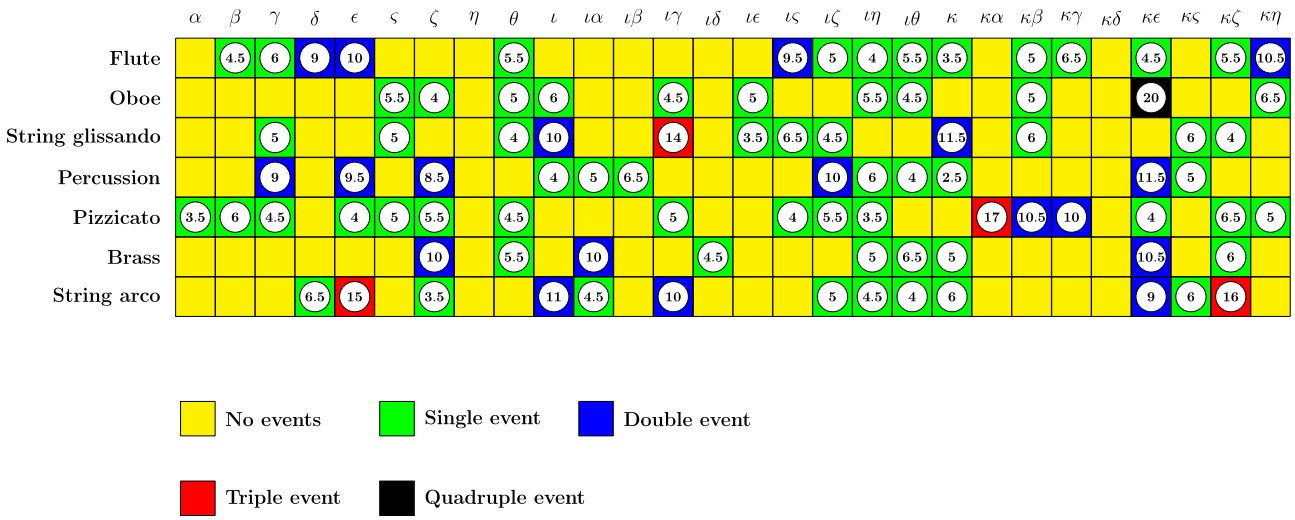

Figure 1: Matrix of Achorripsis.

To illustrate how Xenakis deals with the results of his stochastic distributions in *Achorripsis*, we shall analyse a column that contains only one sonic event: column number 14 (ιδ).[4] It represents the sounds of the sonic event 'Brass,' which includes two trumpets and a trombone. Its density is 4,5 sounds per bar, so it comprises 29 points (4,5 sounds times 6,5 bars).

Time

For Xenakis (1992, p. 12), "The following formula, which derives from the principles of continuous probability, gives the probabilities for all possible lengths when one knows the mean number of points placed at random on a straight line, in which δ is the linear density of points, and *x* the length of any segment."

$$P_x = \delta e^{-\delta x} dx \qquad \delta = 4,5$$

From the law formulated above, it is possible to create a table of durations for any sonic event, provided that its linear density is known. Here, the values of *x* are grouped by class: $x = 0$ means that

[2] The matrix shown in Figure 1 is based on the one reproduced in Mâche (2001, 55-56) but includes minor adjustments drawn from documents found in the Xenakis Archives and catalogued as Œuvres Musicales [OM] 3-12.
[3] Linda Arsenault (2002) provides further details on how the matrix was calculated.
[4] In the matrix, Xenakis numbers the columns using an ancient Greek alphabetic numeral system.

x is included between 0 and 1 (0 < *x* . .1) tenth of a bar.[5] Table 1 reproduces the data that Xenakis notated in his notebook.[6]

Table 1: Table of durations for Achorripsis*, brass instruments, bars 84-91 (ιδ)*

x	δx	$e^{\delta x}$	$\delta e^{\delta x}$	$\delta e^{\delta x} dx$	· 28
0	0,00	1,000	4,5000	0,362	10
0,10	0,45	0,638	2,8700	0,231	7
0,20	0,90	0,407	1,8300	0,148	4
0,30	1,35	0,259	1,1650	0,094	3
0,40	1,80	0,165	0,7430	0,060	2
0,50	2,25	0,105	0,4730	0,038	1
0,60	2,70	0,067	0,3015	0,024	1
0,70	3,15	0,043	0,1935	0,016	1
[...]					
	Totals		12,4152		28
		$\delta x =$	0,0805		

Intervals

A table of intervals can be obtained the same way, using a different law (Xenakis 1992, p. 13):

$$\Theta(j)\ dj = \frac{2}{a}(1 - \frac{j}{a})dj \qquad a = 44$$

Figure 2 shows the probability of the interval *j* taken at random from a range *a* of 44 semitones. Here, Xenakis represents the intervals of the brass sonic event in classes (multiples) of three semitones.[7]

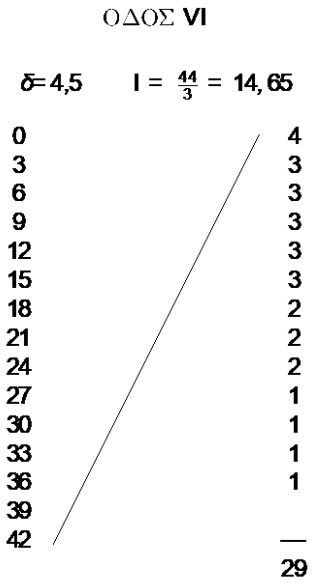

Figure 2: Table of intervals for Achorripsis*, brass instruments, bars 84-91 (ιδ).*

In Xenakis' terms, the tables that calculate the distributions of durations and intervals are outside-

[5] It should be noted that, in *Achorripsis*, the values of *x* vary according to the density of the sonic event.
[6] The data are reproduced as they appear in Xenakis' Notebook 18 [Carnet 18, p. 008]. They contain some deviations.
[7] Figure 2 is also based on a document found in the Xenakis Archives: OM 12-1, p. 035.

time. They do not prescribe any order. They must be arranged in lexicographic time. Other documents found in the composer's archives show that Xenakis represented these data linearly, inside-time, as classes of durations and intervals. In her thesis, Linda Arsenault (2000) gives an example of how Xenakis proceeded from his tables of proportions to the final score. We can illustrate this process relying on another example.

Figure 3 is a transcription inspired by a document catalogued as OM 3-12_1-037 in the Xenakis Archives. Classes of intervals and durations are written out above and below the line respectively. The colours shown on the sketch indicate on which part of the beat the note will fall. Red represents a subdivision by 5 (quintuplets), green by four (quavers), and blue by three (triplets). Black strikes fall on the beat. This sketch is still an intermediate stage in the process of composing *Achorripsis*. It determines the dates of departure of each sound, as they will appear in the score, but the melodic intervals are still defined as classes (multiples of 3 semitones). Furthermore, we do not know if these intervals are ascending or descending, and which instrument is going to play each note.

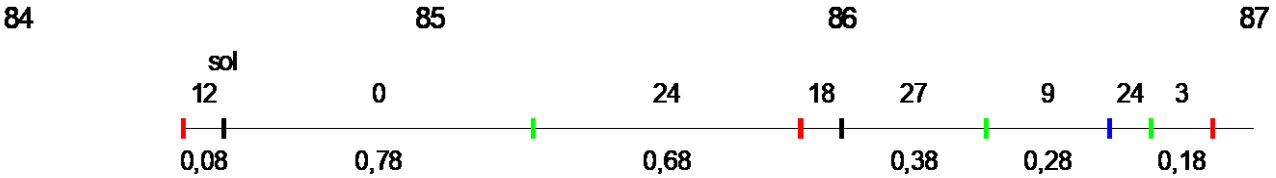

Figure 3: Sketch representing classes of intervals and durations for bars 84-86 of Achorripsis*, brass instruments.*

Other choices are made when these data are drawn on a two-dimensional plane, a Cartesian coordinate system, where the abscissas represent time and the ordinates, pitch. As he had done for *Metastaseis* (1953-54) and *Pithoprakta*, Xenakis also represented *Achorripsis* graphically, in a pitch versus time domain, before he would transcribe it into traditional notation. In Figure 4, Xenakis indicates the instruments and the intervals within each class. The numbers (3, 4, or 5) before each instrument correspond to the subdivision of the beat on which the sound falls, as did the colours in the previous example.

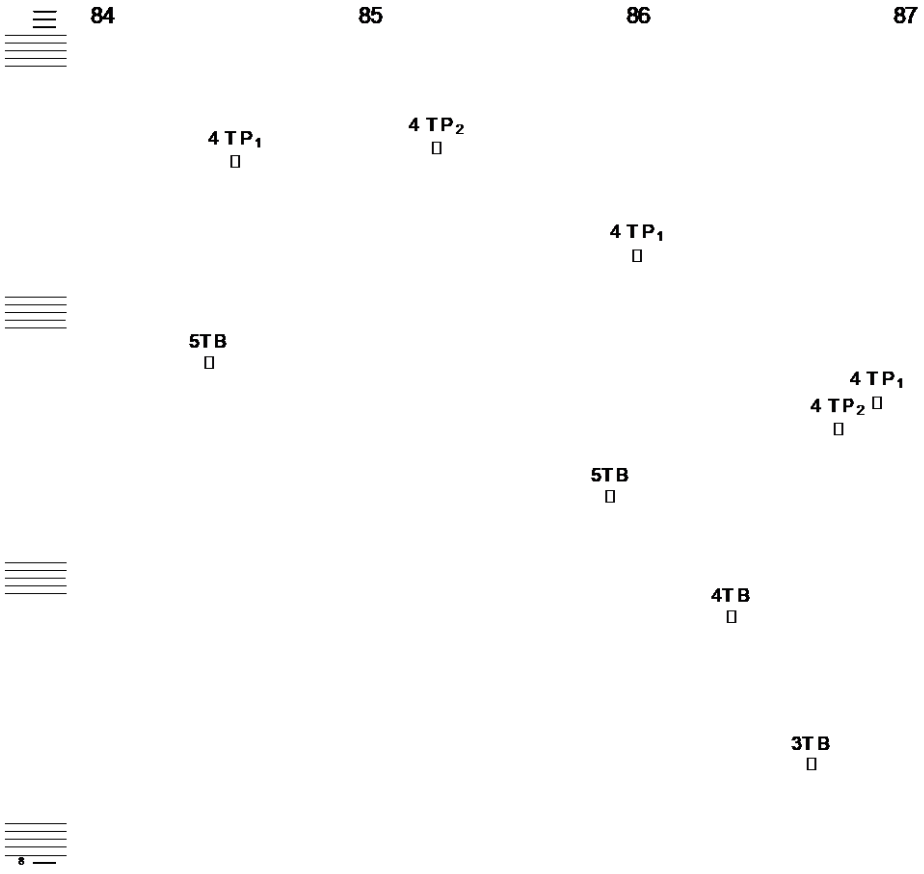

Figure 4: Graphic representation of Achorripsis*, bars 84-86*

This is the ultimate stage before transcribing the data into traditional notation (Figure 5), where Xenakis determines the dynamics and durations of the individual notes.[8]

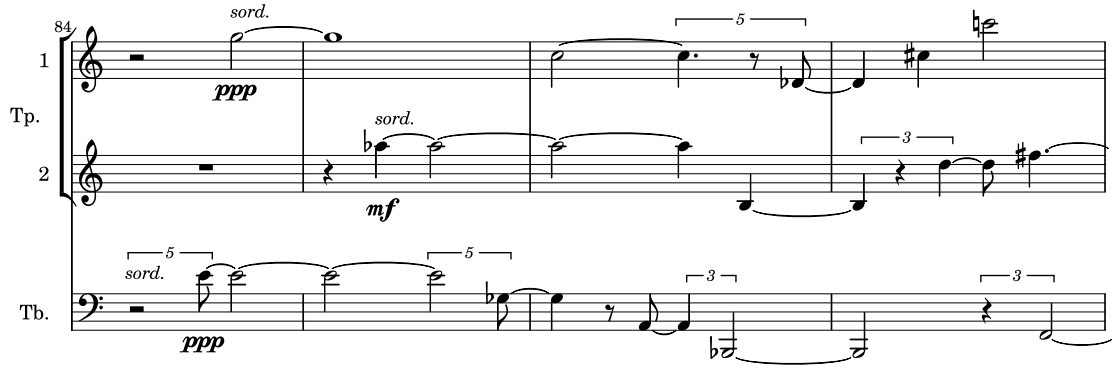

Figure 5: Excerpt from Achorripsis, bars 84-87

The analysis of *Achorripsis* shows us the extent of the degree of liberty given to the composer. The stochastic distributions, expressed as tables of numbers, are outside-time proportions that constitute only one step of the compositional process. Each time, for each cell, Xenakis had to decide in which order to put the intervals, durations, and speeds if glissandi are involved. This is what Mikhail Malt (2005) refers to as "l'espace d'écriture." Since the matrix of *Achorripsis* comprises 10 cells with a

[8] The published score of *Achorripsis* contains many errors or deviations regarding the manuscript (OM 3-15). Here, the first note of the trombone has been corrected to E_4.

density of 4,5 sounds per bar, Xenakis had to reordered (permuted) these values nine times. How? Émile Borel (1937), whose work Xenakis (1992, 39) cites, believed that human mind cannot imitate chance. Be it as it may, to create his stochastic clouds of sounds Xenakis must have relied heavily on his intuition, as he did in other pieces of the same period.[9]

2. Free Stochastic Music by the Computer

Xenakis is also acknowledged as being one of the pioneers in the field of computer music. At the beginning of the 60s, he designed a computer program that implemented the theories and ideas he had developed for *Achorripsis*. It took Xenakis many months of contacts before he could gain access to a computer, the IBM-7090 located at Place Vendôme in Paris. Luckily, he was granted access for free.

The stochastic computer program *ST* (which stands for stochastic) was written in the FORTRAN programming language. For Xenakis, using a computer offered many advantages. One of them was to free the composer from tedious calculations, even though, as he admitted: "It took several months to transcribe the program into language that the machine's organization could assimilate" (1992, 142). Then you only save time if you repeat the process several times, changing the input data to explore the possibilities of the program. And this is what Xenakis did. Eight of his instrumental pieces are based entirely or in part on the stochastic computer program *ST*: *ST-48* (1956-62), *ST/10* (1956-62), *ST/4* (1956-62), which is a version of *ST/10* for string quartet, *Amorsima-Morsima* (1956-62) (withdrawn from the composer's catalogue), *Morsima-Amorsima* (1956-62), *Atrées* (1956-62), *Stratégies* (1962) and *Eonta* (1964). The title or subtitle of each piece indicates the number of instruments, the version and the date when the work was calculated by the IBM-7090. The dates associated with the works suggest that Xenakis had recourse to the IBM-7090 at least five times between January and October 1962.

The output of the *ST* program generates lists of data where each line corresponds to the definition of an individual note. Examples of "provisional results of one phase of the analysis" are reproduced in Xenakis' (1992, 153) text "Free Stochastic Music from the computer." The examples provided by Xenakis for the French and English editions of *Musiques formelles* (*Formalized Music*) are not the same. But in both editions, they are followed by an excerpt from bars 1-5 of *ST-10-1, 080262*. In both cases, the "provisional results of one phase of the analysis" provided by Xenakis do not correspond to the music example that follows. But knowing the classes of timbre, the instruments, the origin, and the intensity forms, it is possible to transcribe these data into traditional musical notation.[10]

Morsima-Amorsima

The output of the *ST* program for *Morsima-Amorsima*,[11] like the one reproduced in *Formalized Music*, shows sequences that take the form of a list of data where each line corresponds to the definition of an individual note (Table 3).

[9] For a good example of the dialectic between formalisation and intuition in Xenakis' music, see Agostino Di Scipio's (2005) text on *Analogique A et B*.

[10] André Baltensperger (1996, 634) gives detailed examples of how to transcribe these data into musical notation.

[11] The data for *Morsima-Amorsima* were found in the Xenakis Archives.

Table 2: Morsima-Amorsima*, annotated provisional results produced by the* ST *program.*

JW= 1 A= 8.13 NA= 59
Q(I)= 0.32/0.05/0.13/ 0.10/ 0.10/0.05/0.15/0.10/

N	TA	CLAS	INST	H	VGL1	VGL2	VGL3	DUREE	DYNAM
1	0.	5	2 ~~1~~	34.0	-19.0	16.0	-11.0	0.92	16
2	0.02	4	3	37.6	0.	0.	0.	2.05	46
3	0.03	5	1	42.3	-4.0	2.0	-2.0	0.31	40
4	0.07	1 ~~4~~	1 ~~2~~	51.7	0.	0.	0.	0.86	4
5	0.21	5	1	52.2	28.0	-13.0	-16.0	1.21	50
6	0.37	1	1	26.7	0.0	0.	0.	1.31	63
7	0.38	1 ~~4~~	1	82.8	0.	0.	0.	0.38	16
8	0.43	1	1	50.3	0.	0.	0.	1.18	9
9	0.60	4	2	35.1	0.	0.	0.	2.10	57
10	0.64	5	1	59.4	23.0	-10.0	13.0	1.11	56
~~11~~	~~0.80~~	~~5~~	~~1~~	~~68.8~~	~~-8.0~~	~~6.0~~	~~-5.0~~	~~0.75~~	~~28~~
12	1.05	5	1	43.3	30.0	-12.0	-17.0	1.45	52

. . .

The following abbreviations and variables apply to Table 3:

JW: Ordinal number of the sequence calculated
A: Duration of each sequence in seconds
NA: Number of sounds calculated for the sequence
Q: Probability of the classes of timbre
N: Line number
TA: Moment of occurrence of the sound within the sequence
CLAS: Class of timbre
INST: Instrument of the class (choice of instrument)
H: Pitch
VGL1, VGL2, VGL3: Glissando speed
DUREE: duration
DYNAM: Intensity form (dynamic)
CLAS 1 = piano
CLAS 2 = arco sul ponticello
CLAS 3 = harmonic
CLAS 4 = arco normal
CLAS 5 = glissando
CLAS 6 = ponticello tremolo
CLAS 7 = pizzicato
CLAS 8 = frappé col legno
INST 1 = (CLAS 1) piano
INST 1 = violin

INST 2 = cello

INST 3 = double bass

From a compositional perspective, the stochastic distributions used in *Morsima-Amorsima* differ from those of *Achorripsis*, where Xenakis had to decide intuitively the order of durations and intervals based on global proportions. Here, it is the *ST* program that determines the moment of occurrence and the pitch of each note, in decimal numbers, with two decimal places.[12] We should add that intensity forms are used freely, and that the difference between classes 2 and 6 is not always clear in the score. Also, only the first glissando speed (VGL1) is taken into consideration.

In Table 3, the first line indicates a glissando with a speed of -19 semitones per unit of time (minim) starting at the beginning of the bar and played by the violin. It has a duration of 0,92 unit of time and starts with G_4, the lowest note on the violin. Probably because the glissando prescribed by the program falls outside the range of the violin, Xenakis changed the instrument of the first line and crossed out the eleventh one. If we look closely at the provisional results for the beginning of *Morsima-Amorsima*, there are six glissandi attributed to the violin in the first bar (CLASS 5, INST 1), each with its own speed and duration. To cope with this situation, Xenakis combines two of them into a parallel ascending fifth and makes many other adjustments. In general, the higher the density, the more adjustments are needed to combine the sounds. In fact, much of what Xenakis does when he transcribes the data of the *ST* program into musical notation amounts to what Makis Solomos (1996, 112) refers to as “bricolage”.

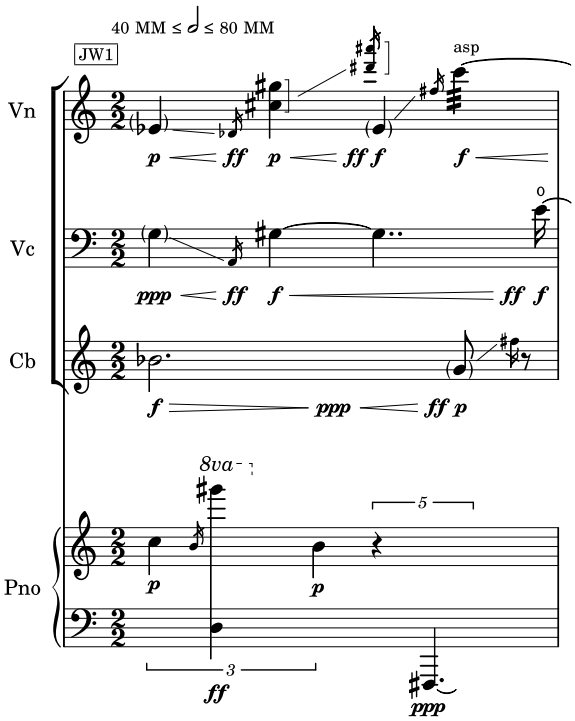

Figure 6: Morsima-Amorsima, bar 1.

Eonta

Xenakis also used sequences calculated for *Morsima-Amorsima* for the piano solo at the beginning of *Eonta*. *Eonta* was written in 1963-64 for piano, two trumpets and two trombones. Since Xenakis only uses the data for the piano part, he ignores the Class and Instrument variables. He also ignores the durations, for the music is adapted to a predefined rhythmic grid which superposes sextuplet in the right hand and quintuplet in the left (Figure 8). We’re left with time abscissas (moments of

[12] The numbers that correspond to pitches are rounded off to whole numbers, not necessarily the nearest.

occurrence), pitches and simplified intensity forms. There are no crescendo or diminuendo on individual notes, but each note has its own dynamic.[13] The origin is the same, the lowest note on the piano: A_0.

The data reproduced in Table 4 indicate that the first note starts at 0 time abscissa (TA) on C_1 (rounding up 2.7 to 3). "D" means the right pedal; and Sigma (Σ), all the sounds of the piano.[14] The second line corresponds to the upper G-sharp; and the third line, to the D-sharp in the right hand, etc.

As opposed to the other *ST* pieces, in *Eonta* Xenakis represented the music graphically before writing down the score. And if we look closely at the graphic representation of the first three bars (Figure 7), we can see that it is based on the output of the program and not on the score. This can be seen from the alignment of the time abscissas.

Eonta is likely to be the last instrumental piece where Xenakis used the *ST* program. It marks the end of a period that Xenakis (1992, 182) summarized as follows: "Today these ideas [Stochastic Music] and the realizations which accompany them have been around the world and the explorations seems closed for all intents and purposes."

Table 3: Provisional results for Eonta

JW= 18 A= 78.52 NA= 1512
Q(I)= 0.54/0.05/0.10/ 0.06/ 0.04/0.04/0.09/0.07/

N	TA	CLAS	INST	H	VGL1	VGL2	VGL3	DUREE	DYNAM
1	0.	1	1	2.7	0.	0.	0.	1.52	33
2	0.12	1	1	70.5	0.	0.	0.	5.66	29
3	0.14	7	1	53.8	0.	0.	0.	0.	2
4	0.15	7	3	22.8	0.	0.	0.	0.	4
5	0.20	1	1	42.9	0.	0.	0.	6.32	0
6	0.30	1	1	63.9	0.	0.	0.	1.65	30
7	0.42	1	1	24.4	0.	0.	0.	0.	33
8	0.55	7	1	34.3	0.	0.	0.	0.	6
9	0.75	1	1	5.3	0.	0.	0.	4.74	17
10	0.82	1	1	9.1	0.	0.	0.	1.45	32
11	0.85	1	1	2.4	0.	0.	0.	3.76	61
12	0.92	1	1	21.0	0.	0.	0.	6.12	5
...									

[13] The six dynamics are approximately used.
[14] Other parts of *Eonta* rely on sets of pitches.

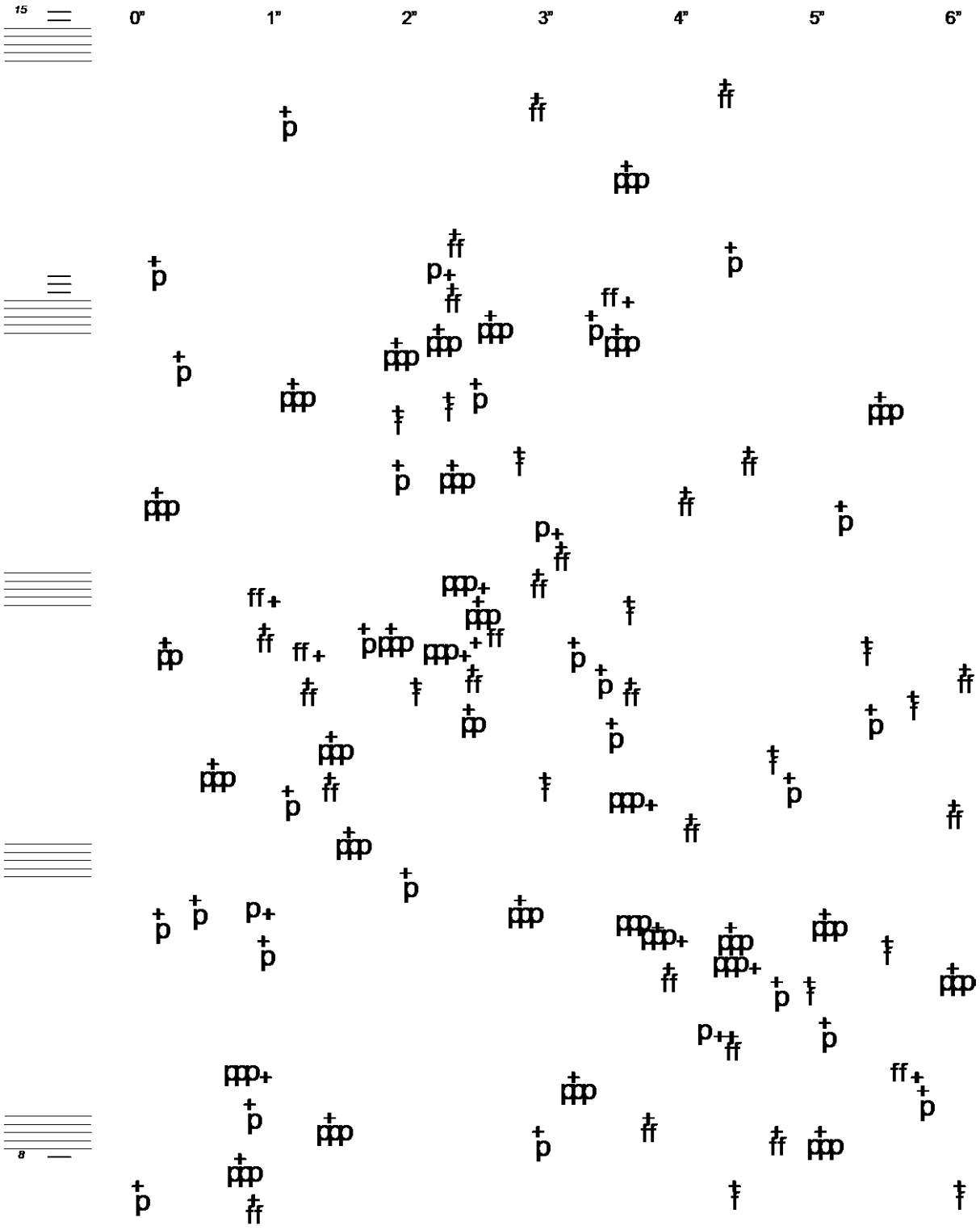

Figure 7: Graphic representation of Eonta, bars 1-3.

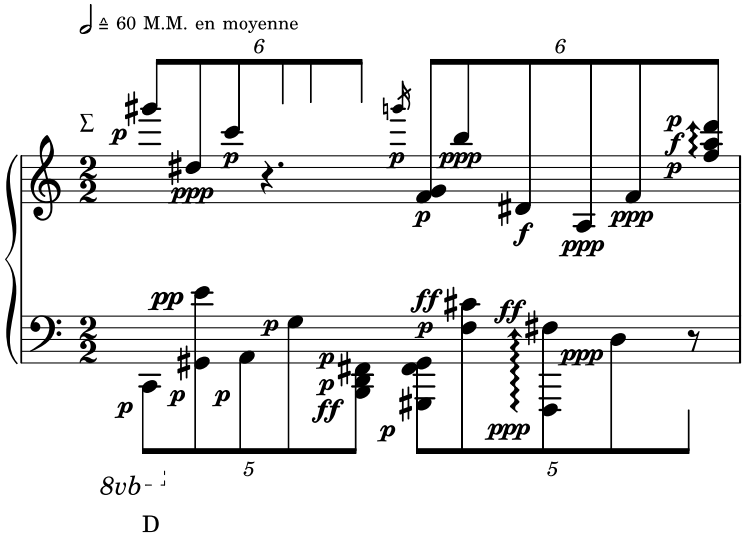

Figure 8: Eonta, bar 1.

4. New Proposals in Microsound Structure

Xenakis reintroduced probability theory in his music at the beginning of the 70s. In his article entitled "New proposals in Microsound Structure" (1992, 242-254), he suggested that the sound pressure be based on probability distributions, creating a stochastic variation of the sound pressure. These new proposals had a great impact on his compositional ideas. Some of the curves developed in the field of sound synthesis were transposed into the pitch versus time domain: "It was with the help of such graphs that I made *Mikka* and *Mikka S. Cendrées*, *N'shima* and *Phlegra* are much more complicated: here, as well as arborescences, I used curves which I call random walk or Brownian movement curves" (Varga 1996, 91).

Mists

There are other instrumental works that benefited from Xenakis' research in the field of sound synthesis, but without relying on graphic representations. *Mists* (1980) for solo piano appears to be the first example. *Mists* features a new notational device. In many sections of the work, the performer is required to play the notes according to their exact geometric positions relative to indicating semiquaver (sixteenth note) values. According to Xenakis, this kind of approximate notation was used to facilitate the reading of the score (Varga 1989, 155). It was also conceived as a means to transcribe into traditional notation the numerical data (decimal numbers) generated by a program specially designed by Xenakis. These data were printed by a programmable pocket calculator[15] on paper rolls. The data shown in Figure 9 correspond to bar 41 of *Mists*. They represent abscissas and ordinates (moments of occurrence and pitches), and were calculated separately according to two different probability functions: exponential and Cauchy. The unit of time is the semiquaver; pitches are indicated in semitones, with A_0 as origin. The equivalent in sound synthesis would be a sound produced by Exponential x Cauchy Densities with Barriers of 43 semitones and Randomized Time.

A comparison between the data printed on these rolls and the score of *Mists* shows that Xenakis followed the moments of occurrence but changed the pitches in order that they correspond to a transposition 36 semitones up of the original sieve of the work. The data are usually rounded off to the nearest pitch of the sieve. Xenakis also modifies the input data of the stochastic distributions to generate series of clouds of different densities.[16]

In his instrumental works, Xenakis had recourse to this notational device about fifteen times, between

[15] The calculator used by Xenakis for *Mists* was a Hewlett-Packard HP 19C.
[16] For further details on the analysis of random walks in *Mists* see Squibbs (1996, 180-202).

1980 and 1987, to create stochastic clouds. And it is very likely that the values of these clouds were also produced with the aid of a similar program.

```
0.32   ***
14.    *** → 15
1.00   ***
13.    *** → 11
1.14   ***
61.    *** → 60
1.21   ***
63.    *** → 62
1.30   ***
1.     ***
6.05   ***
64.    *** → 66
7.15   ***
79.    *** → 80
7.90   ***
83.    *** → 82
11.30  ***
71.    *** → 69
13.74  ***
17.    ***
14.59  ***
40.    *** → 39
15.09  ***
22.    *** → 21
15.44  ***
22.    *** → 21
15.45  ***
17.    ***

[...]  ***
```

Figure 9: Annotated output from calculator program for Mists.

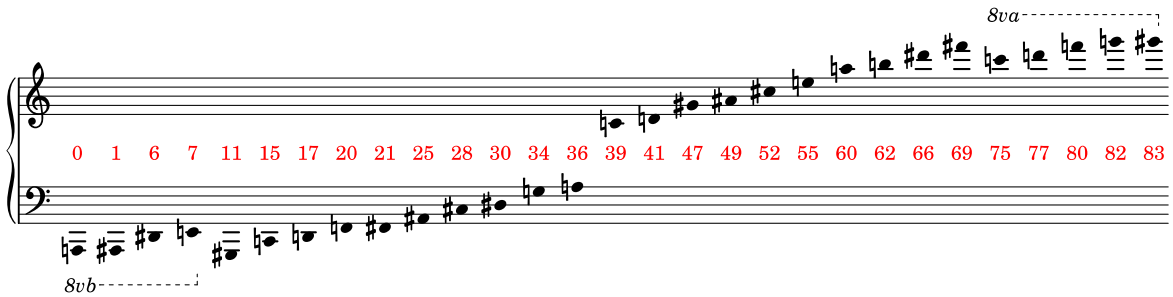

Figure 10: Sieve of Mists in *bar 41.*

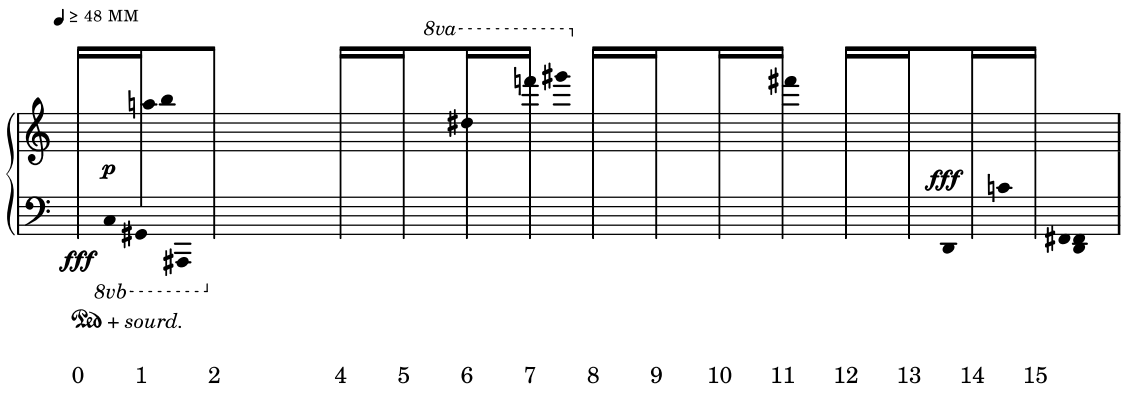

Figure 11: Mists, bar 41 with sequentially numbered semiquavers.

Final remark

With the *ST* program, Xenakis attempted to mechanise the ideas he had developed in *Achorripsis*. For that purpose, he worked with a variety of parameters: classes of timbre, instruments, moments of occurrences, pitches, durations, glissando speeds, intensity forms, etc. But from the 70s onwards, he narrowed the scope of his stochastic distributions. Those used in *Mists* apply mainly to moments of occurrence and pitches, as if Xenakis had learned from the beginning of *Eonta* that it is more practical to work with fewer variables. In fact, the distributions generated by his pocket calculators usually concern a single instrument at a time.[17] They are raw numerical data that the composer can couple with sound characteristics in various ways. That is, even then, when everything could be programmed in advance, Xenakis always seems to leave a gap between the output of his stochastic distributions and the traditional score. A gap that is filled intuitively by hand.

Acknowledgments

I'm grateful to Mâkhi Xenakis, for some of my work is based on documents that I have consulted in the Xenakis Archives in Paris.

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[17] Instrumental works that rely in part on similar distributions include *Waarg* (1988), *Échange* (1989), *Épicycle* (1989), *Oophaa* (1989), *Okho* (1989), *Knephas* (1990) and *Tetora* (1990).

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Contrapuntal procedures and aspects of conflict in the work of Iannis Xenakis

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Abstract

Contrapuntal procedures have always been in the core of musical creation. Polyphonic, or in a wider definition, multipart textures are found to be an essential if not constituent part of almost every musical expression that has been documented, or is assumed to have existed, not only in the context of the longest part of the history of western music but also in the vast multicultural depository of global musical expression. The idea of juxtaposing diverse or merely diversified materials in forming different kinds of contrasting yet interdependent textures has become a crucial part of almost every compositional procedure that attempts to encompass, manipulate and eventually communicate, culturally meaningful, multiple content, in both narrative and even non narrative forms, to a specific audience. In order to effectively communicate, every musical style, any personal or collective expression, –regardless of its level of self-awareness and particularity–has to utilize conceptually and symbolically valid material that in any given moment can be traced and, therefore has to be perceived, in the context of a wide continuum that spans through the two opposing extremes of perfect concordance or complete discordance. In other words, materializing the symbolic essence of conflict, amongst various degrees of consonance and dissonance, in either small or/and grand scale.

Living his entire life on the edge of multiple contrasting forces, Iannis Xenakis stands out as an emblematic maestro of conflict. Moving forward in a constantly changing environment, he straggles to adapt while determined to retain, mostly through his work, his physical, mental and psychic integrity. By overriding traditional restrictions and contemporary norms, by creating mass sonorities that clash over a time continuum, and applying a stochastic perception of the compositional process that is immensely inspired by the dubious outcomes of complex natural as well as social phenomena, Xenakis provides us with a rare opportunity to observe crucial aspects of the compositional process.

In this paper we will attempt to trace these compositional procedures in the multiple contrasting sections and the polyphonic textures in the late works of the composer. In doing so, we will examine the specific notions of conflict and pinpoint to some actual musical instances that seem to adhere to the principles of these expanded contrapuntal procedures. At the end, we will offer some thoughts on the impact of Iannis Xenakis work in the contemporary and current research on compositional thought and analysis.

1. Introduction

1.1. Contrapuntal procedures

Contrapuntal procedures have always been in the core of musical creation. Polyphonic, or in a wider definition, multipart textures are found to be an essential if not constituent part of almost every musical expression that has been documented, or is assumed to have existed, not only in the context of the longest part of the history of western music but also in the vast multicultural depository of global musical expression.

The idea of juxtaposing diverse or merely diversified materials in forming different kinds of contrasting yet interdependent textures has become a crucial part of almost every compositional procedure that attempts to encompass, manipulate and eventually communicate, culturally meaningful, multiple content, in both narrative and even non narrative forms, to a specific audience. In order to effectively communicate, every musical style, any personal or collective expression – regardless of its level of self-awareness and particularity–has to utilize conceptually and symbolically valid material that in any given moment can be traced and, therefore has to be perceived, in the context of a wide continuum that spans through the two opposing extremes of perfect concordance or complete discordance. In other words, materializing the symbolic essence of conflict, amongst various degrees of consonance and dissonance, in either small or/and grand scale.

Living his entire life on the edge of multiple contrasting forces, Iannis Xenakis stands out as an emblematic maestro of conflict. Moving forward in a constantly changing environment, he struggles to adapt while determined to retain, mostly through his work, his physical, mental and psychic integrity. By overriding traditional restrictions and contemporary norms, by creating mass sonorities that clash over a time continuum, and applying a stochastic perception of the compositional process that is immensely inspired by the dubious outcomes of complex natural as well as social phenomena, Xenakis provides us with a rare opportunity to observe crucial aspects of the compositional process. His continuous multifaceted productivity, profoundly affected by his encounter with ancient Greek philosophical thought and deeply scarred by an astonishingly big number of traumatic instances throughout his entire life, offers us valuable keys to unlocking the underling forces that has enabled his original creativity as well as his idiosyncratic personal expression.

2. The legacy of polyphony

2.1. Dissecting the past

Polyphony has been with us for ages. Although it is generally assumed that polyphonic practices in western music originated in the gradual polyphonic treatment of the early plainchant and acquired formal structure around the Notre Dame School, we can detect traces of polyphonic manipulation, –even beyond the conveniently blurred limits of heterophony–in Middle East and Mediterranean antiquity as well as non-western cultures all around the world. It is, in fact, this widespread presence of polyphonic practices that, despite the sparse physical evidence, seem to direct us towards regarding polyphony as a social phenomenon that is being directly linked to spontaneous or premeditated musical expression of hierarchically structured cultural groups in the context of a narrative or ritual performance.

It is true that for the most part of our recent music history we tend to regard polyphony as a fundamentally vocal, archaic and basically outdated craft that grew out of medieval practices, evolved and expanded throughout Renaissance, gradually shifted towards instrumental premises and culminated in Baroque only to give way to the homophonic dominance of the Common Practice Period, before being reduced to a technically and educationally significant yet rather anachronistic

and fairly marginal practice. Ironically though, and while contrapuntal procedures survived for long, hidden between the lines, deep under the surface of otherwise elaborate homophonic tonal structures, it was the eventual dissolution of Tonality that lead to the re-emergence of the basic principles that govern multipart textures and could compensate for the lack of harmonic functionality, re-introducing the old craft as a vital tool of linear and mostly temporal organization.

Starting out as a literary *note against note* procedure this eventually polyphonic practice that emerged due to political necessities, transcended through many stages of development before crystallizing to what we tend to recognize as the firm and well defined set of principles that deal with the musical organization of individual linear texts through the apparatus of dissonance. Yet it has always been about conflict. And all these should be irrelevant to our subject if it were not for the abstract and symbolic nature of this fundamentally modular process.

Although music theory concerning the treatment of dissonance in the last few hundred years asserts that regular accented notes in a polyphonic texture should be consonant, it was, as it seems, Goscalcus in the previously anonymous Berkeley Treatise of 1375 that observing the musical practice of his time concerning the construction of a multi-note melody over a given long note, –a discantus– who stated that "...it is possible to place some of them [that is the sung notes] dissonant as long as the greater part of at least half are consonant."[1] Bearing in mind that this approach tries to comply with the rules imposed some decades earlier through the *Docta sanctorum partum*[2] bull issued by Pope John XXII of Avignon in 1325, concerning the banning in the use of rhythm –that is smaller note values– in discantus, we can trace in this basically oral and quasi-improvisatory approach the equivalent of a statistically implemented operation. In other words, a Stochastic approach.

2.2. Towards a revival of the old tools

This is not really new. Many composers of the 20th century, especially those who had the opportunity to get acquainted and eventually study some newly discovered medieval and Renaissance works, were able to grasp new ideas, or revisit some old concepts, under the light of a pre-tonal –and definitely pre-atonal– view that seemed to offer inspiration through old material and even older compositional tools. The emergence of this sonic archaeology that made the music of the past available as never before to the musicians of the present,[3] strongly amplified by the advent of a vivid technological *r-evolution*, continued to culminate through the next turbulent decades. From Arnold Schoenberg, Anton von Webern, Ernest Krenek to Paul Hindemith, Igor Stravinsky, and even further to Pierre Boulez, luigiNono, Georgy Ligeti, Witold Lutosławski, Krzysztof Penderecki and Wolfgang Rihm, to name but a few[4]of both the *old masters,* and the new ones,one can find numerous instances of applied compositional thought that delves into aspects of early polyphony. Implemented either as a way of linear manipulation, micro or macro-formal construction, or by means of isorhythmic, mensural and eventually polyrhythmic temporal organisation and, of course, canonic transformations, the old tools of polyphonic composition found new life in a brave new world.

[1]Bonnie J. Blackburn, "On Compositional Process in the Fifteenth Century." *Journal of the American Musicological Society* 40, no. 2 (1987): 210–84: 234-35.https://doi.org/10.2307/831517.

[2]Rob C. Wegman "What is Counterpoint", *Improvising Early Music: The History of Musical Improvisation from the Late Middle Ages to the Early Baroque,* Rob C. Wegman, Johannes Menke and Peter Schubert. Ed. Dirk Moelants, Collected Writings of the Orpheus Institute. Leuven: Leuven University Press, 2014, pp. 9-68:33-35, *Renaissance Quarterly* 69 (3). Cambridge University Press: 1159–60, doi: 10.1086/689136.

[3]Richard Taruskin, "Solidarity with the long-departed: fifteenth-century echoes in twentieth-century music, Anna Maria Busse Berger, and Jesse Rodin. 2015. The Cambridge history of fifteenth-century music, 833-847:833. https://doi.org/10.1017/CHO9781139057813.

[4]On further details concerning this subject see the entire Chapter 45 and the suggested bibliography in *The Cambridge history of* fifteenth-*century music* by Richard Taruskin, ibid. 833-847.

3. Expanding the concept

3.1 Xenakis on Polyphony

It is in this context that Xenakis will talk about polyphonic procedures. Summing up his train of thought in the context of a text that he titled *Towards a Metamusic*, also chapter VII of *Formalized Music,* he will give us an important key to unlocking how he understands polyphony.

> In 1954 I denounced linear thought (polyphony), and demonstrated the contradictions of serial music. In its place I proposed a world of sound masses, vast groups of sound-events, clouds, and galaxies governed by new characteristics such as density, degree of order, and rate of change, which required definitions and realizations using probability theory. Thus stochastic music was born. In fact this new, mass-conception with large numbers was more general than linear polyphony, for it could embrace it as a particular instance (by reducing the density of the clouds). General harmony? No, not yet.[5]

It seems that for Xenakis, Stochastic music is a kind of generalization. An extended compositional practice that could actually contain linear polyphony. One that eventually overcomes the restrictions as well as the deadends that result from the *partial implementation* of this *mass-conception with large numbers*. Although, as he rushes to add, *in a* not yet *absolute General harmony*.

Does this kind of polyphony represent for Xenakis an actual end? I feel that on a deeper level, this is where it all leads. As Xenakis puts it –in terms of sound–:

> We can even express a more general supposition. Suppose that each point of these clusters represents not only a pure frequency and its satellite intensity, but an already present structure of elementary grains, ordered a priori. We believe that in this way a (sic) sonority of a second, third, or higher order can be produced.[6]

And indeed! As he points out:

> Music, then, may be defined as an organization of these elementary operations and relations between sonic entities or between functions of sonic entities.[7]

And what is a Composer according to Xenakis?

> A thinker and plastic artist who expresses himself through sound beings. [through sound entities] These two realms probably cover his entire being.[8]

Now! A word of caution seems to be of necessity here. Polyphony is not the same as simultaneity of parts. As I already mentioned at the beginning of this paper polyphony calls for an

[5]Iannis Xenakis, 1971. Formalized music: thought and mathematics in composition. Bloomington: Indiana University Press, (1992 Revised Edition by Pentragon Press), 182.
[6]Iannis Xenakis, Formalized music, ibid. 47.
[7]Iannis Xenakis, Formalized music, ibid. 4.
[8]Iannis Xenakis, Formalized music, ibid. 255.

interdependence of parts. Regardless of any kind of micro-formal principles that seem to govern each individual texture, we need to have a, preferably audible, relation on a higher level of organization. A Contrapunctus Simplex per se. With points of rhythmic or other temporal connections and instances of concordance. In our case, a number of successive points that could define a space that seems to demonstrate a degree of correlation and comes in contrast with previously or simultaneously presented textures and/or textural conflicts to come.

In fact, we can distinguish between two different kinds of polyphony. On the one hand we would have the one that Xenakis initially denounced in confronting the linearity of serialism. A kind of polyphony that he eventually utilized as a means of microformal –textural– construction of sound sonorities. An approach that, in not so distant a synchronicity, Ligeti would call: micro-polyphony. Here, we could also include *halos sonores*[9]. These sound heterophonies, typical in non-western music, that introduce minute melodic differences instead of the stochastic or otherwise devised rhythmic and intervallic displacements, resulting in micro-polyphonic textures.

On the other hand, what we could call the Contrapunctus Simplex principle, which, on a macro-formal level would create a way of organizing large formal units, even pre-composed ones. Sometimes, sets of calculations or even actual modules that are revoked out of a completely different context. Something, at least, symbolically analogous to a well defined Renaissance quotation technique, widely known as Parody. A technique where entire multi-part sonic entities would be literary copied -along with their symbolic and their generative connotations- and would thus constitute the core or an intriguing fragment of a new composition.

As Xenakis would probably put it elaborating on both, sound entities and the role of composer, –while pointing, once more, at the beginning of this quest: the landmark of Metastaseis–:

> In 1954, I introduced probability theory and calculus in musical composition in order to control sound masses both in their invention and in their evolution. This inaugurated an entirely new path in music, more global than polyphony, serialism or, in general, "discrete" music. From hence came stochastic music.

And he shall add:

> But the notion of entropy. As formulated by Boltzmann or Shannon, It became fundamental. Indeed, much like a god, a composer may create the reversibility of the phenomena of masses, and apparently, invert Eddington's "arrow of time[10].

Near the end of his *revised Formalized Music* and while attempting to further define sonic entities, *of any sound production*, as multi-vectoral distributions represented in a multi-dimentional space, and considering this as *a synthesis of several conveniently chosen linear stochastic processes,* Xenakis will also state:

> A sufficiently long fragment of this distribution constitutes the musical work. The basic law defined above generates a whole family of compositions as a function of the superficial density. So we have a formal archetype of composition in which the basic aim is to attain the greatest possible asymmetry (in the etymological sense) and the minimum of constraints, causalities, and rules.[11]

3.2 In search for polyphony

Depending on the way we choose to define polyphony, and specifically on the degree of

[9]Makis Solomos, *Iannis Xenakis*, P.O. Editions, 1996, hal-01202402, pp. 1-132:64.
[10]Iannis Xenakis, Formalized music, ibid. 255.
[11]Iannis Xenakis, Formalized music, ibid. 23.

interdependence of more or less simultaneously presented music *entities,* one can trace contrapuntal procedures even in the early works of Iannis Xenakis. Yet, after 1970s, the composer seems to expand his creative palette in a way that, although still innovative seems to be more compatible to the usual perception and analysis of the *musical categories of the past.*[12]

As detailed analysis of different works would exceed by far the limited space available in the context of this paper, I will attempt here to offer some quick references.

Starting out with *Jonchaies* of 1977 *pour grande orchestra.* Micropolyphony on a grand scale. In the beginning section of the work, after the characteristic initiating glissando and the homophonic tutti introduction of m.10-12, the successively emerged differentiations of the already introduced string subgroups based on peculiar *divisi*, will form a kind of imitatively presented multi-part texture of instrumental lines. Although the sweeping macro-form and the superimposed polymorphic glissandi scatter the individual textural details, a zoom in on the local textures reveals articulations of various alternating densities that employ rudimental micro-polyphonic techniques. The entire first section, up until m. 63[13] feels like a distorted polyphonic motet with its initally isorhythmic parts gradually displaced. A massive texture that along with its complex timbre distribution –due to the blended *divisi*–and articulation alterations, creates an evolving spatially dependent swirling sound mass.

Omitting, the multi-part polyrhythmic, micropolyphonically textured next section, strongly reminiscent of a choral distribution of eventually Tallian proportions,[14] let me just mention the successive entrance of the horns beginning at m. 169, a micro-polyphonic accelerating texture, that despite the decompressing, practically soloistic, intervention of the trombones in m. 182-186 will lead to an entire section of overlapping yet powerfully contrasting events, just before the pulsating final section that will eventually implode, fading out to silence.

Moving on to multi-dimensional *Anemoessa* of 1979 for mixed choir and orchestra, with its simultaneous polyphonic textures in micro and macro scale. Its phonematic and timbral blending, combined in evolving textures. Its violent bursts contrasting fine points of appeasement.

The mimetically related sieves and the micro-polyphonic development of *Dikhthas* of 1979 for violin and piano. A work that in Xenakis own words *is like a person with two natures, is bifold* [*δυικό*] *because its natures contradict each other although sometimes they fuse in rhythm and harmony.* A kind of mostly asymptotic dualism, even at the points of unison, where approximation lies at the level of –detuned– interjection. The conflicting self.

The micro-polyphonically textured parts in *Aïs* of 1980, for amplified Baryton, solo percussion and grand orchestra, along with its profound symbolic connotations.

The extended string and vocal sections, the dense micro-polyphonic textures and the overall macro-formal contrast in *Nekuïa* for mixed choir and orchestra of 1981.*Shaar,* for string orchestra of 1982, *Lichens* for Orchestra of 1983. And, of course, this short list of references could be anything but thorough.

4.Observing the threads

Throughout Xenaki's compositional output one can find various instances that exhibit a degree of implementation of Xenaki's abstract theories or partially utilized theoretical tools. Yet, as Makis Solomos points out, only a few of Xenaki's works were actually composed with the help of theories and that there are always gaps between theory and practice.[15]Amongst them, especially in the works after late 1970s, one can find a number of techniques that comply –graphically and

[12]On this subject see: Mihu Iliesu (2002) Notes on the late-period Xenakis, 21:2-3, 133-142, especially 137, 140-141.
[13]Notes and measure numbers refer to the 1987 revised edition *Éditions Salabert*, EAS. 18248.
[14]See *Spem in Alium* 40-part motet of Thomas Tallis, composed around 1570 consisting of eight five-part choirs, potentially devised to be performed in an intriguingly polygonal spatial distribution. On this subject see Philip Legge, (2004).
[15]Makis Solomos, Three components of Xenaki's universe, 2016. hal-01789673

audibly–with the Contrapunctus principles previously mentioned. Some of these instances, while on a macro-formal level do exhibit a great degree of linear conjunction that is inconsistent with polyphony, they nonetheless present micro-formal properties such as interrelated event distributions, frequency or/and density fluctuations, random selections that instead of being labeled as sound heterophonies, they could, despite the traditional connotations, be rendered as polyphonic.

The application of internal rules and laws of construction, points towards similar practices of internal organization in the music of Renaissance Polyphony more rigidly than any other era of, at least western, music history. Observing theoretical concepts such as rules of concordance in interval species, or rules of temporal correlation of distinct –and fairly ordered– sets of individual sound durations, as expressed by the rather obscure rules of many different flavors of mensural polyphony could establish some remarkable analogies. Going even further and choosing to speculate on the actual results, and not so on the original intentions, of composers –let alone performers– of late medieval and Renaissance practices, one could detect stochastic elements in the various, and often conflicting, attempts to implement mensural, or other type of soft or hard compositional rules.

Makis Solomos, relating Xenaki's notion of polyphony to the Varésian legacy and the criticism of linear polyphony as opposed to the notion of contrasting sound masses has rightly noticed that "…the term polyphony is then inappropriate and it is better to simply speak of superimposition."[16] I could readily add juxtaposition as well. Yet, I feel that the critical component which connects these approaches to polyphony is, indeed, the notion of conflict, in both macro and micro scale. In a direct analogy to the way the historical emancipation of dissonance and the evasive manipulations of an audience's expectations resulted in the formal construction of a tonal musical narration, the multifaceted contrast of Xenakian sound entities, provides us with the web of his creations. In this context, the notion of contrapuntal procedures, in what seems to be the oldest and most resilient meaning of these words, would, actually, suffice.

Now, let's talk a bit about politics. As I mentioned earlier this was an approach of a deeply hierarchical society. This is how late medieval and Renaissance people perceived their choices as to the degrees of freedom they could apply in their *stochastic* processes in the context of a rather stiff political system. This is how they artfully confronted the prohibitions imposed by a higher authority, and their collective answer devised a practice that evolved to what we now know as Counterpoint. A craft that, for many centuries has been –in more than one ways– synonymous to Composition.

Fast-forward to 20th century. The inherent quality of the individual gas particles to move autonomously, and independently, forming, through their eventual stochastic distribution, a dynamically defined space could be viewed as a profound symbolism of Xenakis political beliefs. The self motivated engagement of individual entities that accumulates in sweeping, collective, action. Either on the basis of a pre-prescribed plan, or through autonomous movements that obey the laws of nature. Bearing in mind Xenakis's famous description of the chaotic evolution of events during a protesting march, we could read behind the contemplative distributions the composer's vision for a society of autonomous units in collective action. An isotropic distribution of individuals –the multiple meanings of the Greek word *άτομο*[17] has to be taken into account here, – in a collectively formed framework. Initiated to a certain extend by the *composer,* yet*,* articulated by the mutual action of all those that are involved.

It is in the extended polyphonic sonorities and the dense multidimensional textures of the orchestral works of the 80s that Xenakis returns, once again, to the idea of an individualized collectivity. Although, this time, in a massive way. Through dense gestures, both in their conception and implementation that through the invocation of intense dynamics, –characteristic of his entire work–symbolically reclaim the power of *the many* through the will and the drive of each and any one.

[16]Makis Solomos, Three components, ibid. 2.
[17]Derived from the Ancient Greek Philosophy the word means an undivided particle of matter/a person/an individual both in ancient as well as in Modern Greek language.

Indeed! The power of abstraction as a mechanism of a potential transcendence of trauma[18] or a dystopic reality should be taken into account here. Is it a futuristic obsession or perhaps just an attempt to create useful tools able to overcome –or even bypass – the deadlocks of the future? Could it be reaction to internalized real-life experiences of a multi-traumatic past? Or perhaps an inner drive to actually experience utopia?[19] And of course, all of the above, mixed in a profoundly unique way? I feel that a retrospective answer to such a – by its nature problematic –set of questions ought to be anything but unambiguous. Yet, the attempt to find some answers may help us appreciate Xenakis on a deeper level.

5. Conclusion

Throughout his entire life, Iannis Xenakis came across a constellation of conflicts. Having to cope with the traumas of both death and separation as early as in the age of 6. Growing up in a constantly changing environment and having been fairly exposed to the immense social and political turbulence of his era seems to have been crucial for the mental and psychic formulation [*diamorphosis*] of a tough fighter. That, combined with his a-typical education and his contact with both ancient and contemporary philosophical, and eventually scientific, thought, led to the man who, along with many of his generation, choose to vividly engage to the battles of his time. Both in a physical and eventually symbolic, yet equally, if not more so, influential a way. Remaining in his core, throughout his life, a true political being.

Having acquired the ability to effectively focus at the essence of the *problems* he has to face, Xenakis straggles to come up with solutions. Actual ways to control chaos. To eventually reduce entropy in acceptable ways. Sometimes even by pointing towards them in an abstract and visionary manner. This is what, I feel, the composer stands for.Whatever the formalistic mathematician cannot control, the expanding artist can, eventually, map through. Even if, the perilous voyage leads away to previously unknown territories. And where his untamed creativity calls for firmer shapes, the mind of the architect would provide the suitable forms[20].A peculiar equilibrium of contrasting forces judged at their end. And even then, when circumstance dictates, his work, revisited and transformed, remains open to interpretations on new grounds.

Today, the work of Iannis Xenakis stands out as an emblematic depository of creative possibilities. Following his trails in a new technologically enhanced global musical universe, many composers and researchers already expand his visionary legacy well beyond the first two decades of the 21st century. In attempting to approach Xenakis and his work in the context of contrapuntal procedures we provide ourselves with the tools required to allow us a closer and more effective view in the multifaceted creation of this unique mind. A task that, in addition to the technical and aesthetical aspects of our quests, I feel strongly calls for closer attention to the various conflicts in the life of the man, and the traumas he accumulated and eventually transformed.

While presenting remarkable resilience to narrow sided analysis, both music and thought of Iannis Xenakis remain impressive and current. A little more than twenty years after his physical end, his life can be viewed as a bright reminiscence of the human condition through dark times. His work constitutes a crucial open code transcending our post-modern and avant-garde past towards the multiple worlds of current musical creation. An already established lingua franca, equally accessible to both man and machine. Yet, potentially, albeit creatively, open to misinterpretation to both.

[18]Sokratis Georgiadis, “Iannis Xenakis, penseur en exil : réflexions sur la dynamique du trauma ”, *in* DESMONS, Éric / SINOU, Despina (dir.), *Penser en exil : les intellectuels grecs en France (1945-1980)*, *Revue française d'histoire des idées politiques*. (pending publication)
[19]Iannis Xenakis, *Arts/Sciences. Alliages,* Tournai, Casterman, 1979, 16-17.

[20]On this subject see: Makis Solomos, De la musique au son. L'émergence du son dans la musique des XXe-XXIe siècles. Presses universitaire de Rennes, 2013, 298-301.

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Organizing Just Intonation Pitches through Xenakis' Sieves and Prime Decomposition

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Abstract

In this article, we will present how we can create, organize and understand pitches of Just Intonation using 1) the theory of sieves (XENAKIS, 1992) to filter the numbers of the harmonic series, 2) the decomposition by prime-numbers (EXARCHOS et al., 2011) applied to the numbers resulted from the sieve, 3) the concept of harmonic identities by Johnston (2006), and finally, 4) the Combinations-Product Set (CPS) by Erv Wilson (NARUSHIMA, 2018), that allows us to see the relationships between harmonic identities. When we understand that only prime numbers generate new harmonic identities in the interval sense (JOHNSTON, 2006), and odd-numbers create just a new pitch-class from staking prime numbers, we can apply the prime-decomposition for all the numbers of one sieve and claim that: all the non-prime numbers can be understood how intersections between distinct harmonics series. Based on Exarchos' (2011) analysis of sieves, this idea can help us find a way to use the sieves of Xenakis in the Just Intonation context. Complementary with this compositional idea, we will present two OpenMusic libraries developed to help the compositional process.

1. Introduction

The Just Intonation is a system where all the pitches can be represented using ratios, which means that all pitches have integer relations with one fundamental pitch. The theories of Harry Partch, Ben Johnston, and Erv Wilson are some efforts to develop ways to organize the infinity of possible ratios used in a compositional context.

In Partch's theory, understanding two terms are fundamental to comprehending his work: the concept of *limit* and *identity*. The former idea defines the biggest odd number used in the *Diamond Theory* (see Partch, 1974), and the term *identity* defines what Partch understands how harmonic identity. For him, all odd numbers are new harmonic identities. However, unlike Partch, we understand the idea of *identity* using Johnston's (2006, p. 27) claim: "Each *prime number* used in deriving a harmonic scale contributes to a characteristic psychoacoustical meaning." This choice will become clear ahead.

Less systematically than Partch, one of Johnston's few systems exhaustively described by himself is used in the String Quartet no. 2 and no. 3. This system proposes stacking (up and down) the intervals 4/3, 3/2, 6/5, 5/4 until the pitches overlap. At the end of the process, it creates a 53-pitch set. It is implemented in the OM patch below (note that Johnston does not define when the notes start to overlap, so this patch is an excellent approximation but not exact).

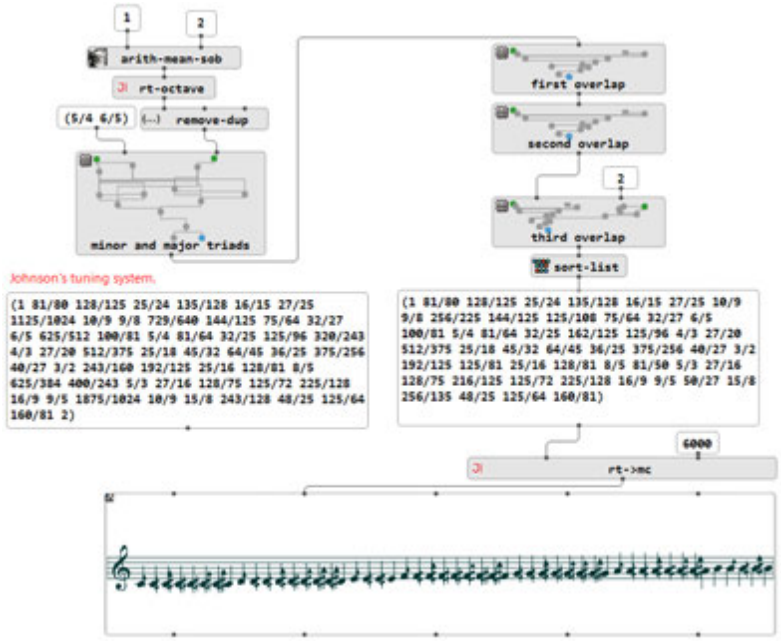

Figure 1 - OM patch to reproduce the microtonal system of String Quartet no. 2 and no. 3 of Ben Johnston.

We realize that one interesting way to see the concept of *identity* used in Partch and Johnston (2006, p. 27) is through Wilson's theory of Combinations Product Sets (CPS). See the structure named Hexany:

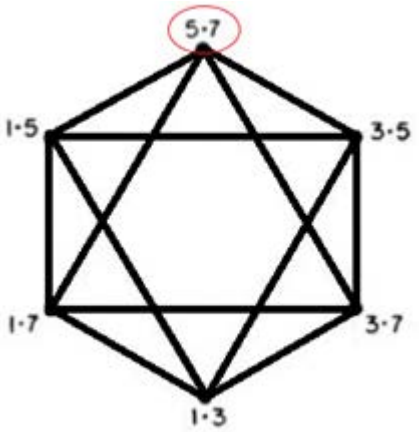

Figure 2: Hexany by Erv Wilson (Narushima, 2017, p. 153).

The main characteristic of CPS is the connection between vertices of the geometric structure. For example, the vertice (5-7) is connected with (3-5) because they share the number 5. In a musical sense, it means that (5-7) is the 7º harmonic of the number 5, and the vertice (3-5) is the 3º harmonic of the number 5 – note that the number in common in these two vertices transforms in the fundamental of the harmonic series.

Assuming the interpretation of the list of prime numbers that compose some non-prime numbers – like (3 5 7) in the prime-decomposition of 105 – how vertices in CPS's, it will be possible to see the same harmonic connections present in the Hexany (This is why we use the identity conception of Johnston). See the image below:

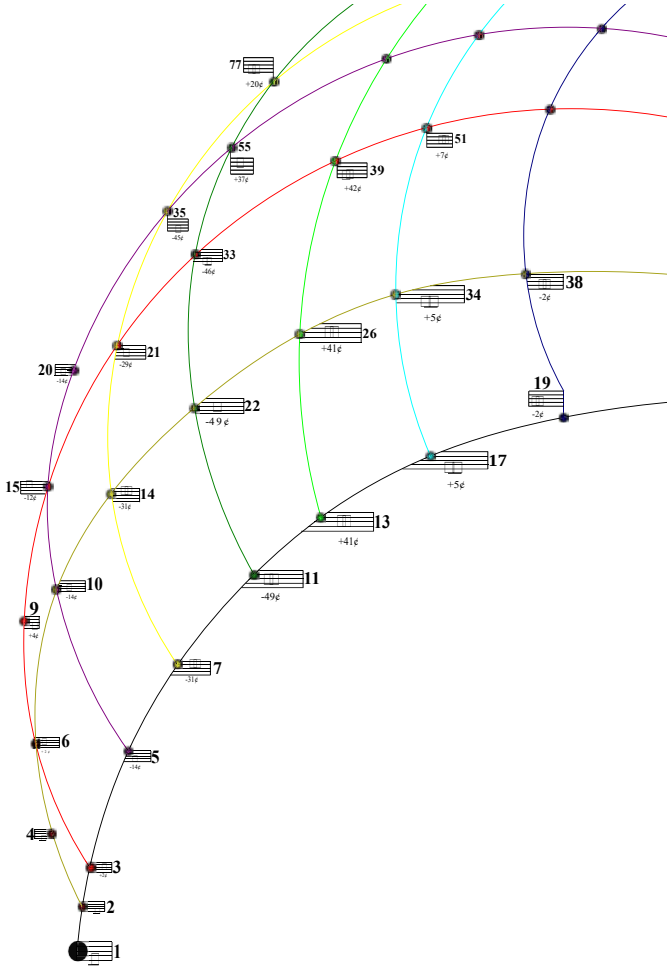

Figure 3 – The structure of harmonic series in Wilson (NEIMOG, 2021, p. 60).

Note that a new harmonic series (with new pitch classes) is born in all prime numbers. It has the same interval structure as the harmonic series over the number 1. Figure 3 has the numbers 6, 9, and 15 connected because, in the decomposition by prime numbers, they share the number 3, same for the numbers 7, 14, and 21 for sharing 7. In this perspective, we approach the harmonic conception of Johnston, where new prime numbers add new psychoacoustical meaning, and James Tenney, wherein the harmonic space, 'each dimension within the space is defined by a prime number' (Tenney, 1988, 206).

Based on this point of view, it is possible to incorporate one approach grounded on Exarchos (2007) and apply it to the sieve result. This method can provide tools for organizing and choosing pitches, building melodic contours, symmetrical chords/timbres, changing partials of timbres with some symmetrical chords, among other procedures.

The next topic will present how we link the JI and the sieves world

2. The sieves of Xenakis used in a JI context

One of the essential links between the Exarchos approach to sieves and the approach presented to JI is the decomposition of non-prime numbers. First, Exarchos proposes that sieves with non prime modulus can be decomposed using intersections between two or more sieves. For example, the sieve 35_0 could be constructed using $7_0 \cap 5_0$. This decomposition can "enable transformations that might not be as obvious in the actual scale" (Exarchos, 2007, p. 74). If we again see the geometric structure by Wilson, the vertice (7 5) represent the same idea in one different context. The harmonic series build in 5 (5, 10, 15, … 35) and 7 (7, 14 … 35) have one intersection (harmonic in common) in the number 35. Because of that, the number 35 can be interpreted as 7º harmonic of the number 5 or the

5º harmonic of 7. So, if we are in one harmonic series in C, the harmonic 35 (D+5¢) is at the same interval distance from 5 that Bb-31¢ (7º harmonic) is from C (fundamental) or the same distance from 7 that E-14¢ is from C. Therefore, like when we work with analysis of sieves like proposed by Exarchos, we can do "transformations that might not be as obvious in the actual scale." For example, 105 becomes not a high harmonic, but the 7º harmonic of the number 15, the 5º harmonic of 21, and 3º of 35. Thus, the pitches that can be interpreted in different ways can help the JI music not become 'grabbed' in one fundamental pitch, building a multi-dimensional space (the idea of the CPS) using these notes as pivots to modulate between harmonic series.

One possible next step is to build sieves where the harmonic result intersects one or more harmonic series in one already implicit mode in the build. For example, the sieve $((7_{35} \cap 17_{34}) \cup (19_{38} \cap 11_{33}))$ gives (7 133 154 187 231 266 308 323 374 385 399 462), with the decomposition, we will have connections between the harmonic series in 7, 17, 19, and 11, including yet 5 and 3. See the result of the OM object *prime-decomposition* that will give all these intersections between different harmonic series.

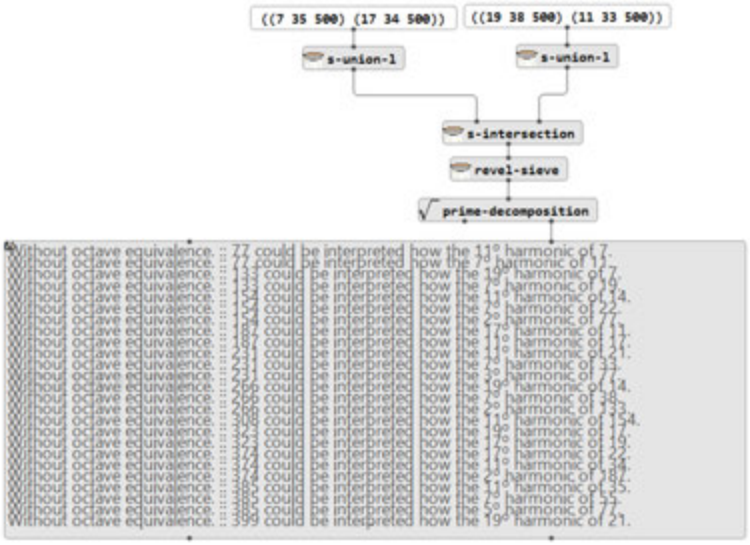

Figure 4 - Examples of the sieve analysis using the object prime-decomposition.

Three observations: First, the number starting each set needs to belong to the harmonic series of the modulus, 35 belongs to the harmonic series of 7, 23 belongs to 17, and so on in the sieve $((7_{35} \cap 17_{34}) \cup (19_{38} \cap 11_{33}))$. Second, it is not applicable in the 'orthodox' Diamond Theory because we cannot choose the numbers, just the limit. Because of that, we remove the limit concept of the Diamond Theory, allowing the choice of the numbers that will compose it. To use it in the OM environment, we need the object *diamond-identity*. We are working on a visual representation available in the next version of OM-JI. 3) It is common in the Diamond to work with pitch classes and not keep the note's octave. The octave reduction will not apply in this research context.

Once we have the sieves and the JI structures linked with some symmetry properties, we can use the

sieves to build melodic contours (link of examples: https://bit.ly/3CwW0iq)

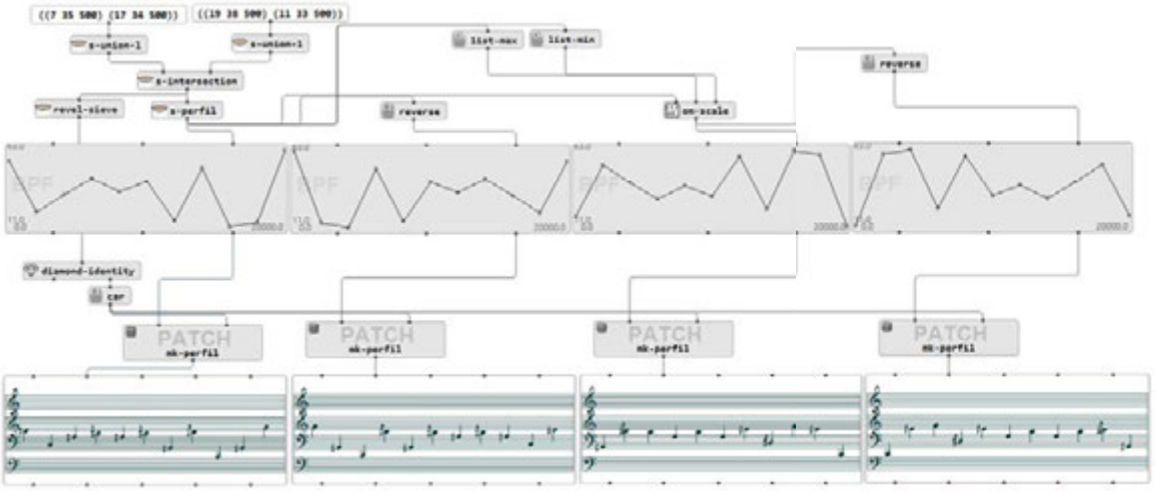

Figure 5 - Patch example to create melodic contours with sieves.

Use different sieves and Just Intonation Systems to modulate <https://bit.ly/2Y1xNOg> between then

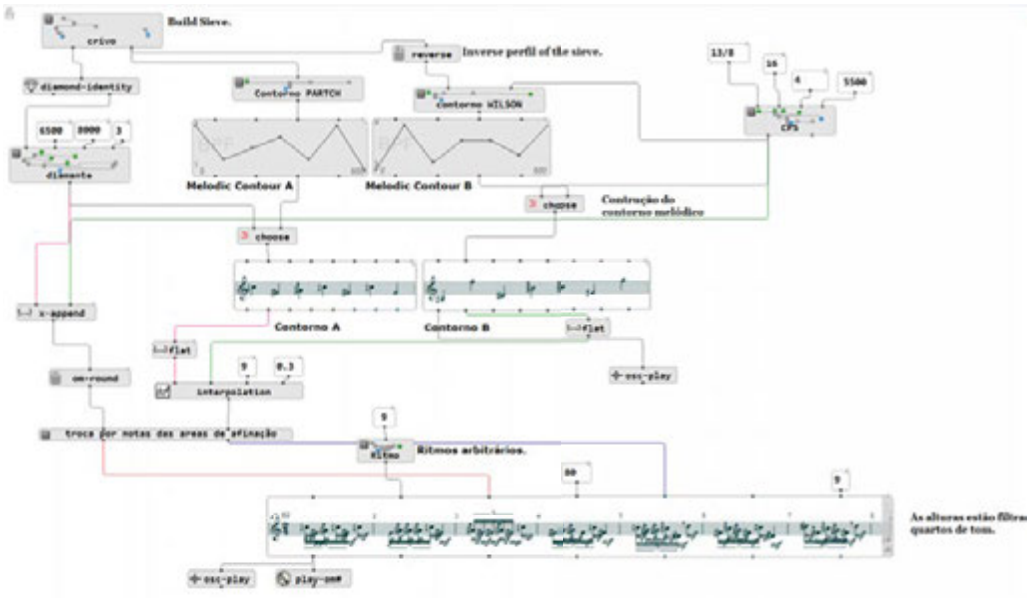

Figure 6 - Patch that creates a modulation between two different JI systems.

Another possibility is to use JI structures and the sieves in the timbre approach usig the object *interval-sob* of OM-JI. It will stack some interval following the *perfil* of some sieve (https://bit.ly/368lGFL).

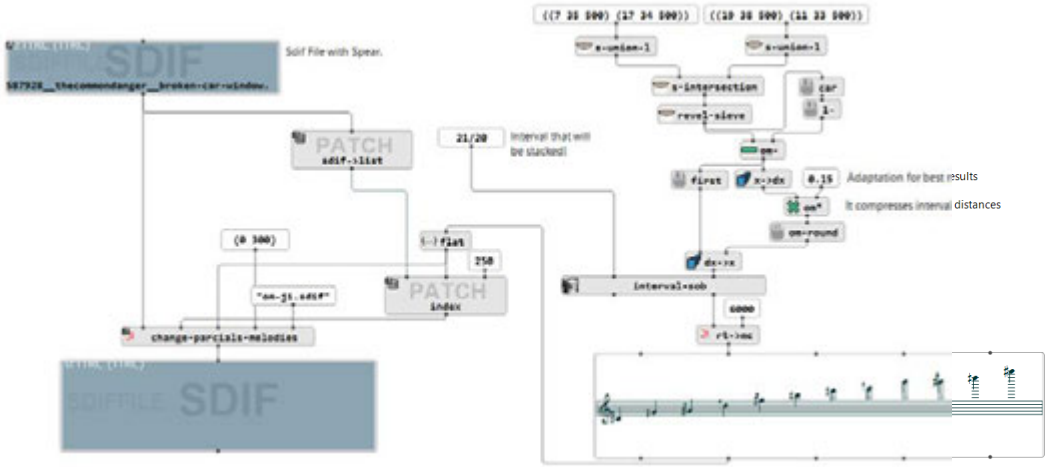

Figure 7 - This algorithm is best introduced in Neimog et al. (2022).

As shown, when we incorporate the sieves of Iannis Xenakis in the JI context, we can build ways to work with melodic contours, symmetries, timbre manipulations, and others. Mainly with the analysis method proposed by Exarchos (2007, 2011) and the connections between decomposed prime-numbers, we can organize pitches and build coherence without using the intervals set often used in JI context (3/2, 4/3, 9/8, 5/4 and others that are(was) the basis of tonal music), mainly when we work with larger prime numbers.

I believe that think Just Intonation music linking it to sieves, timbre, electroacoustic, maybe in the future some probabilities properties, could help composers of the mixed and acousmatic music take advantage of the possibilities of using any pitch by mixing tempered and JI approaches and adding, more often, the tunning thinking in electroacoustic music. Like Roads (2016, p. 237) claims: "Microtonal harmonies can become so complex that they mutate into timbre and texture. With so many pieces in free intonation, it is clear that pitch need not always be aligned to the grid of a fixed scale or intonation."

3. The compositional approach in the CAC environments

We will briefly show the two libraries developed in OpenMusic and OM-Sharp environments. The first is called OM-JI (of Just Intonation), and the second is called OM-Sieves, with the basis of Sieves (*cribles*) used in MathTools (by Carlos Agon and Moreno Andreatta) adding some features based on the work of Exarchos *et al.* (2011) and Ariza (2005).

3.1 OM-JI: Partch, Johnston e Wilson theories

The Just Intonation tools developed are divided into four parts. The first one is some of the essential and personal tools used: The objects included are:

1. *rt->mc*: convert the ratio to midicents;
2. *range-reduce* and *rt-octave*: reduce the range (midicents and ratios respectively) to some limits defined;
3. *filter-ac-inst*: Rather than use JI pitches "flattened" to quarter-tons or eight-tones notes, this object will filter pitches that can be played using fingering diagrams found in books like *Techniques of flute playing*, it can help keep the lack of beat (characteristic of JI) without the need for a group of specialized interpreters.
4. *Modulation-notes* and *modulation-notes-fund*: Based on the idea of Huey (2017), where he claims that are pitches in common between two different microtonal systems in String Quartet no. 5 of Johnston, these objects show the notes in common between two other microtonal systems. The first object without any modification of the fundamental of the pitches. In the

second object, it is possible to change the fundamentals.

5. *Ji-change-notes*: present the idea to change notes in a *sdif* file; the main idea is to retuning multiphonics. This object was described in Neimog *et al.* (2022).

In the second part, we have all the objects to build the Diamond theory of Harry Partch; the third is the objects used in Ben Johnston's theory presented in Johnston (2006), the fourth part is the objects used to build MOS and CPS theory, by Erv Wilson. The object has examples available on the website: https://www.ufjf.br/comus/cac_patches/, and all the procedures are described in detail in Neimog (2021).

3.0 *M-Sieves*

The base of OM-Sieves is developed in MathTools by Carlos Agon and Moreno Andreatta. We added some objects to facilitate the interaction between composer and OM environment, and we changed all the objects of *crible* to *sieve* (French to English).

1. With the objects added, it is possible to build sieves more quickly:

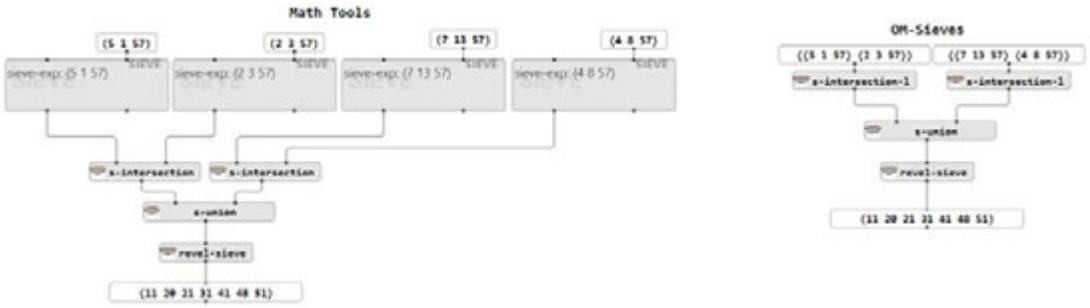

Figure 8 - Comparison between the same procedure in MathTools and OM-Sieves.

2. It is possible to use the syntax proposed by Ariza (2005). Nevertheless, in the OM environment, it is impossible to use the symbol '|', then I changed the union symbol to '*u*' and the intersection symbol to *i*. Then *24@3 | 30@3 | 104@70 | 0@0* became (24@3 u 30@3 u 104@70 u 0@0) and 3@2 & 4@7 & 6@11 & 8@7 | 6@9 & 15@18 | 13@5 & 8@6 & 4@2 | 6@9 & 15@19 became ((3@2 i 4@7 i 6@11 i 8@7) u (6@9 i 15@18) u (13@5 i 8@6 i 4@2) u (6@9 i 15@19)). Ariza does not use the parenthesis structure in the second sieve; however, it is used by Xenakis (1992[1971]).

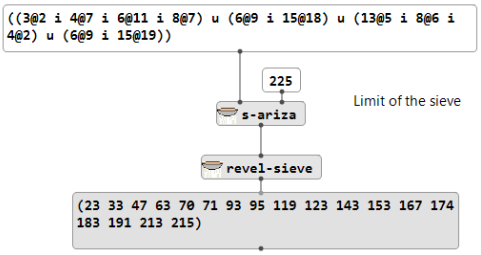

Figure 9 - Example of the creation of sieves using Ariza's (2005) syntax.

3. Also, based on Ariza (2005, p. 45), we add the possibility to discover the unions used in one sieve with the object *s-decompose*:

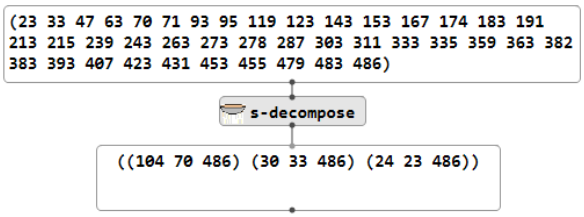

Figure 10 – The patch exemplifies the decomposition of one sieve in unions.

4. We add some of the analysis developed by Exarchos, like discovering with what limit will the sieve's *perfil* be symmetrical (palindrome):

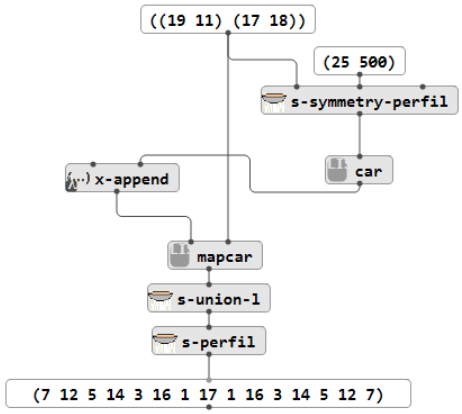

Figure 11 - It uses s-symmetry-perfil to find symmetrical sieves (Exarchos *et al.*, 2011).

5. It is possible to do the decomposition of sieves with non-prime modules.

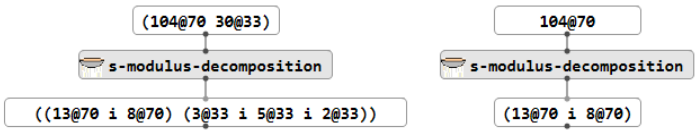

Figure 12 - The decomposition of non-prime modules proposed by Exarchos et al. (2011).

These are the main objects included in OM-Sieves. OM-JI and OM-Sieves are available to OpenMusic and OM-Sharp environment on the link https://github.com/charlesneimog/OM-JI and https://github.com/charlesneimog/OM-Sieves. If there is some doubt about the use or suggestion, you can write me.

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What's the use of music?

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Abstract

Sara Ahmed asks, 'What's the use?', and I want to ask, what's the use of music? And more specifically, in the context of this conference, what's the use of the music of Iannis Xenakis? At a historical moment of crisis, when the concerns of economy, public health, and ecological collapse might compel us to ask, on a daily basis, 'what's the use?', I want to consider how the approach to sound and music developed by Xenakis offers a reproach to traditional aesthetic concerns, and propels us, through an active engagement with sound, to face the forces that animate human and non-human encounters within the situation we inhabit. I will argue that the force of this engagement comes through our attachment or attunement to specific music artefacts, using recent work by Rita Felski on the aesthetics of attachment. I will also propose, following Mariagrazia Portera, that this attuned engagement allows a sort of 'grip' on what is around us that is effortful and exploratory, allowing an *environmental* aesthetics that answers to current ecological concerns. Taking the technology of the UPIC computer music system as a case-study, I will discuss how the approach of Xenakis might reframe use and usage in ways that allow music, both through technology and as a technology, to be use-full. Ahmed is concerned to counter notions of utility and utilitarianism, forcing us to acknowledge that the invocation of use includes the necessary qualities of the use-less, the mis-used and the un-used, the dis-used and the re-used, and so on. Xenakis, in his predilection for the ancient rather than the modern, repurposes the practices of music away from Eurocentric and aesthetically disinterested concerns, opening up its qualities of use in ways that offer a positive counter to dismay and frozen contemplation.

1. Introduction

It is 2022, one hundred years since the birth of Iannis Xenakis, and we are trying to find ways to celebrate and to acknowledge the impact of this extraordinary person who has touched us all in one way or another. And yet: in a lull - who knows how temporary - in a global pandemic that has left no corner of the world untouched, almost certainly engendered by the unthinking intrusion of the human activities of extraction into the deep recesses of the life of the planet; in the midst of a climate emergency that threatens to engulf our traditional ways of living, and brings the spectre of mass extinctions - perhaps even our own; in an era of war that has devastated the Eastern Mediterranean and beyond, and now extends even into the heart of Europe; one might ask, what is the use of music? In celebrating an artist who devoted his life to a radical reconsideration of sound, image, architecture, and design, are we - to use a very old cliché - simply fiddling while Rome burns?

I propose this beginning, not to intend some sort of sermon on the last days, nor to indulge in historical tropes of 'cultural pessimism' (Bennett 2001), but in order to think more clearly about the uses of music. If music is a fundamental life-practice, then, to follow the legacy of Ludwig Wittgenstein, it is really a *practice*, with uses for us, and not some object for disinterested aesthetic contemplation, as Kant would have us believe. Contemporary notions of aesthetics may have taught us about relations and emergence, about social constructions and distinctions, but they still present art as, in the words of Rita Felski, "a fragile moment of freedom from the tyranny of instrumental reason and the slick seductions of the marketplace" (Felski 2020, x); that is, as still somehow apart from our daily practices and concerns. And yet, as Greta Thunberg tells us so simply, "Our house is falling apart." (Thunberg 2019, 30) At a moment when Thunberg calls for "cathedral thinking" (Thunberg 2019, 27): that is, for simply acting, without the reassuring knowledge of solutions, in the knowledge that the moment has actually arrived for that, do we have time for music? What is the use of music?

These are the images that distract me as I write, but of course there have always been distractions, of one sort or another, and perhaps they are - merely - distractions. Xenakis himself, at the start of his book *Musiques Formelles* recounts some of his own moments of distraction: his experiences in Greece at the end of the Second World War - street demonstrations, and by implication the moment of violence that affected his own life unalterably. And yet, those distractions led him to a moment of insight: the way in which random or stochastic processes form a conceptual bridge between the social world of humans, the contingent worlds of non-humans, and the phenomena of the physical world which both inhabit. This conceptual bridge is one of the pillars of Xenakis's thought and work, but from my present standpoint it is the fact that it is a sort of conceptual *bridge* that seems that critical point: to what use could such a bridge be put, and how can music figure in that usefulness?

2. Use

In this discussion, I may be putting the expression 'What's the use?' in a certain relation to music, but the expression is not *aimed at* music. It is aimed at the matters of concern that threaten to take up all our attention, at the expense of music. In a colloquial sense, it is an expression of despair and helplessness in the face of matters of concern that seem overwhelming; ungraspable. To turn the expression into a proper question is to propose that something has a use, and to enquire about what that use might be. The neo-liberal turn that has dominated the social and economic spheres in recent times has made explicit that the dominant sense of use is an economic one: thus, for example, the UK government has recently imposed restrictions on the use of student loans for courses that represent a 'poor return on investment.' Music, as well as the Creative Arts and the Humanities in general are likely to figure in this lower use-category, since the 2020 statistics for the UK show only 23% of graduates from these areas in full time employment[1]. This restricted sense of use is not an example of 'cathedral thinking': this is, indeed, trying to build the roof before the foundations are in place. Ahmed, in her exploration of the notion of use, is concerned to counter notions of utility and utilitarianism by asking 'not only where usefulness is found but also how the requirement to be useful is distributed'. (2019, 20) Is music required to be useful, and then only in the

1 See https://www.hesa.ac.uk/news/18-06-2020/sb257-higher-education-graduate-outcomes-statistics/study [Accessed 07 March 2022]

restricted, utilitarian senses of economic gain and aesthetic pleasure? What other uses might it have? What does it even mean for something to have or require a *use*?

One of Ahmed's recurring images is the well-trodden path: 'The more a path is used, the more a path is used.' (2019, 40) Here we see how a way is found, and a habit is formed: use and habit are closely linked. Once a way is found, it gets used, again and again, until it seems like the only path there is. This is William James's account of the neural connections that shape our psychology ([1890] 1950, 108). Music is no different from other human activities in placing practice, including the colloquial sense of rehearsal: the repetition of actions and perceptions to the point where they become habitual, as a defining encounter with sound and its production. To hear music is to have a habit of listening (or dancing), in the same way that to play music is to have a habit of performing, developed through use. 'Use it or lose it.' (Ahmed 2019, 4) And yet, habit is a coin with two sides, up and down: the well-trodden path may not be the only, or even the best way through the terrain. Use implies also the existence of what is over-used and used-up: a habit may blind us to the possibilities in a situation, just as a path may turn to mud, and provide a barrier to our progress rather than a way through.

The way through, of course, proposes a direction and a destination. Use is often use-for: when we have a goal or purpose, we have to find something to use in order to approach that goal or purpose, and it is often the case that things with habitual uses turn out to be use-ful for other things too, once the other purpose is clear: the building brick that holds open the door, the compact disc suspended in the fruit tree that scares away birds. This invokes the term *bricolage* that Claude Lévi-Strauss puts at the heart of culture. (Lévi-Strauss [1962] 2021, 20) The use of something is often not apparent until we see the pressing need that proposes that thing as the nearest and most appropriate solution: the poetic solution. Could music turn out to have a use, or uses, in the face of our current distractions, that are not so apparent from our habitual practices of music?

In the face of global warming, in challenging the extractive use of the resources of the planet - where extraction even defines those resources in terms of habitual uses - our habits are put in question. How can our living through music inform us about or lead us to reassess our habits? Can our attending actually to music be a useful response to an expression of despair - what's the use? The work of Xenakis calls for very specific sorts of attending, and it is for this reason that it seems like an appropriate, useful, productive focus for the development of this discussion. I want first to consider what it takes to perform the scores of Xenakis, before thinking about how those strategies required for performance make their impact on listening to and participating in specific realisations of the work. In particular, I want to think about the ways in which Xenakis reveals the habits of music, and in revealing them allows the terrain through which those paths of habit have been beaten to come into view.

This relation between habit and terrain is clearly expressed by the violist Geneviève Renon in her account of interpreting the works *Mikka*, *Mikka S* and *N'Shima*. She writes:

> … the research for perfection - and I repeat the word "research," - has taught me to take the time, sometimes a very long time, repeating over and over again certain passages, be they short or long. A fascinating phenomenon then occurs. Little by little, micro-worlds appear that join each other, transform, stretch out, are turned upside down, and sometimes even collide. If for an inattentive ear or a negligent performer, one glissando can be

> replaced by another glissando, it is not at all true in reality. Time becomes a melting pot, this repetitive phenomenon engenders an alchemic transformation … (2010, 265-66)

Here we have an account of repetition as revelation: a terrain is laid out and explored, against all habit or conventional pathway, conjured between action and perception. Xenakis's notation defeats utilitarian approaches to the presentation of an idea, forcing habit into 'micro-worlds' whose very appearance is only possible through the use of effort in relation to specific notational strategies. A similar use is related by the trombonist Benny Sluchin, writing about the use of the horn and the trombone in *N'Shima* and *Keren*:

> We are in a real no-man's land, the entire instrument's arsenal is at our service: half-valves, faked pitches obtained by non-orthodox positions of the lips (called 'lips down' technique), hand in bell and different amounts of hand stopping, and more. The result is far from what one might expect: extremely expressive and personal. … The score provides no explanations regarding the notation … (2010, 17; 19)

Perhaps this passage of description approaches Greta Thunberg's paradigm of 'cathedral thinking': there are foundations - an instrument, a player with lips and breath, effort, and good intentions - but no idea yet how the 'roof' gets built: what the outcome of building on these foundations will be; what music will appear. Habits, whether of listening or acting, are put in question. There are things to use, but no clear uses for them.

This brief discussion of use and habit is itself only a foundation: it is not at all clear yet how music, either in general or in the specific work of Xenakis, gains any purchase on the pressing concerns that distract us: has any real use for us. I want to turn now to think how it is that we care about music: what care means in this context, and why we might care particularly about the work of Xenakis.

3. Attachment / Attunement

If contemporary aesthetic theory has taught us anything, it has made us more careful in our thinking about subjects and objects. Subject-ness and object-ness specify, above all, relation and attachment, and I want to think now about attachment. As Rita Felski points out in her recent book *Hooked: Art and Attachment* (2020), despite a certain philosophical embarrassment about personal tastes, it is only because we feel an attachment to a novel or a piece of music that we bother with it at all. The attachment may be subject to a sociological or political analysis, but in a strong sense, we cannot help what we like, and those moments where we develop a passion for a particular piece of music - whatever it is - are strongly marked. As Tia DeNora remarks, in the case studies which underpin her book *Music in Everyday Life* (2000), people's music choices are clearly correlated with memories of specific people, places and events: there is nothing 'objective' or disinterested about it. Indeed, DeNora remarks that subject-ness is deeply implicated in those moments of response to a particular piece of music, such that 'it was possible to speak of consciousness as emerging *in interaction with* musically configured environments.' (2000, 60) In a similar way, Bruno Latour puts engagement and subject formation together, though in a way which also recognises the subject-ness of the artwork with which we engage:

> A work of art *engages* us, and if it is quite true that it has to be interpreted, at no point do we feel that we are free to do "whatever we want" with it. If the work needs a *subjective* interpretation, it is in a very special sense of the adjective: we are *subject* to it, or rather we *win* our SUBJECTIVITY through it. (2013, 241)

Felski is at pains to calm those concerned that this talk of attachment is too personal or emotional to carry any proper critical weight: as she says, 'attachments involve thought as well as feeling, values and judgements as well as gut response.' (2020, ix) Indeed, we have seen in the accounts by performers of their ways of approaching the particular music notational practices of Xenakis that a considerable amount of engagement and attachment is required in order achieve an acceptable outcome, and that such attachment informs rather than obscures critical engagement. It is this context that Geneviève Renon is explicit about discounting 'an inattentive ear or a negligent performer.' And furthermore, as if it were necessary, we are all concerned with thinking about the work of Xenakis because it affects us deeply. How could we not acknowledge that?

At the same time, to note our attachment to something may not be particularly revealing unless we take a moment to interrogate how attachment operates. Attachment is often an instantaneous effect, but it also invokes the notion of care. To care about something is to commit to an ongoing co-ordination of attention, action, and affect. Felski characterises this as *attunement* which she describes as 'not a feeling-about but a feeling-with.' (Felski 2020, 42) I want to think through one of Felski's key examples - an account by the British writer Zadie Smith of her sudden conversion to the music of Joni Mitchell - in order to suggest a mode of operation for our attachment and attunement to the work of Xenakis. I want to suggest that this sense of 'feeling-with' is a *use* for music, and that Xenakis configures this use in conscious and very specific ways.

Smith's account of her utter dislike of, and then passionate love for a particular music contains a few key elements that are central to how attachment operates: in the first place, her conversion was instantaneous - an *epiphany*. In the same way that a joke can never be funny if it has to be explained, an attachment can never be made properly if it has to be argued for. It happens or it doesn't; and when it happens, it is real. This mirrors Xenakis's own account of listening:

> In music, listening to a piece – to a performance – is nothing but an experiment. ... Suddenly we understand something: that is revelation, intuition. (Varga 1996, 113)

It is also the case that the affect, the emotion of this moment is extreme: in Smith's words:

> An emotional overcoming, disconcertingly different from happiness, more like joy - if joy is the recognition of an almost intolerable beauty. It's not a very civilized emotion. (2018, 105)

Lastly, there is a catalyst: in this account, a brief stop at a famous English beauty spot, on the way to a wedding. Smith accounts for this catalytic effect as follows:

> Put simply: you need to lower your defences. (I don't think it is a coincidence that my … epiphany came through the back door, while my critical mind lay undefended, focused on quite another form of beauty.) (ibid., 113)

This presents a moment of subject-formation, where one is, after one's 'defences' are overcome, no longer the same person. Felski sees this as an example of 'the status of the artwork as an active force in the world' (2020, 53), but I want to level out this scenario, and indeed reverse it to think also about 'the world' within which this force is active. Felski draws on the thought of the anthropologist Alfred Gell, in his book *Art and Agency* (1998), where he views 'art as a system of action intended to change the world rather than encode symbolic propositions about it.' (1998, 6) For Felski, 'This means …turning away from aesthetic questions in order to define art objects as actors that sustain social relations' (2020, 63), but what if those 'social relations' are redrawn to include everything? This is the move made by Latour (and others), and it brings us to an interesting possibility: just as the physical beauty of her surroundings made Zadie Smith lower her defences to the music of Joni Mitchell, could not the reverse - *does not* the reverse also occur? That a work of art, a piece of music to which one is attached, changes one's perception of and relation to one's surroundings? The epiphany can arise *from*, as well as *to* a work of art. As Xenakis himself proposes, in his definitions of music, 'It is catalytic: its mere presence permits internal psychic or mental transformations ...' (1992, 181) Art can itself cause us to 'lower our defences.' Could it be a *use* of art to attach us, through its attendant affects and dispositions, to our surroundings, both personal and physical. At a moment where a re-attunement with our surroundings is called for so strongly, might music - even quite specific music - turn out to be use-ful?

4. Situation

My focus on *use* and *attachment* already contradicts the traditional aesthetic criteria of detachment and disinterestedness, but in this, I am only really following the example, already cited, of Xenakis who, in the first chapter of *Musiques Formelles* (1992), 'Free Stochastic Music', draws an indelible connection between beauty and terror, aesthetics and situation, through the conceptual bridge of the stochastic process. (Xenakis [1958] 2001, 9) Since *situation* is also key to the catalytic moment of attachment, just described, I want to consider for a moment how that situated-ness is implicated in the notion of care which seems to me to be a critical aspect of attachment. If we are disposed to exclaim, 'What's the use!' it is because we care.

Aesthetic theory has already noted and explored the relationships between, in the traditional terms of Western thought, 'art' and 'nature' where in more recent times 'nature' has come to be figured as 'the environment.'[2] Even if we follow Latour in conceiving of that term not as concerning a 'visible world' (Latour 2013, 184) but rather as consisting of a constellation of material encounters, beliefs, narratives and histories, institutions, measurement data and so on, environmental or ecological perspectives have come to play a significant role in recent aesthetic discussions. One of the key elements of these discussions for the current argument is the way in which environmental aesthetics also disavows detachment, preferring instead to situate the aesthetic experience as a sort of engagement. Thus, Arnold Berleant writes:

2 Cf. Adorno 2004.

> Aesthetic engagement renounces the traditional separations between the appreciator and the art object .... The psychological distance that traditional aesthetics imposes ... is a barrier that obstructs the participatory involvement that art encourages .... In contrast with this, boundaries fade away in aesthetic engagement and we experience continuity directly and intimately. (2005, 152)

In an earlier exposition of this sort of engagement, Berleant situates engagement specifically within a notion of environment:

> Perceiving environments from within, as it were, looking not at it but being in it, nature ... is transformed into a realm in which we live as participants, not observers .... The aesthetic mark of all such times is ... total engagement, a sensory immersion in the natural world. (1992, 169-70)

Disregarding for now the historic and rather essentialist notion of 'nature', Berleant notes the ways in which aesthetics, with all of its normal baggage of disinterested, individual experience, nevertheless paves the way for committed action:

> Experiencing environments aesthetically is ... an embodied argument for the importance of environmental values. Furthermore, an aesthetic encounter is a way to approach environmental education by helping to cultivate feelings of care and responsibility for the earth. (2005, 94)

This perspective on aesthetic experience proposes a use-value for the aesthetic encounter, asserting the importance of affect in situating the co-ordination of attentiveness and responsible action that constitute care.

In a further move along this line of enquiry, Mariagrazia Portera invokes the notion of "grasp"[3] to identify a sort of exploratory representation and situation of our personal interactions and the habits that underlie them. She specifies aesthetic engagement as the action of "grasp" because of its ability to attach us firmly to other things by means of bonds that change the configuration of ourselves as subjects: just as black girl Zadie found herself changed by the white girl 'piping' of Joni. (Smith 2018, 101) As Portera writes:

> engaging in aesthetic/artistic experiences may be an effective strategy to "grasp" our embodied habits - the habitual layer of our perceptual trade with the environment - and gently lead them back to awareness. (2018, 166-7)

The urgent necessity of this strategy is clearly laid out:

> in order to effectively address the current environmental crisis no less than a profound rethinking of our notion of human "nature," including the habitual layer of human experience and the role of the arts and the aesthetic dimension of human life, is required. (ibid., 168)

3 See Kiverstein et al for a discussion of how this concept engages with the notion of 'extended mind.'

I have tried to argue that use, attachment, and situation are key terms in an effective aesthetic discourse, and that these terms already spring to life from and through the work and thought of Xenakis by means of the conceptual bridge provided by stochastic processes. Furthermore, I have proposed that the catalytic effect of *situation* on the process of the individual attachment to an artwork can also operate in reverse, and that this may give us a critical use-value for music - and for certain musics in particular - as it *enables us to attach to situations that concern us in ways that evoke care*. In this sense, Xenakis's compositional use of gas dynamics or symbolic theory[4] is not so much an anecdotal account of an inspiration as a property of the music that allows a catalytic moment of attachment outwards, *from* the music to our surroundings. The music is not fantasy or pure imagination but bears a radical similarity to 'a universe open to spontaneous creation, which could form or disappear without respite, in a truly creative vortex.' (Xenakis 1992, 260) Perhaps this is an element of what Kundera is getting at when he describes his own moment of attunement to the music of Xenakis? (Kundera 2010)

5. UPIC

The UPIC system must count as one of Xenakis's major contributions, even if its history was difficult and curtailed.[5] In the context of this discussion, UPIC will stand as a point of enquiry into notions of use; as an apparatus (*dispositif*) demonstrating the ways in which Xenakis disarms conventions in order to open a field of positive action, for the exercise of effort, in which sound and music figure as use-full ways of acting and knowing. Giorgio Agamben defines the 'apparatus' as 'a heterogeneous set that includes virtually anything. … The apparatus itself is the network that is established between these elements.' (2009, 2-3) In this sense, UPIC pulls together diverse elements such as: the digital memory of moments of audio - recorded or drawn by hand, a large magnetic drawing board and pen, the physical actions of drawing as an exploratory and habitual practice, notions of dimensionality where audio perceptions such as high and low are configured as spatial, and so on. The seeming simplicity of the arrangement of these elements belies the openness of the apparatus to multiple reconfigurations. Its productions figure not as score and performance, but as simultaneous manifestations of the same productive impulse. Thus, the drawings rendered in the production of Xenakis's work for UPIC, *Mycenae Alpha* are as important as the sound they produce. In a way, the sound - which is so unlike our habitual experience of sound as to be a challenge to the senses - only makes sense in the presence of the images which subtend it. The unity of image and sound is striking, even though the image - as a simple plot of musical elements against time - contains a highly deficient representation of what is heard.

As Rudolph Frisius points out, Xenakis came to music from an unconventional starting point, with a strong multidisciplinary background and a fundamental commitment to education. (Frisius 2020) UPIC figures clearly in a history of education. While it is true that the UPIC served Xenakis's own creative vision, as an apparatus it had a specific educational role, evidenced in the work undertaken by Les Ateliers UPIC in providing creative instruction for children of all ages, amateurs, and both student and professional composers.[6] The openness of the apparatus makes it a fertile space for creative play, and in that sense it is, in Agamben's terms, a sort of 'profane' device, where ' "to profane" signified … to restore the thing to the free use of men.'(Agamben 2009, 18) Agamben is concerned with the ways in which an

4 See Xenakis 1992, 49; 155 et seq.
5 cf. Marino et al 1993; Nelson 2010.
6 cf. Després 2020.

apparatus is implicated in subject-formation, or, in the case of the contemporary technologies he despises, 'de-subjectification'. The openness of the UPIC - its blank space for drawing, unaided, with all the impetus and gestural potential of the human hand - makes it a space for searching; for the forming of a creative subject, in relation to sound, image, and the imagination of a disposition of events in the world. One could exemplify that 'openness' by considering the ways in which the UPIC renders an audio technique such as Frequency Modulation open both to use, and to mis-use, as becomes apparent in the work of Richard Barrett.[7]

6. Conclusion

I began by expressing a moment of despair, 'what's the use!' directed at a moment of distraction by events of concern, and referring to a recent consideration of the notion of *use* by the philosopher Sara Ahmed: more specifically, the question might concern an approach to music, and by implication to the work of Iannis Xenakis, that seeks to find a position for what could be seen as the 'merely aesthetic' in a moment of existential crisis. The aesthetic, in this view, might be seen as the American artist Willem de Kooning saw it when he compared aesthetics to ornithology, seen from the point of view of a bird: as something categorically removed and external, looking in. Following Ahmed and Rita Felski, I have tried to configure the aesthetic as attached and situated, internal; as part of a process of subject formation where subjects are fluid and not necessarily human. And I have argued that attachment, through a catalytic moment, can revolve outwards *from* a work of art as well as inwards towards it.

The work of Xenakis, with what I have taken to be its central conceptual bridge of the stochastic process, and its fundamental orientation towards active seeking, seems to me to form a uniquely use-ful moment for music, whether one is participating as a performer or as a listener. As we respond to the voices of our young people, who urge us to a fundamental reconsideration of the life forces, this work shows us what it is to engage in a practice of care and concern with respect to what is around us, not seeking music as solace but as a source of energy that throws us outwards. The encounter is not a simple one. As Xenakis recounts:

> We live more intensely when we must confront swathes of problems, when we must decipher this growing complexity, which is here, before our eyes, hieratic, even if we try to ignore it. That which we live is a bloody hand-to-hand with nature. (1987, 46-47).

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7 cf. Barrett 2020.

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Musical Enunciation: the modes of temporal existence in Iannis Xenakis

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Abstract

Based on three specific writings by Iannis Xenakis, *Trois poles de condensation* (1962), *Vers une Métamusique* (1967), and *Sur le temps* (1988), we draw a connection between the composer's temporal algebras (*hors-temps*, *temporelle* and *en-temps*) and the *modes of existence* (*virtualized*, *actualized*, *realized* and *potentialized*) presented by the tensive approach of discursive semiotics, developed by Jacques Fontanille and Claude Zilberberg (1998). By bringing the two approaches together, we aim to discuss how composing, interpreting, and listening acts are part of what we call musical enunciation, whose process dynamizes – with the modes of existence, actualized, realized and potentialized – the characteristics of a musical and sound system, individually invented or stabilized by collective *musical praxis* throughout the history of music. Xenakis notes that the calculation of probabilities, "whose stochastic term is an abbreviation"[1] (Xenakis 1971, 26 – our translation), functions as a way of inventing and inferring the interplay of probabilistic dominances of a system in direct relation to its processes of sound and music manifestation. Thus, musical composition becomes concerned not only with putting into process historically stabilized musical systems, but also with the construction of new minimal restrictions that are more or less hierarchical, more or less indeterminate. Xenakis observes that the germ of this movement is already there in Schöenberg's dodecaphonic propositions, yet it is only with the probabilistic invention that one can speak of a manipulation of feedback and systematic variation (or of a memory) that proposes new enunciative praxis. To make clear the connection between Xenakis' algebras and the modes of existence of a possible musical enunciation, let us point out how the composer's algebra *temporelle* acts in the interaction between the musical elements *hors-temps* and *en-temps*. The result of this *temporelle* acting is directly associated with the two main directions of the enunciative existence thought from the perspective of an enunciative praxis: i) the path from the *hors-temps* system to the *en-temps* process; ii) the path from the *en-temps* process to the *hors-temps* system. In the first direction, we take into account the creative processes and interpretive choices of the works. In the second direction, we can talk about the perceptual impacts of the works and how much this impact has changed or varied the minimal premises of musical systems. Both directions point to a cyclical chain of musical existence that helps us understand the stages of dynamization and transformation of musical systems and processes throughout history. Finally, we briefly present the idea that in addition to the cyclical nature of the modes of existence, there is a *thickness* that deals with the superposition of the existential modalizations that motivates musical utterances in different ways. We bring the score of Mycenae-Alpha (1978) by Xenakis to exemplify the possible modulations of this *thickness* of existence.

1. The impalpable

Talking about time today is to take a step on the road to exhaustion, both for the weariness of the

[1] "[…] dont le terme stochastique est une abréviation" (Xenakis 1971, 26).

theme, especially in the field of music, and for the uneasiness inherent to the contact with the impalpable but implacable. From Gisèle Brelet's tomes of *Le temps musical* (1949) to the moment, images proliferate that unfold the tension between temporal continuities and discontinuities that make musical sounds live in perception. Based on three specific writings by Iannis Xenakis – *Trois poles de condensation* (1962), *Vers une Métamusique* (1967), and *Sur le temps* (1988) – we will deviate somewhat from aspects of our temporal perception of musical sonorities to a mechanism underlying their appearance: enunciation.

The interplay between Xenakis' temporal algebras (*hors-temps*, *en-temps*, and *temporelle*) ties in with the central idea that enunciation is the act of putting the system of a language (whether verbal, nonverbal, or syncretic) into use, which is the same as saying in process (Benveniste 1966, Greimas and Courtés 1982, and Fiorin, 1996). In *Sur le temps* (1988), Xenakis questions himself more forcefully about a space without time, a *hors-temps* that would function as a framework of possibilities for a vectorial and musical topology – such as pitch scales, modes, architectures of fugue, mathematical algorithms generating sounds etc. – to be temporally *actualized* and *potentialized*. But let us not rush to conclusions. Before we present our proposal for merging Xenakis' temporal algebras and semiotic modes of existence (virtualized, actualized, realized, and potentialized), it is worthwhile to present a brief section on the functioning of enunciation.

2. Enunciative presence

From the standpoint of the tensive semiotic approach, proposed by Jacques Fontanille and Claude Zilberberg (1998), the problem of enunciation splits into two major interconnected questions: that of *presence* and that of *existence*. The first one bears the tension between a subject (of the enunciation) and an object (utterance) that mutually invent each other when they relate. The body of the subject of enunciation opens into two bodies: that of the *enunciator*, who by "saying" what he/she "says" in a certain way, builds a profile of the *enunciatee* to whom he/she "says" something. For this theory, enunciation is always an instance presupposed to the utterance. The characteristics that make up the identity of the subject of enunciation (divided into enunciator and enunciatee) are inferred from the marks and figures that build the manifested utterance, be it verbal, non-verbal (as it is the case of sound-musical works) or syncretic (verbal and non-verbal). The unfolding of *presence* (Fontanille and Zilberberg 1998, 91-111) is very extensive and we do not intend to further explore it in this paper. Before we move on to the second and main issue of this investigation, that of *existence*, it is enough to make clear two important points about *presence*:

i) the subject of enunciation is not the ontological subject or the flesh-and-blood subject of biography (Greimas 1974). The identity of the subjects is understood as a dynamic figure that manifests itself implicitly from the characteristics projected onto the object-utterance. To make our point clearer, we can take the example of Fernando Pessoa's heteronyms (Alberto Caiero, Ricardo Reis and Álvaro de Campos) or even the composer Epaminondas Vilalba Filho, Villa-Lobos' heteronym who composed neo-classical music. In short, the subject is constructed enunciatively in one or several languages, based on different enunciative and, therefore, discursive figures. From this point of view, there is no way to postulate the existence of a referent or a being outside language.

ii) it is from the sensitive and intelligible *presence* that one can investigate the well-known trinary instance of enunciation: *actant-person*, *time* and *space*. Enunciation studies are already moving towards the idea of different levels of analysis of this trinary apparatus (Mancini 2019) and, moreover, towards different applications depending on the constraints of different languages (Manetti 2020). In this field one can explore more carefully the aspects linked to the sound and musical perception of the works, as we did in an article on Villa-Lobos' Choros nº6 (Bonin 2019).

3. Enunciative existence

As a direct declension of the modulations of *presence*, enunciative *existence* concerns the dynamic

and ever-renewed act that makes enunciation the instance of mediation between the elements of systems and their uses in societies. To better understand the issues involved in the notion of existence, it is important to grasp the distinction between *system* and *process* (Hjelmslev 1969), reasonably well known in the general field of sciences, and also its renewed tensive version with the concept of *enunciative praxis* (Fontanille and Zilberberg 1998, 127-50). We do not know whether Xenakis has had contact with the glossematic theory developed by the Danish linguist Louis Hjelmslev in the 1940s, an author who, in addition to renewing the thinking of Ferdinand Saussure, stands as one of the basis for discursive semiotics. We bring this parallel because the difference between *hors-temps* and *en-temps* of the Greek composer is very close to the distinction between *system* and *process* proposed by Hjelmslev.

The stochastic law allowed Xenakis to envision a composition in which musical form was "based on a minimum number of logical constraints, a minimum number of relationships between sound events" (Xenakis 1971, 31). Along the same lines, Hjelmslev will say that “for every *process* there is a corresponding *system*, by which the process can be analyzed and described by means of a limited number of premises” (Hjelmslev 1969, 9).

Although the pragmatic goals of the two authors are diametrically opposed, one towards creation and the other towards analysis, both are in search of the minimal **correlations** that make up the dependencies or functions between the elements of a given *virtual system* that can be achieved, in analysis and creation, by the **relations** contained in a *realized process*, as it is the case of the cicadas' song brought by Xenakis (1971, 26) as an example of a *realized* sound object that can be "re-presented" and varied from a minimum set of musical rules. We will draw on a certain "algorithmic" and logical[2] advantage (or perhaps disadvantage?) of Hjemslev's glossematic theory to present two more concise definitions of *system* and *process*:

> Df. 9. A PROCESS is a Relational Hierarchy. -- opp Df 11 SYSTEM (Hjelmslev 1975, 5).
>
> Df. 11. A SYSTEM is a Correlational Hierarchy. -- opp Df 9 PROCESS. -- Df 311 GENERAL-SYSTEM, Df 312 SCHEMA (Hjelmslev 1975, 5).
>
> Another importat distinction for linguistic theory is the one between the *both-and* function, or “conjunction” [Relational Hierarchy], and the *either-or* function, or “disjunction” [Correlational Hierarchy]. This is what is behind the distinction between process and system: in the process, in the text[3], is present a both-and, a conjunction or coexistence between the funtivos entering therein; in the system is present an either-or, a disjunction or alternation between the functives entering therein (Hjelmslev 1969, 36 – our insertions).

In *Sur le temps*, Xenakis' first question concerning the existence of a "space freed from the tutelage of time" (1989, 86) is at the heart of the description of a musical system. For composers, musicologists, and people who experience music in some way, it is commonplace to talk about the musical structures or systems that build musical language, whether they are "natural," as the result of a diachronic, historical, and collective transformation, or "artificial," as the outcome of an individual proposition. We can consider Schöenberg’s dodecaphonic system as occupying a hybrid place between natural and artificial in this qualification, since Xenakis points out that the Austrian composer “had no reason, [...], to introduce a temporal order in the twelve sounds and, as a consequence, to reforge a polyphonic structure, pure, of course, but outdated” (1971, 28). By doing so, Xenakis, at the time of *Trois poles de condensation* (1962) and *Vers une Métamusique* (1967), wanted to take a step further

[2] The sense of logical here does not refer to the classical logic of the implicative chains of intelligibility, as in Carnap (1928 and 1930). Hjelmslev's glossematic theory seeks, from a logico-mathematical inspiration, to identify a sub-logic or a pre-logic that ultimately results in oppositions or participatory correlations that are far from a binaristic logic.

[3] *Text* for Hjelmslevian-based discourse semiotics can be verbal, nonverbal, or syncretic, and is constituted by the articulation between a plane of expression and a plane of content (Hjelmslev 1969, 47-60).

towards the minimal premises of a musical system that would be described based on stochastic laws. Therefore, Xenakis very well distinguishes the *en-temps* process from the *hors-temps* musical system. In the former, *realized* sonorities coexist in a syntagmatic chain that is apprehensible in the time of phenomenological perception, and in the latter, *virtual* paradigmatic schemes alternate topologically and vectorially such as categories of pitches, intensities, durations, timbre combinations, overlapping sound layers, acoustic projections in space, etc.

> In other words, from a totally timeless space or from a totally reversible time we move to a time in which memory is present in the form of habit[4] (Ferraz 2014, 16).

As we said at the beginning of this article, time is relentless: the 26-year period between Xenakis' writings does not fail to reveal certain metamorphoses in the way the composer presents his temporal algebras. The transformation that we believe is indeed relevant is the difference between two **directions** in which the *temporelle* algebra acts in the interaction between *hors-temps* (system) and *en-temps* (process). This distinction will be essential for us to understand musical enunciation from a musical praxis.

The first direction: in *Vers une Métamusique* (1967) the *temporelle* category acts to temporally actualize and realize *en-temps* the minimal schemes of the musical system. Xenakis goes so far as to say that "a melody or a chord [*en-temps*] in a given range is composed from the relationships of the *hors-temps* category with the *temporelle* category"[5] (Xenakis 1971, 42 – our translation and insertion). In this article, the composer presents some historical musical systems, such as the ancient and the Byzantine, based on a hierarchical classification in levels (first, second, third etc.) of the *hors-temps* schemes.

In *Trois Poles de Condensation* (1962), the composer even proposes a sequencing for this first direction:

a) Thus, a musical composition can be seen first from the point of view of fundamental, time-independent operations and relationships, which we will call *logical structure* or *hors-temps algebraic*.
b) Second, a musical composition examined from a temporal point of view shows that sound events create durations on the time axis that form a set with interconnected group structures. This set is structured with the help of a *temporelle algebra* that is independent of the *hors-temps algebra*.
c) Finally, a musical composition can be examined from the point of view of the correspondence between its *hors-temps algebra* and its *temporelle algebra*. We obtain the third fundamental structure, the *algebraic en-temps* structure[6] (Xenakis 1971, 36-7 – our translation).

The second direction is mostly present in *Sur le temps* (1988). In the attempt to axiomatize *temporelles hors-temps* structures, Xenakis starts from the primary force of temporal perception: separability (or difference, discontinuity, separation, etc.). Therefore, he starts from the notion of perceptual

[4] "Ou seja, de um espaço totalmente sem tempo, ou de tempo totalmente reversível, passamos a um tempo em que a memória se faz presente na forma de hábito" (Ferraz, 2014, 16).
[5] "[...] une melodie ou un accord sur une gamme donnée sont faits de relations de la catégorie hors-temps avec la catégorie temporelle (Xenakis 1971, 42).
[6] "a) Ainsi une composition musicale peut être vue d'abord sous l'angle d'opérations et relations fondamentales, indépendantes du temps, que nous appellerons *structure logique* ou *algébrique hors-temps*. b) Ensuite une composition musicale examinée du point de vue temporel montre que les événements sonores créent, sur l'axe du temps, des durées qui forment un ensemble muni de structures de groupe abélien. Cet ensemble est structuré à l'aide d'une *algèbre temporelle* indépendante de *l'algèbre hors-temps*. c) Enfin, une composition musicale peut être examinée du point de vue de la correspondance entre son *algèbre hors-temps* et son *algèbre temporelle*. Nous obtenons la troisième structure fondamentale, la *structure algébrique en-temps*" (Xenakis 1971, 36-7).

anteriority caused by temporal discontinuity (without which the flow of time would not be perceived) to infer the musical system from the musical traces retained by memory:

> 1. We perceive separable events.
> 2. Thanks to separability, these events can be assimilated to points of reference [*temporelles*] in the flux of time, points which are instantaneously hauled up outside of time because of their trace in our memory (Xenakis 1989, 89 – our insertion).

It is from this bidirectional way of thinking about the *temporelle* category that *en-temps* events become complex events that can be composed (1st direction) or inferred (2nd direction) in the relationship between *hors-temps* schemes and *temporelle* sets of interconnected group structures. In this sense, the category or algebra *temporalle* is what, for Xenakis, makes the transition from *system* (*hors-temps*) to *process* (*en-temps*) and vice-versa. If we allow ourselves a little subtlety, we will notice that the two directions were already underlying the first quote of the author we brought in this article: a musical form [*temporelle*] "based on a minimum number of logical constraints [*hors-temps* $\rightarrow$ *en-temps*], a minimum number of relations between sound events [*en-temps* $\rightarrow$ *hors-temps*]" (Xenakis 1971, 31 – our insertions).

At last we have reached the crucial point regarding the blending between temporal algebras and semiotic modes of existence: the *temporelle* category is directly associated with enunciation taken as an *enunciative praxis* that mediates between *system* and *process* and vice-versa. There are still some details to make this association more robust, so we must now understand how the two directions we have presented compose a cyclical and logical movement based on the *elementary transformations* (Fontanille and Zilberberg 1998, p. 185-6) of semiotic existence: *virtualization*, *actualization*, *realization*, and *potentialization*.

4. The cyclic illusion of temporal existence

There is a very specific peculiarity in the enunciative existence of the arts when one of the final utterances is a live performance: its segmentation and its intrinsic collectivity. In other words, performing arts have subject-figures that perform distinct stages in the path of enunciation that end up segmenting the passage from *system* (*hors-temp*) to *process* (*en-temps*).

In music, we can think of at least four general utterances already established in the musical language: the *score*, the *musical instrument*, the *live musical performance*, and the *musical audio*. If, for example, we only take the live performance of any instrumental ensemble as a *realized* (accomplished) utterance, we can canonically think of at least two subject-figures: the composer and the performers.

In the cyclic narrativization of enunciation, or in both directions mobilized by the *temporelle* algebra, the composer usually *actualizes* (*temporellement*[7]) in score or in any graphic representation a set of musical elements of a *virtualized* system that will be interpreted and sonorously *realized* by the performers. It is in the *realization* (*en-temps*) of the utterance live performance that we can speak more clearly of the relationship between the enunciator (composer+performer) and the enunciatee (listener) in action. The sound-musical elements are put into memory by the subject of enunciation (enunciator and enunciatee) in the stage of *potentialization* (*temporelle*) that feedbacks the musical system, or as Xenakis puts it, "they are instantaneously hoisted into *hors-temps* by their trace in our memory"[8] (1991, 102 – our translation).

[7] In *Trois poles de condensation* (1962), Xenakis is more concerned with the first direction of the *temporelle* algebra and specifically with the enunciative stage operated by the figure of the composer. Therefore he will address the questions of determinism and indeterminism in compositional processes.

[8] "[...] sont instantanément hissés hors le temps grâce à leur trace dans notre mémoire" (Xenakis 1991, 102).

It is important to bear in mind that composer, performers and listener are discursive positions, enunciators and enunciatee, that have been segmented and crystallized by the uses of musical language and that can, for example, be occupied by the same flesh and blood subject. We will not work on the details of the relationship between the subject of enunciation and the enunciative presence, but it is useful to mention just two musical practices that usually override this somewhat classical segmentation of enunciative existence: improvisation and electroacoustic music. On one hand, the improviser-interpreter usually makes the direct transition from the system to the process without the intermediation of the figure of the composer, it is common to say that he plays and composes in act; on the other hand, the electroacoustic music composer makes use of the computer+diffuser prosthesis to transport his sound composition, in act or pre-composed, directly to *realization* without the intermediation of performers. Of course, we are talking about extreme cases because we know that within these practices there can be some exceptions. Our goal is simply to clarify how the transition and interaction between *hors-temps* and *en-temps* algebras takes place.

In the second to last section (5.), we will see that depending on the choice of the musical utterance in question, whether for purposes of creation or analysis, there may be differences in narrativization and in the very configuration of the enunciative existence. But first, there are two necessary distinctions to be made for our proposal of approximation between temporal algebras and modes of existence to gain more weight: i) the difference between perceptual temporality and logical enchainment; ii) and the distinction and interdependence between virtual system and virtualized system.

i) perceptual temporality, under the tensive view, concerns the sensitive and intelligible apprehension in the flow of phenomenological time, that is, the perception of the relationships between sound and musical *en-temps* events in an "extended present"[9] (Teixeira and Ferraz 2019, 500). Zilberberg (1990) proposes four categories for this temporality (*chronological*, *rhythmic*, *mnesic*, and *kinetic*) that have some connections with Xenakis' three temporal algebras. However, due to their density, this discussion is beyond the scope of this work. In this proposal, logical sequencing concerns the cyclical and analytical sequencing of the transformation path of enunciative existence (fig. 1) that should not be confused with the temporal perception of a musical work in act.

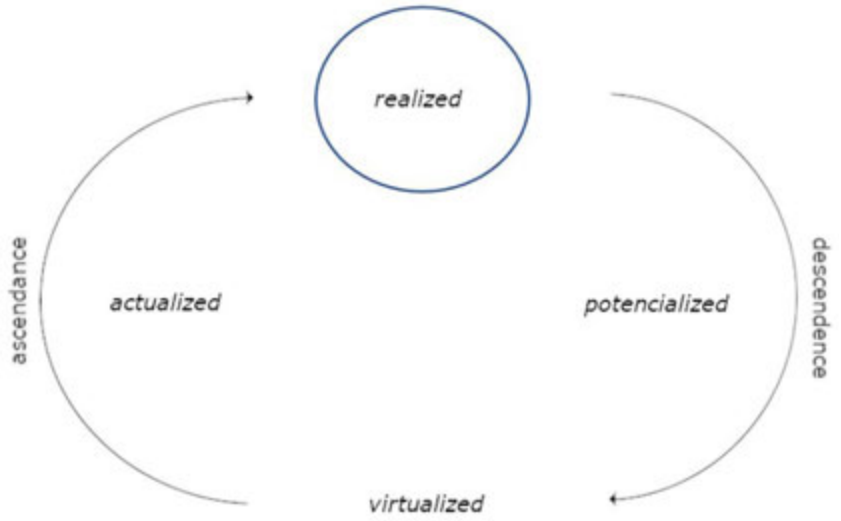

Figure 1: Cycle of modes of existence.

[9] In the article *The performance of time (or the time musical performance)* (2019), by William Texeira and Silvio Ferraz, there is an idea that the "apprehension of temporal flux in musical performance in act demands another sense of time, an *extended present* where the whole being is applied in the actualization of a musical action between movement and sound and, at the same time, connects these movements and sounds to those just produced, already anticipating and planning the next technical step, listening internally to the next time or the next attack. […]. All these movements happen simultaneously, like an energy that rationalization cannot contain. It is indeed a dilation of the present that promotes the synthesis of past and future in the performative act" (Teixeira and Ferraz 2019, 500).

ii) a major strength of the tensive approach (Fontanille and Zilberberg 1998, Zilberberg 2006) is the understanding of the paradigmatic schemas that structure a pure system (*hors-temps*) as if they were vestiges, fossils, or photographs of a collective memory that can be deduced from the individual and collective operations that make up the realized objects in discourse. With that,

> one should probably distinguish between the "virtual", pure systemic presupposition of the discourse, and the "virtualized", obtained by detachment from a praxeme; however, from the point of view of discourse analysis, these two modes overlap exactly, insofar as - memory of the collectivity (virtual system) or memory of the operations of discourse (virtualized entities) - both appear as the memory of the enunciative praxis (Fontanille and Zilberberg 1998, 175 – our translation).

> Therefore, it can be seen that “after all” paradigmatic identities are...syntagmatic; the paradigmatic is only a vestige (Zilberberg 2006, 8 – our translation).

At this stage there is an essential turning point. If we consider the temporal categories discussed by Xenakis from the point of view of the tensive approach, we have to assume that *hors-temps* features not only a bifurcation between *virtual* and *virtualized*, which implies the difference between paradigmatic traces and paradigmatic operations arising from use, respectively, but also a certain system dynamics that concerns the changes and variations resulting from the relationship between sound events *realized en-temps*. In short, this point of view assumes neither the origin nor the end of systems and processes, but rather the course of continuous transformations of the existence. Our epistemological choice grants *temporelle* algebra a central role for the functioning of semiotic existence, since it sets in motion the existential cycle or becoming (*devenir*).

A clear proof that the *temporelle* category is the "glue" that puts Xenakis' algebras in contact is the second pole of condensation (1971, 33-35) proposed by the composer: the Markovian chains. The probability calculation of one sound event happening after another is not concerned exclusively with modeling the *en-temps* sound relationships or the sound constructions that implicatively follow the composite probabilities, but rather it has to do with the process of feeding and feedback that can change or vary the probability indices of the chains. In essence, it is a possible simplistic description of the workings of an artificial intelligence algorithm that stalks us on social media from the moment we pay attention to a new thing.

Another point that attests to the dynamics of musical systems is the section called "progressive degradation of *hors-temps* structures," present in *Vers une Métamusique* (1971, 58-9). Despite the tone of regret regarding the transformations or "impoverishment" (1971, 59) that the Western musical system has undergone since the lower Middle Ages, Xenakis describes the stages of systemic change that ultimately emphasize the *temporelle* category. For Xenakis, the impoverishment of Western music has to do with the synthesis of the paradigmatic categories that make up the musical system in the historical diachrony.

Finally, it is left to point out that the curved arrows in Fig. 1 are two tensive directions, *ascending* and *descending*, to be associated with the *temporelle* directions that we find in Xenakis (1962, 1967, and 1988). These directions or operations refer to the elementary transformations of the enunciative existence proposed by the tensive approach and constitute a kind of “prosodic-syntax” (Fontanille and Zilberberg 1998, 135): i) *apodosis*: from the *system* to the *process* and ii) *prostasis*: from *process* to *system*.

> i) [*apodosis*] the *ascending* operations by which forms are summoned with a view to manifestation:
> - Virtualization $\rightarrow$ Actualization [*Virt.* $\rightarrow$ *Act.*] represents the *emergence* of a form;
> - Actualization $\rightarrow$ Realization [*Act.* $\rightarrow$ *Real.*] describes its *outset*;

> ii) [*protasis*] the *descending* operations by which forms are implied, stored in memory, or even erased and forgotten:
> - Realization → Potentialization [*Real.* → *Pot.*] is the condition of a form's *decline* in a particular discourse, and eventually its fixation in use as a pontential praxeme;
> - Potentialization → Virtualization [*Pot.* → *Virt.*] describes the *disappearance* of a form (Fontanille and Zilberberg 1998, 186 - our translation and insertions).

If an investigation aims to describe a creative process, we would be in the realm of the *emergence* [Virt. → Act.] of a musical form, a stage canonically linked to the figure of the composer and often materially concretized by a graphic and visual representation. The *outset* [Act. → Real.] and the sound realization itself, that is a study on the interpretative choices of a work already actualized, are operated by the figure of the interpreters who act as translators, as they interpret a source text, the score, to produce (realize) a target text. These are the two fields best explored by musicology *lato sensu*.

If the intention is to observe how the perceptive effects of an already accomplished (realized) work are stored in the memory of an individual or collective subject, the *decline* [Real. → Pot.] or impact of that musical form is taken into account. Luiz Tatit (2019, 144-7) proposes a gradual difference between *tonic* and *atonic* potentialization and thus we can differentiate a more or less tonic memory from a more or less atonic memory. In the tonic memory, surprise subverts one, some or all of the mnesic characteristics of a musical system. In the atonic memory, some or all of the mnesic characteristics of a musical system that arise from use are confirmed. At this stage, it is possible to study the revolutions or major turning points brought about by specific musical works or movements. The *disappearance* [Pot. → Virt.] of a musical form concerns the return of elements already stored, with more or less tonicity in our memory, to the virtualized musical system. It is at this stage that we can study in more detail the systemic changes and variations of the musical language.

If the goal is to understand sensitive and intelligible perception (or *enunciation*) *in act*, in the condition that Teixeira and Ferraz call "*extended present*" (2019, 500), it is enough to transport this whole mechanism of existence to the complexity of the musical act and, in this case, the directions cease to be sequential and become simultaneous.

Even though there is much to be detailed from specific musical objects and practices, we have a first chaining model of musical existence operated by a *musical praxis*[10] inserted in a time lived collectively. A brief warning must be done about the figures that deal with the tensive directions we present. We have made a distinction between the thematic roles of composers, performers and listeners just for the sake of clarity; the one who operates the whole cyclical movement is the *subject of enunciation*, therefore, *enunciator* and *enunciatee* at the same time. A composer always composes something with a potential listener in mind, which can even be the image he/she has of himself/herself, and the same is true for the performer. Therefore, the enunciatee is not only present in the realization of the work, but in fact since the very *emergence* of the musical form.

In the next section we will conclude our reasoning with the idea that musical language as a whole depends on collectively shared arrangements of a “thickness” of musical existence. That way, we move from existential cyclicity to a proposed superposition of the modalizations of existence that mobilize musical utterances in different ways.

[10] Fontanille points out that "*enunciative praxis* was defined some thirty years ago (Greimas and Fontanille (1991), Bertrand (1993), Fontanille and Zilberberg (1998)) as comprising all the operations which, through an appropriation of the system of deep structures of narrativity, produce semiotic configurations sufficiently stabilized to be put at the disposal of other uses, which are apprehended, for that very reason, in a constant movement of remodeling of forms. [...]. Enunciative praxis thus implies chains of operations, organized in collective time, and a capacity for creation and renovation in the production of the figures of meaning, under the coercion of cultural conditions" (Fontanille 2017b, 986).

5. The “thickness” of musical existence

The intent of this section is to meet an explicit desire in *Sur le Temps* (1988): to reach a possible "unio[n] [of] Parmenides and Heraclitus" (1989, 91-2).

The *enunciative presence* for the tensive approach is always conceived in degrees of experience, from the maximum plenitude to the greatest vacuity. This implies that the utterance gains an enunciative depth: the utterance-object is either closer and more intimate or further away and distant in the perceptual *field of presence* (Fontanille and Zilberberg 1998, 91) of the subject of enunciation. This gradient is closely related to the modes of existence. Thus, besides the cyclical directions of existence, we can also think of an existential depth that operates from a regime of dominances or a “thickness” that comprises the *virtualized*, *actualized*, *realized*, and *potentialized* modes.

> Semiosis is thus both tension and competition. And the scenarios of manifestation [*realization*] feature competing processes in the modes of existence depth: in the same segment of manifestation, virtual, potential, and actual semioses would coexist[11] (Fontanille 2017b, 213 – our translation and insertion).

Therefore, "from the moment the utterance is conceived as an *enunciative depth* structured on the superposition of the degrees of existence of the *enunciative praxis*, it then comes to be understood as a regime of dominances between *modes of existence*." [12] (Mancini 2019, 81 – our translation).

The idea of a possible “thickness” of existence gives us the chance to deepen the way we consider the different faces that musical enunciations assume within musical language: the *score*, the *musical instrument*, the *live musical performance* and the *musical audio*. Let's take as an example the score utterance from the work Mycenae-Alpha (1978) by Xenakis.

Drawn entirely in UPIC, the visual representation of the piece can be understood as the visual concretization of the transition from the *virtualized* to the *actualized*, thus serving for the synthesizer to "translate" the visuality into the sound *realization* of a *musical audio*. This is the most canonical function of a score and it would occupy, in the degrees of dominance of a thickness of existence, the *actualized lack* that requires a realization of the sound *plenitude* in an audio. After its function is completed, its visual materiality could be discarded from the musical manifestation, in this case, purely audible.

Figure 2: Mycenae-Alpha (1978) by Iannis Xenakis

[11] “La sémiose est de ce fait à la fois tension et compétition. Et les réglages de la manifestation disposent ces procès concurrents dans la profondeur des modes d’existence : en un même segment de la manifestation, coexisteraient alors des sémioses virtuelles, potentielles et actuelles” (Fontanille, 2017b, p. 213).

[12] “A partir do momento em que o enunciado é concebido como uma *profundidade enunciativa* estruturada na superposição dos graus de existência da *práxis enunciativa*, este passa a ser entendido como um regime de dominâncias entre os *modos de existência*” (Mancini 2019, 81).

However, if we take the video of the piece posted on Youtube[13], or even in demonstrations of the UPIC system operation, the *score* can no longer be considered only in the stage of *actualization* of existence, but must also be taken as a fundamental part of the construction of meaning accomplished (realized) in the musical manifestation, generating sensitive and intelligible expectations that were not only in the musical audio. Thus, the *realized* musical experience would have the audio-score as a component part of the manifestation. We know that the musical experience or perception cannot be restricted to the hearing aspect, otherwise we would have to discard the visualities of the score, the somatic and tactile elements of musical instruments and the various scenic and polysensorial aspects of live musical performance. Finally, the *score* could also be thought of as a way of recording a performance or musical audio already *realized*, or in other words, it would be part of the stage of *potentialization* of the existential thickness. There would be a "translation" or transduction of the sound material into a visual representation that would serve as a tangible concretization of the memory of what was *realized*.

Today it is not difficult to observe that programming languages and technological advances have consolidated themselves as a strategy that helps to modulate the thickness of the existence of musical utterances. It is enough to notice that a simple algorithm can serve, almost instantaneously, to model a work already *realized* and serve as an *actualization* of a new work. Therefore, contemporarily there is an acceleration in the modulations of existential thickness and being aware of which stage of existence is at stake contributes for the practices of creation and analysis to gain greater clarity and density.

6. What is the enunciative existence of music for?

Xenakis may not have foreseen the use of his temporal algebras as we are proposing here, but he certainly knew of their universal vocation. No wonder that the composer, when dealing with the algebras, often touched on subjects that went beyond the limits of musical language, such as the kinetic theory of gases, the differences and events between micro and macro physical levels, quantum physics and mechanics, and even more philosophical passages about the meaning of life: “As if the entire universe fought desperately to hang on to existence, being by its own tireless renewal at every instant, at every death. Union of Parmenides and of Heraclitus.” (Xenakis 1989, 91-2).

This time around, we believe that Xenakis' temporal algebras can help us understand the mechanisms inherent to the transformations of musical existences, which means that it contributes to observe the way musical enunciations occupy different stages of existential *becoming* (*devenir*) and thus building the musical perception of the subjects involved in the various musical practices. Regardless of the specific tools of creation and analysis, the science of modes of existence takes us more and more towards what Jean-Jacques Nattiez called "vast general musicology" (2020, 429).

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[13] https://www.youtube.com/watch?v=yztoaNakKok

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Atrées: Is it a proper name or… something else?

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Abstract

Atrées is one of the five "ST works" that Iannis Xenakis composed in 1962, revolutionizing the composition process with the aid of the IBM computer. Three out of five simply carry a code-like title denoting the number of players for which the piece was scored and the exact date on which its data were computed (e.g., ST/4-1, 080262); the other two, however, apart from their serial number, do carry a mysterious title each: *Morsima-Amorsima* and *Atrées*. And while *Morsima-Amorsima* has been explained by the composer himself as being the transliteration of two ancient Greek words (one of which being his own invention) that stand for "those ruled by Fate-those not ruled by Fate," *Atrées* has been treated by scholarship somewhat lightheartedly, considered to be the plural of the proper name Atreus, in French – but is it so? And if it is so, why such a title?The paper touches on Xenakis's problematics during that period regarding probabilities vs. determinism and its interplay with Fate and Ancient Greek thought all the while hypothesizing an Ancient Greek epigram as the occasion for his choice of the title *Atrées*; a choice which initiated a long process of choosing titles for his works that were meant to be both implicit and obscure, inextricably bound up with his personal quest.

Atrées, commissioned by ORTF (Office de Radiodiffusion-Télévision Française), belongs to the group of works that Iannis Xenakis produced in 1962 with the help of the IBM computer. They all carry a serial number as a title, which denotes the *family* of works (*stochastic*, that is, probabilistic), the *number of players* for whom the work was scored, and the exact *date* on which its data were calculated on the IBM 7090 computer at Place Vendôme in Paris. Thus, the complete title of *Atrées* is *Atrées (ST/10-3, 060962)*, meaning that it's the *third stochastic* work for *ten* players,[1] and that it was computed on *September 6, 1962*.

Atrées (ST/10-3, 060962) and *Morsima-Amorsima (ST/4-1, 030762)* are the only ST works, however, that have another word/phrase for a title next to their serial number, which in their case becomes a subtitle. Concerning *Morsima-Amorsima*, one can easily surmise that Xenakis decided to give it an indicative title because it was it, together with another work with an inverted twin title, *Amorsima-Morsima*,[2] that he chose to submit to the ATI (Athens Technological Institute) composition competition/Manos Hadjidakis Awards in 1962. *Morsima-Amorsima* actually won the 1st prize at the competition (together with a work by Anestis Logothetis), an event that was Xenakis's first sign of recognition in his homeland and fueled his later international career in many ways. Concerning *Atrées*, however, why was this given such a distinctive title next to its serial number?

1 The first one is *ST/10-1, 080262* and the second *ST/10-2, 080262*, which is called *Amorsima-Morsima*. *Atrées* is an ST/*10* – however, according to the score, it calls for 11 musicians. Perhaps Xenakis initially thought that the percussion could be played by two players, and not three.

2 *Amorsima-Morsima* is not included in the Xenakis catalogue of works and remains unpublished.

It is true that *Atrées* stands out from the ST works for many reasons: it is the longest in duration (ca. 15 min.); it displays a ritualistic feel that would become characteristic of Xenakis's music in the years to come; it acquires an indefinite form, since it is in five sections, but the order of the sections can be changed according to the conductor's wishes, with or without pauses between the sections, as it is explained in the Preface to the score.[3] Last but not least, it does not strictly apply the results of the calculations of the IBM computer, but a number of liberties were taken: as Xenakis explained in 1966, "wishing to marry together two modes of composition, I allowed myself a larger degree of intervention at the output."[4] Nevertheless, as of today *Atrées* remains the least known of the ST works: it was probably premiered in 1962 although there is scarce evidence about it; it is seldom (if ever) performed; and it has been recorded only once, in 1967, by the Ensemble Instrumental de Musique Contemporaine de Paris under Konstantin Simonovic,[5] who was closely working with Xenakis during the 1960s and had premiered *ST/10-1, 080262* as well.

Xenakis's Preface to the score of *Atrées* includes this remark: "Meaning of the title: the unbending laws of Necessity. It was composed and performed in memory of Blaise Pascal who was, together with Fermat, one of the inventors of the probability calculus." The dedication to Pascal is eloquent, given the composer's dealing with probability theory at the time – moreover since Xenakis had an early affinity with Pascal's philosophical *Pensées* during his youth in Greece: The *Pensées* was one of the few books Xenakis reportedly knew and carried with him at his arrival in Paris in 1947.[6] Thirty one years later, in 1978, he would include parts of it in the texts that comprised the "statement" of the *Diatope* in the program book.

In the explanation of the title that the composer provides, "the unbending laws of Necessity" (which, nota bene, appears only on the original, French version of the Preface and is omitted from the English translation, that's why it is easily overlooked), the word "necessity" points towards *ananke* (ἀνάγκη): Ananke, meaning *necessity*/*constraint*, is a primeval personification of *destiny* in Greek Antiquity.

Necessity is, first of all, one of the crucial concepts in Parmenidean philosophy. In his poem *On Nature*, Parmenides speaks of the sky "and how Necessity came to bind it to hold the ends of the stars ["καὶ ὥς μιν ἄγουσ' ἐπέδησεν Ἀνάγκη πείρατ' ἔχειν ἄστρων"]."[7] Xenakis had probably begun to deal with Parmenides during his composition of *Achorripsis*: he first referred to the philosopher in 1958, when he used Parmenides's verse "for it is the same to think as to be [τὸ γὰρ αὐτὸ νοεῖν ἐστίν τε καὶ εἶναι]"[8] together with his own paraphrase "for it is the same to be as not to be" as the frontispiece of his article "In Search of a Stochastic Music."[9] Xenakis's contemplation of Parmenides led to his work *Eonta* in 1964, which is dedicated to the philosopher since he "was one of the first to bring in inference as an approach to truth, to existence."[10] *Eonta* is partly an ST work as well, since certain parts of it, notably the piano solo in the beginning, were calculated on the IBM computer.[11] The title *Eonta* is derived from Parmenides's *being*, τὸ ἐόν in Greek, denoting *That*

3 Éditions Salabert, engraved score, © 1968. All citations translated by the author.

4 Mario Bois, *XENAKIS: Musicien d'avant-garde*, Bulletin d'information, no. 23, Boosey & Hawkes, Paris, 1966, p. 9.

5 Recording issued on CD by EMI CLASSICS, 2010.

6 See Iannis Xenakis, *Music and Architecture*, compilation, translation, and commentary by Sharon Kanach, Pendragon Press, New York, 2008, p. xvii. There is a 1784 edition of *Pensées* still to be found in the composer's library.

7 *On Nature*, fragment 10, vv. 6-7.

8 Ibid., fragment 3.

9 *Gravesaner Blätter*, nos. XI/XII, p. 98 – NB: Parmenides's verse and Xenakis's paraphrase are only printed on the German original and are not reproduced in the English translation on p. 112. Cf. Iannis Xenakis, *Formalized Music: Thought and Mathematics in Composition*, edited and translated by Sharon Kanach, Pendragon Press, Stuyvesant, N.Y., 1992. p. 24.

10 Bálint András Varga, *Conversations with Iannis Xenakis*, Faber and Faber, London, 1996, p. 102.

11 See Preface to the engraved score, Boosey & Hawkes, © 1967. Another work of Xenakis that is partly an ST work is

Which Is. When speaking about the unicity of *being*, Parmenides maintains that "Mighty Necessity keeps it at the Ends, in fetters, which shut it out, wherefore it is meet and right for That Which Is, not to be interminable ["Κρατερὴ γὰρ Ἀνάγκη πείρατος ἐν δεσμοῖσιν ἔχει, τό μιν ἀμφὶς ἐέργει, οὕνεκεν οὐκ ἀτελεύτητον τὸ ἐὸν θέμις εἶναι"]."[12]

Contrasting two views of reality, that of *the world of appearances*, which is deceitful, and that of *truth*, Parmenides furthermore asserts: "It is ruled, out of necessity, to see the one as inconceivable and unnamed (for it is not the true path) and the other as though it is and is real ["Κέκριται δ' οὖν, ὥσπερ ἀνάγκη, τὴν μὲν ἐᾶν ἀνόητον ἀνώνυμον (οὐ γὰρ ἀληθὴς ἔστιν ὁδός), τὴν δ' ὥστε πέλειν καὶ ἐτήτυμον εἶναι"]."[13]

Necessity also recurs in Aeschylus's *Prometheus Bound*, where the hero is in advance aware that all his trials are dictated by necessity. "One must bear one's destiny most lightly, knowing that necessity's might is unassailable ["τὴν πεπρωμένην δὲ χρὴ αἶσαν φέρειν ὡς ῥᾷστα, γιγνώσκονθ' ὅτι τὸ τῆς ἀνάγκης ἔστ' ἀδήριτον σθένος"],"[14] says Prometheus, his words displaying a remarkable similarity to the explanation of the title *Atrées* provided by Xenakis, "the unbending laws of Necessity," especially if one considers that Aeschylus was the composer's favorite tragedian.[15] Later on in the Aeschylean tragedy, a renowned dialogue occurs:

Prometheus: Craft is far weaker than necessity.

Chorus: And who's the helmsman of necessity?

Prometheus: The three-form Fates and the remembering Erinyes.

[ΠΡΟΜΗΘΕΥΣ: τέχνη δ' ἀνάγκης ἀσθενεστέρα μακρῷ.

ΧΟΡΟΣ: τίς οὖν ἀνάγκης ἐστὶν οἰακοστρόφος;

ΠΡΟΜΗΘΕΥΣ: Μοῖραι τρίμορφοι μνήμονές τ' Ἐρινύες.][16]

Not surprisingly, Necessity was also an aspect of Plato's cosmic view since the latter was strongly influenced by Parmenides. In Plato's dialogue *Timaeus*, Timaeus says:

A compound indeed, the constitution of this world was born out of a union of necessity and intellect; and with intellect being necessity's ruler in persuading her to lead most of what comes into being to what's best, everything was in the beginning thus put together through necessity's yielding to sensible persuasion.

[μεμειγμένη γὰρ οὖν ἡ τοῦδε τοῦ κόσμου γένεσις ἐξ ἀνάγκης τε καὶ νοῦ συστάσεως ἐγεννήθη· νοῦ δὲ ἀνάγκης ἄρχοντος τῷ πείθειν αὐτὴν τῶν γιγνομένων τὰ πλεῖστα ἐπὶ τὸ βέλτιστον ἄγειν, ταύτῃ κατὰ ταῦτά τε δι' ἀνάγκης ἡττωμένης ὑπὸ πειθοῦς ἔμφρονος οὕτω κατ' ἀρχάς συνίστατο τόδε τὸ πᾶν.][17]

At the time of the composition of *Atrées*, Xenakis's struggle to impose order through the calculation of probabilities rested exactly on a union of *necessity* and *intellect*. As the composer repeatedly stated, he had been an ardent reader of Plato in his youth in Athens during the Axis

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Stratégie: although being an application of Game Theory, certain parts of its material were also calculated on the IBM computer – that's why it carries the subtitle *ST/VENISE, 101062*.

12 *On Nature*, fragment 8, vv. 30-32.

13 Ibid., fragment 8, vv. 16-17.

14 *Prometheus Bound*, vv. 103-105.

15 Iannis Xenakis, *Musique et Originalité*, Séguier, Paris, 1996, p. 51-52.

16 *Prometheus Bound*, vv. 526-28.

17 *Timaeus*, 48a.

Occupation. The philosopher's ideas combined with Marxist ideology played a crucial role in his worldview. "I always went around with a Plato in my pocket; then I read Marx which is partially Platonism but with more realism,"[18] he stated in March 1966, and would return to Plato's ideas again and again: Necessity also appears at the end of *The Republic*, in the so-called *Myth of Er*, which inspired the title of *La Légende d'Eer*, the music that accompanied Xenakis's *Diatope* in 1978. During his journey in the afterlife, Er encounters *The Spindle of Necessity*, the representation of the cosmos that Necessity's three daughters, The Fates, must keep eternally revolving:

Clotho, touching with the right hand, helped at intervals with the spindle's outer revolution, Atropos, with the left, helped with the inner one, also in like manner, while Lachesis helped now with this and now with that revolution, touching with each of two hands.

[καὶ τὴν μὲν Κλωθὼ τῇ δεξιᾷ χειρὶ ἐφαπτομένην συνεπιστρέφειν τοῦ ἀτράκτου τὴν ἔξω περιφοράν, διαλείπουσα χρόνον, τὴν δὲ Ἄτροπον τῇ ἀριστερᾷ τὰς ἐντὸς αὖ ὡσαύτως· τὴν δὲ Λάχεσιν ἐν μέρει ἑκατέρας ἑκατέρᾳ τῇ χειρὶ ἐφάπτεσθαι.][19]

The relation between Necessity and the ST pieces is clear – especially if one considers the explanation of the title *Morsima-Amorsima* that the composer provided in 1966: "*moros* is fate, death, destiny. *Morsima* is what comes about by fate. *A* is privative: *Amorsima* is that which does not come about by fate. Today, the calculation of probabilities, the theory of large numbers, with the problems of choice, causality, and determinism, connect to and clarify the ancient idea of Fate."[20] But the question arises: what do "the unbending laws of necessity" have to do with the title *Atrées*?

At first sight, the word *Atrées* is the proper name *Atrée* in plural (spelled differently although sounding the same in French); *Atrée* is Atreus in English, therefore *Atrées* stands for *Atreuses*. Atreus, father of Agamemnon and Menelaus, killed and then cooked the sons of his brother Thyestes, in order to trick him into eating his own flesh and blood, thus adding to the curse of the House of the Atreidae, which was thus named after Atreus. Was the choice of the title indeed meant to be a reference to the curse of the house, therefore to the unavoidability of destiny, and its "unbending laws?" This is not an adequate explanation, because the curse of the house was put to force not because of Atreus, but because of his grandfather Tantalus, who had also slain his son Pelops and unsuccessfully tried to feed him to the gods.

Moreover, in 1962 Xenakis hadn't yet launched into setting to music the *Oresteia* trilogy that deals with the curse of the Atreidae, and the *Polytope de Mycènes* was still many years away, although, as he has said, he treasured deep in his heart his visit to Mycenae when he was a child.[21] Had he wanted to particularly refer to the Atreidae, he would not have done it in such a straightforward manner, let alone chosen a theme overloaded with associations (something he actually never did). [22] The title seems very uncharacteristic for Xenakis, since it is the only time in his creative life that he used a mythological proper name *in plural* for a title. So, why *Atrées*?

As the "spindle of necessity" revolves, the riddle is being solved: etymologically speaking, *Atreus* (Ἀτρεύς) comes from the privative *a*, and the verb *treo* (τρέω), which means "to be afraid of" but also "to cause fear;" therefore, *atreus* may stand for the *fearless* as well as the *defied* one, that

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18 Bois (1966), p. 22.

19 *The Republic*, Book X, 617c-d.

20 Bois (1966), p. 18.

21 Cf. his note on the program book of the *Polytope de Mycènes* (p. 10): "It happened that I had my first contact with Mycenae during a school excursion when I was 14 years old. In front of the beauty of the site, of the Cyclopean ruins and of the strange beehive tombs, I had experienced impressions of infinity and inevitability. What I was seeing looked familiar and [at the same time] extraordinary, as if it belonged to another world. I buried this memory, deep down."

22 In fact, Aleka Symeonidou, in her translation of Varga's book *Conversations with Iannis Xenakis* in Greek (Μπάλιντ Άντρας Βάργκα, *Συνομιλίες με τον Ιάννη Ξενάκη*, Εκδόσεις Ποταμός, Αθήνα, 2004), erroneously rendered the title *Atrées* as *Ατρείδες* (Atreidae), as though it had been *Atrides* in French.

does not cause fear.

In the *Greek Anthology* (Anthologia Graeca), the vast collection of poems spanning Classical and Byzantine Greek literature and mainly comprised of the *Palatine Anthology* and the *Anthology of Planudes*, there are two epigrams to be found, attributed to Marcellus of Side, a physician and poet of the 1st-2nd century AD. These epigrams were commissioned by Herodes Atticus to be inscribed on the latter's villa, called Triopio, built on property belonging to his wife, Regilla, who had died young. The villa was situated outside Rome, on the legendary Appian Way. One epigram was written in honor of Regilla, while the other, consisting of thirty-nine verses, calls for the gods' protection of the monument and includes threats to those who might want to damage it. Verses 15 to 19 of the second epigram are as follows:

[. . .] And with the immortal head
Athena nodded, shaking the terrible crest:
do not move a single clod or stone unavenged,
for The Fates' necessities are not to be defied
if one offers wicked sacrifices to the Gods' temples.

[. . .] ἡ δ' ἐπεί οἱ ἐξ ἀθανάτοιο καρήνου
σμερδαλέον σείσασα λόφον κατένευσεν Ἀθήνη,
μή τῳ νήποινον βῶλον μίαν ἢ ἕνα λᾶαν
ὀχλίσσαι, ἐπεὶ οὐ Μοιρέων ἀτρεῖες ἀνάγκαι,
ὅς κε θεῶν ἐδέεσιν ἀλιτροσύνην ἀναθείη.[23]

It is significant that this epigram is written in the Homeric dialect (albeit in a rather clumsy manner), literally citing Homeric words in phrases such as "with the immortal head" or "shaking the terrible crest," something which relates to the Homeric derivation of the word "morsimos" in Xenakis's relevant work *Morsima-Amorsima*. Later on, the epigram also speaks of "somber Hades [κυανέου Ἄϊδος],"[24] using the exact words that Xenakis, decades later, used in his titles *Aïs* and *Kyania*. But what is most striking in the cited excerpt is the phrase "The Fates' necessities are not to be defied [οὐ Μοιρέων ἀτρεῖες ἀνάγκαι]:" it displays a great resemblance with Xenakis's explanation of the title *Atrées* (the unbending laws of Necessity) since it contains both the word *atreus* as an adjective in a rare form of feminine plural, *atreies* [ἀτρεῖες], meaning *defied*, not causing fear, and the keyword that Xenakis himself provides in his explanation, *necessity*, in plural – *anankai* [ἀνάγκαι].

These inscriptions by Marcellus on Herodes's villa, carved on Pentelic marble, are today preserved in the Louvre. It is possible that Xenakis saw them there, as he may have been attracted to the name of Herodes Atticus who is known to all Greeks for the Roman Odeon he built underneath the Acropolis of Athens. Perhaps this phrase stuck in his mind for its singularity, its connection to the name of *Atreus*, its Homeric touch as well as its affinity with the interplay of necessity, chance, and probability he was dealing with at the time. Or had he read this epigram in the *Greek Anthology* in his adolescent years in Greece, when he "devoured the poets," as he mentioned in an interview in 1980?[25]

The title *Atrées*, as it stands, in addition to being the proper name *Atrée* in plural, could be seen as an attempt to transliterate the word *atreies* [ἀτρεῖες] in its uncontracted form (atreees [ἀτρεέες]) – a practice that was to become so typically Xenakian in later titles of his works, such as *Kraanerg*, *Dmaathen*, *Ikhoor*, *Oophaa*, *Waarg*, *Ioolkos*. Using a rare form of an Ancient Greek word was going to recur in later titles, such as *Theraps*, *Dikhthas*, *Akéa*. A title like *Atrées* initiates a long process of choosing titles that were meant to be both implicit and obscure – and particularly words that are

23 Christian Friedrich Wilhelm Jacobs, ed., *Anthologia Graeca*, vol. 2 (*Appendix Epigrammatum*, no. 50), Libraria Dyckiana, Leipzig, 1814, p. 772-74 (IG14.1389ii 18).
24 Ibid., v. 25.
25 Varga (1996), p. 15.

seemingly referring to a mythological figure or site all the while projecting an (unorthodox, sometimes) etymology that linked the title with the compositional matter of the work: Let us recall for example *Eridanos* (1973), that points towards an ancient river but at the same time underlines the combative character of the music through the word *eris* (ἔρις), meaning *strife*; *Evryali* (1973), that points towards the Gorgon but actually links her snaky locks to the application of *arborescences* in his work for the first time; *Keqrops* (1986), that names a legendary king but intends to refer to *woven texture* by etymologizing the proper name through the Sapphic verb *kreko* (κρέκω), meaning *to weave*.

Should the title *Atrées* in the end be understood as *Defied*, suggesting a challenge, in concordance with the fundamental duality of *Morsima-Amorsima*, a defiance of necessity, of determinism as such? A *tantalizing* question (to recall Tantalus once more).[26]

Acknowledgements

Gratitude to Sharon Kanach for her guidance in French bibliography and her help in translating relevant excerpts from French and to the philologist and translator Irkos Apostolidis for reviewing my translation of Marcellus's epigram.

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[26] James Harley, not seeing any connotations in the explanation of the title provided by Xenakis, read "the unbending laws of necessity" as possibly being ironic – see Harley, *Xenakis: His Life in Music*, Routledge, New York, 2004, 2011, p. 30.

Control or Chance? Considerations of Xenakien compositional strategies in contrast to Cageian approaches

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Abstract

In 2011-12 in Berlin, there was a large, interdisciplinary focus on John Cage (1912-1992) on the occasion of his centenary. As part of this presentation, there was an exhibition of Iannis Xenakis's "graphic works and sound installations." The aim was to examine "the controversy between the seeming anarchy of Cage's 'Chance Music' and Xenakis's strictly mathematical constructions." The supposed controversy between the compositional approaches of Cage and Xenakis deserves closer scrutiny. Cage, with some exceptions, primarily involving music intended for performance within multimedia contexts, was highly systematic, applying algorithms to generate musical structures and details. Xenakis's graphic-derived works were, with significant exceptions, some of his least systematic works, and his "installations" sometimes involved large numbers of performers creating global (chaotic) patterns. Cage had no background in mathematics, but developed sophisticated systems for his creative processes, using random numbers (tossing coins, later replaced by custom-built computer programs), the decisions process constrained by the limits of the work (e.g., the 88 notes of the piano, the limits of performer capabilities—speed, stretch). With his background in civil engineering, Xenakis was able to draw on more sophisticated tools for his algorithms and processes, but he for the most part was uninterested in using music to exemplify mathematical processes. He very often altered algorithmic outputs in order to assert his creative judgment. In the case of his most systematic works (the ST compositions, the GenDyn computer-synthesized works), he reordered computer-generated sections (e.g., *ST/10*) and changed details of the outputs. The processes are tools to support the artistic vision. With Cage, his entire aesthetic goal was to sublimate artistic "will", meaning he was entirely prepared to accept algorithmic outputs with no intervention. Where is the "control" and where is the "chance?" The use of algorithms is in itself a highly deterministic process, requiring a rigorous degree of control. The use of random, or stochastic, processes within the algorithmic design adds an important element of chance, whether or not the composer chooses to accept the output directly. In the context of system design (compositional approach), the opposition of control and chance recedes into differences that lose significance. Chance is built into the control!

1. Introduction

John Cage (1912-1992) was 10 years the elder of Iannis Xenakis (1922-2001), close to the same age when they died. They were not close, personally—Xenakis was good friends with Morton Feldman (1926-1987), a close colleague of Cage, by contrast—but there were points of connection (and disagreement) in their compositional approaches (Paparrigopoulos-2005).

Both composers developed elaborate systems for their compositional work. These systems are rigorous, but based on very different approaches and aesthetic foundations. This paper explores the common understanding, exemplified in the events in Berlin in 2011-12, that Cage's work is more "intuitive" and Xenakis's more "calculated."

"Control and Chance" was an exhibition in Berlin from 7 September—27 November 2011 that focused on Xenakis's "graphic works and sound installations." This exhibit was presented as part of a larger focus on John Cage: "A Year from Monday," at the Akademie der Kunst.[1]

In the exhibition program, there is a description of Xenakis's graphic work: "in his works on paper, Xenakis gave graphic form to his complex calculations at the intersection of art, architecture and mathematics. They are visual preliminary stages of an art that finds its expression mostly in the listening experience." I would instead propose that mathematical thought and methods were foundational to his thinking, made manifest in numbers, notes, and graphic designs. Similarly, with Cage, he applied algorithmic methods to much of his work, whether it was music, text, multimedia, or graphics.

2. John Cage Methodology

Cage acknowledged a large inspiration from Arnold Schoenberg, with whom he studied in Los Angeles, 1935-37. He did not adopt the 12-tone method that Schoenberg had developed, but he seems to have absorbed the elder's concern for rigour. He methodology focused more on rhythm and temporal structure. He developed a "micro-macrocosmic rhythmic structure," based on phrase and section lengths (Pritchett-1993, 16). Cage's early attention was drawn to creating music for percussion, piano, and prepared piano. Part of this focus was circumstantial: these instruments were available, and in 1938 he was hired at the Cornish School in Seattle as a "composer, instructor of percussion, and accompanist to the dance department" (ibid, 9). His earlier studies with Henry Cowell, and acquaintance with Lou Harrison, opened his imagination to new sonic and rhythmic resources as well as music of Asian cultures. Creating music for dance led to a deep exploration of the extended possibilities of the prepared piano, combining piano and percussion and evoking non-western instrumental possibilities such as Indonesian gamelan. Of his early works, the most important would be the Construction pieces for percussion ensemble (1939-41), the Imaginary Landscape cycle (1939-52) for percussion, electronic sounds, and recorded sounds, and *Sonatas and Interludes* (1946-48) for prepared piano.

Cage's separation of structure (temporal organization) from content (melodies, harmonies, etc.) eventually led him create a musical structure with no content—*4'33"* (1952). He first applied a selection process to generating content using the *I Ching* (*Book of Changes*) in his *Concerto for Prepared Piano and Chamber Orchestra* (1951). He made use of rigorous selection processes to determine content in various ways throughout the rest of his life. His approach to structure was more wide-ranging, including many scores of graphic or indeterminate notation. His last major set of works, the "number" pieces (e.g. *One*, *Four*[4]) uses "time brackets" (durations within which events begin and end, indeterminately). Again, structure and content are treated separately, in this case the content being set in advance (using selection processes) and the structure having some flexibility built in (Cage-1961, 18-56).

3. Iannis Xenakis Methodology

After his important and iconoclastic early orchestral scores, *Metastaseis* (1954) and *Pithoprakta* (1956), Xenakis turned his attention to articulating a methodology, his "Fundamental Phases of a Musical Work" (Xenakis-1971, 22). In his case, the method shows an engineering influence, and was

[1] https://www.adk.de/de/projekte/2011/cage/programm2011.htm

later adapted to form the basis for a music-generative computer algorithm (ibid, 134-42). He investigated a number of other compositional methods, each derived from mathematical principles. These were incorporated into works, in some cases briefly and in other cases more foundationally. These include: stochastic techniques; Markov chains; probability screens, granular conception; Boolean logic; game theory; theory of groups; sieves; random walks/Brownian motion. By the time *Formalized Music* was published in 1971 (a number of techniques/theories were added to the 1963 publication of *Musiques formelles*), Xenakis had incorporated his various methodologies into his musical practise. His approach developed into a network of concerns that were fluidly applied to individual compositions, sometimes exemplifying individual techniques (e.g., *Mikka* for solo violin, 1971, Brownian motion mapped onto continuous string glissandi), more often drawing in a number of conceptual strands (Harley-1996).

3.1. Xenakien graphic design

Xenakis's earliest graphic manifestation of music is likely related to *Metastaseis*, where he created drawings representing string glissandi, sonic parallels to the hyperbolic parabaloids he used in his design of the Philips Pavilion (ibid, 2-11). It is important to keep in mind that these visual-architectural-musical designs derive from mathematical functions. The complex graphics representing parts of *Pithoprakta* again are transferences of mathematical stochastic processes (ibid, 16-21). Even the designs that appear to be drawn in order to create music directly, in works such as *Erikhthon* for piano and orchestra (1974) were partially guided by mathematical processes.[2] One detail in Fig. 1 is the rotational treatment of various of the graphic figures.

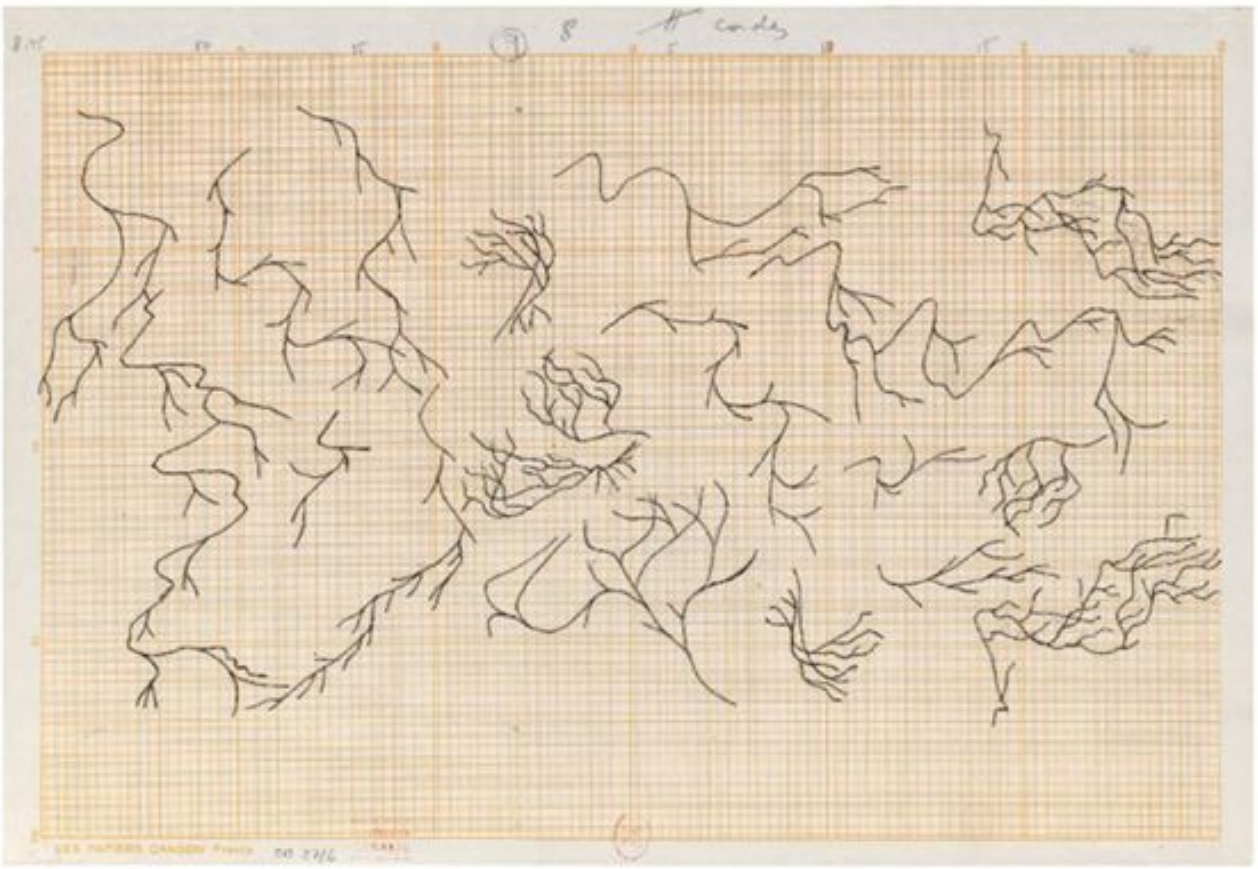

Figure 1: Graphic element from Erikhthon for piano and orchestra (1974)

[22] In his lectures at the Université de Paris (1985-87), Xenakis made reference in this regard to complex variables and topological spaces/transformations.

The most direct connection between drawing and sound is found in the UPIC computer-generated works. With this digital system, developed by Xenakis at CEMAMu, design is translated into frequency and time (Fig. 2). In this case, the graphics were created to be turned directly into sound, but the visual design was clearly intended to make a stand-alone impression.

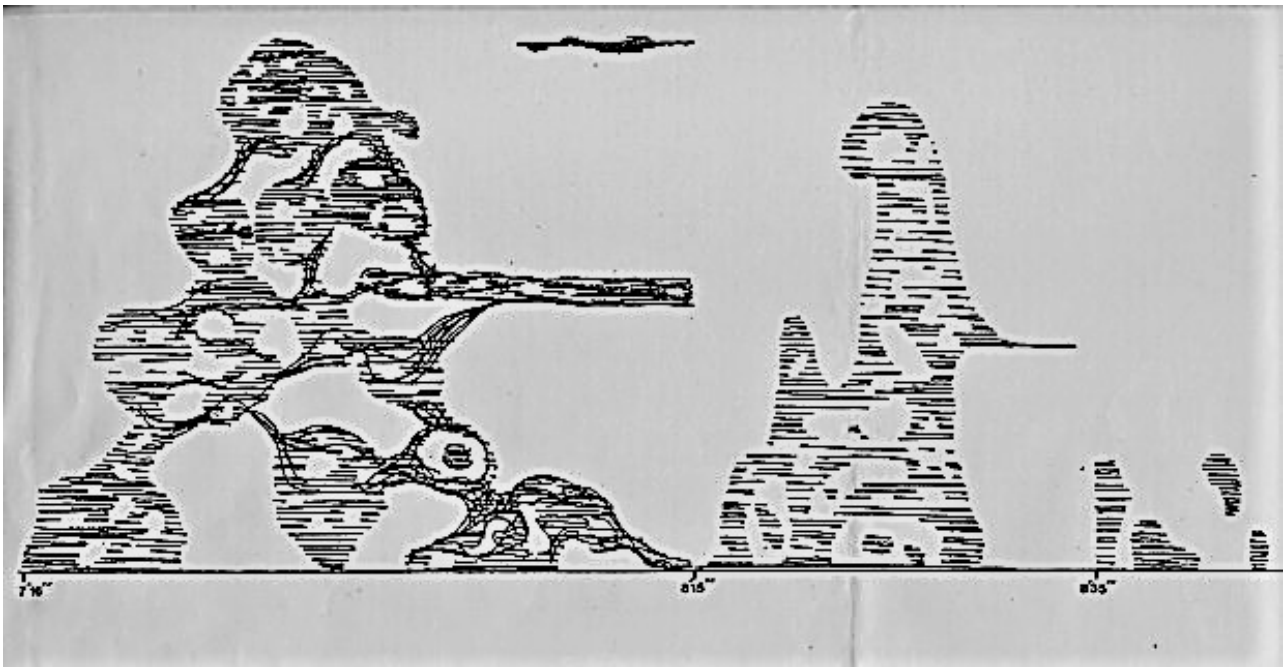

Figure 2: Page from graphic "score" for Mycenae Alpha for computer-generated sounds (1978)

4. Algorithms and elements of chance

In the case of John Cage, the use of chance elements in his compositional process was philosophical. It came out of his engagement with teachings primarily from Asian philosopher-leaders: Sri Ramakrishna, Ananda K. Coomaraswamy, D. T. Suzuki (Pritchett-1993). The separation of structure from content enabled elements of chance to first enter the realm of content, then structure (e.g., the later use of time brackets). He first began to incorporate "randomness" in his use of dice or coins to select elements from the *I Ching*. His collaboration with computer music pioneer Lejaren Hiller on *HPSCHD* (1969) introduced programming to Cage, by means of chance operations governing not only digitally produced sounds on 51 tapes but selections of materials for 7 harpsichords partially based on W. A. Mozart's *Musicalisches Würfelspiel* dice-based music generating game. In 1981, Cage began collaborating with Andrew Culver, who developed a number of computer programs that the composer used for the last 11 years of his life (Culver et al.-2001, 193). The computer enabled Cage to more efficiently implement the compositional methodology he was already working with, generally described as "constrained random" processes (ibid, 192).

In engineering, probability functions are used to model processes that cannot be known with full certainty. Statistical analysis enables, for example, a building's construction to support the weight of the materials taking into consideration factors such as height, weight, wind, ground tremors, etc., within safety guidelines, i.e., risk analysis. All factors cannot be known with full certainty, but constraints can be nonetheless calculated within determined limits. Xenakis turned this analytical/modeling process to creative ends, setting the limits (e.g., duration, density, ambitus) and then generating the details using stochastic (constrained random) processes. As his methodology evolved, he continued to apply stochastic selection processes to additional limits. These included pitch sieves, time-point patterns (rhythm sieves), orchestration/timbral changes, etc. Xenakis did not draw on stochastics exclusively, but it remained a foundation of his methodology throughout his creative life. The

element of chance was for him tied to the engineering tools he adapted from analytical to generative purposes.

5. Conclusion

For both John Cage and Iannis Xenakis, core elements of their compositional methodology relied on chance, more specifically on constrained random processes. These processes were constrained in the sense that complex decision-making guidelines were defined, then filled in by chance operations. While both composers explored a range of other interests and techniques (Xenakis, in his most rigorous application of group theory, such as *Nomos Alpha*, eschewed chance completely), the combination of determinate structure and random content was key to their work. Cage came to this through his philosophical-spiritual evolution while Xenakis adapted engineering principles to music at the same time as he rejected the hyper-determination of integral serialism based on his understanding of the limits of perception (Xenakis-1955). These two composers embraced chance, but within controlled methodologies. The ways they spoke about this core element of their work was very different, based on their backgrounds and their educational inputs, but there is much that is common to their compositional approaches.

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Entropy and Sound Mass in Xenakis' *Jonchaies*

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Abstract

Iannis Xenakis composed *Jonchaies,* a work for large orchestra of 109 musicians, in 1977. Despite being densely orchestrated for the majority of the piece, *Jonchaies* is a work of extreme dramatic contrasts ranging from sharp violence to delicate lyricism. Using stochastic processes, Xenakis generates sound masses and manipulates them with a wide variety of techniques to drive the piece's unpredictable and relentless unfolding. Speaking about *Jonchaies,* Xenakis acknowledges that the listener's experience is largely dependent upon their understanding of the piece's patterns and tendencies. The dramatic arc of the piece shapes the listener's expectations and at times creates tension by inhibiting the arrival of expected goals. In this paper, I present an analysis of the first two sections of the piece and their dramatic arc to understand the ways that Xenakis manipulates listener expectations. The analysis is meant to complement the work of other authors who have either discussed subsections of the piece or analyzed the piece in relation to other works that have influenced it. My analysis examines Xenakis's techniques in each of the piece's sections and uses perceptual theories of expectation to understand the piece's form.

1. Introduction

Iannis Xenakis was fascinated by the behaviors and transformations of the small particles that make up mass events. In *Formalized Music,* he describes "natural events such as the collision of hail or rain with hard surfaces, or the song of cicadas in a summer field." He continues, "These sonic events are made out of thousands of isolated sounds; this multitude of sounds, seen as a totality, is a new sonic event." He also writes in the same manner about the behavior and transformation of a mass group of people participating in political demonstrations (Xenakis 1971, 9).

Jonchaies, for large orchestra of 109 musicians, consists almost exclusively of particulate sounds that give rise to sound masses, as many voices together give rise to the thunderous din of a protest. The listener's attention focuses on the overall effect of the whole as opposed to the individual instruments, each of which plays a part in creating it.

Though he speaks in such an evocative way about his real-world inspirations, Xenakis insists that after many years of reflection, these events, including the war-time demonstrations, no longer carry emotional meaning for him. Rather, they left him with technical questions regarding the behavior of such mass events: "How were they structured and how did they evolve in time? …These were macroscopic phenomena made from a profusion of small isolated phenomena" (Xenakis 2006, 25). Xenakis claims that the laws that govern the patterns of events like those described above are stochastic laws (Xenakis 1971, 9). Through analysis of the first two sections of the piece, I seek to understand the techniques that Xenakis uses to transform the sound masses and to reproduce the dramatic power of his life's inspirations.

In 1977, while working on *Jonchaies,* Xenakis was designing his newest polytope, *Le Diatope,* a multimedia architectural structure, for the inauguration of the Georges Pompidou Centre in

Paris. To be diffused through the eleven loudspeakers dispersed throughout the interior of *Le Diatope,* Xenakis composed *La légende d'Eer,* a seven-channel acousmatic work lasting approximately forty-six minutes (Solomos 2006, 162). In the first pages of the score to *Jonchaies,* Xenakis states that the piece is both technically and musically inspired by *La légende d'Eer* (Xenakis 1977). In *À propos de Jonchaies,* Xenakis writes that "*Jonchaies* is the result of an analogy, a transfer. It is the translation of work conducted in the domain of sound synthesis, work that I have done for fifteen years…since *La légende d'Eer"* (Xenakis 1988, 133). The two pieces differ tremendously in form: unlike Xenakis's typical forms, *La légende* develops very gradually and without interruption, while *Jonchaies* features sudden ruptures and wildly dynamic contrasts. Nonetheless, it is clear upon listening to both pieces that a number of the textures are undeniably related. I will refer to several other articles that discuss the formal similarities between the two pieces (Pires 2008) as well as timbral and textural similarities (Solomos 2012).

Whereas the form of *La légende* develops gradually, Xenakis utilizes both gradual processes and abrupt changes in *Jonchaies.* The combination of these two techniques corresponds well to Xenakis's description of war-time demonstrations and of the stochastic laws that govern such mass events: "They are the laws of passage from complete order to total disorder in a continuous or explosive manner" (Xenakis 1971, 9). Xenakis states that the listener's sense of disorder and irregularity in *Jonchaies* relies on "the inability of the human brain to follow wide complexity" (Xenakis 1996, 148). Specifically, layering variants of the same motive on top of each other will eventually result in a level of density that exceeds the listener's capacity to discern individual strands. David Huron's *principle of limited density* confirms Xenakis's claim that listeners can only handle so much musical information at a time (Huron 2001, 45). After a certain threshold of density, the listener perceives a large texture – often referred to as *sound mass* – and potentially some movements within it, as opposed to actual polyphony (Noble 2020). Among other factors, the perception of order and disorder in *Jonchaies* is largely shaped by shifts – both gradual and sudden – from minimal to maximal density. Referring again to the disorder he creates in *Jonchaies,* Xenakis claims, "For the listener, it is perhaps like being in a river, drowning, and holding on to one log or another, depending on whether you can catch them or not. So, there is a flow of expectancy and denial" (Xenakis 1996, 148). *Jonchaies* is an immensely dramatic work, and as Xenakis says, its effectiveness stems from the establishment and subsequent inhibition of listener expectations.

In his seminal book, *Emotion and Meaning in Music,* Leonard Meyer proposes that listener expectations can result from perceived meaning, patterns and tendencies in the music. Meyer introduces a definition of musical meaning: "If, on the basis of past experience, a present stimulus leads us to expect a more or less definite consequent musical event, then that stimulus has meaning" (Meyer 1958, 35). According to Meyer, tension can arise in music when listener expectations are thwarted. This leads to two important questions that I seek to answer in this analysis:

1) How does each texture in *Jonchaies* acquire meaning in the listener's mind?
2) How does Xenakis create tension and manipulate listener expectations in *Jonchaies*?

To begin answering these questions, the first two sections of *Jonchaies* will be analyzed to identify patterns or processes. I will distinguish between the different types of sound mass and identify the musical characteristics that create expectations in the listener. Once the construction of musical expectations is understood, I will isolate critical points in the piece where Xenakis contradicts the expected goal, creating tension. Finally, I will examine the ways in which Xenakis contrasts gradual processes with abrupt changes, giving the piece a feeling of jagged unpredictability. In my analysis, I will refer both to the score, as well as the recording of *Jonchaies* by Arturo Tamayo and the Luxembourg Philharmonic (Tamayo 2001).

2. Analysis

Each of the sections of *Jonchaies* is radically different from the others. Some sections, such as the second, strongly reflect the influence of *La légende d'Eer,* while others show less resemblance. Figure 1 presents a summary of the sections and subsections of *Jonchaies*. Presented below the overall form, the piece's waveform illustrates the turbulent nature of its transitions.

Figure 1 shows the piece's tendency toward dramatic swells of energy. Whereas *La légende d'Eer* is essentially one large swell, *Jonchaies* is composed of many varying waves. One type of swell is based on changing loudness, such as the traditional hairpin gesture of crescendo and decrescendo. However, as Xenakis often writes, he is interested in bringing the listener's attention to diverse musical parameters. *Jonchaies* thus also includes swells of density, velocity and register, among other parameters. These waves of energy play an important role in guiding listener expectations toward a particular goal.

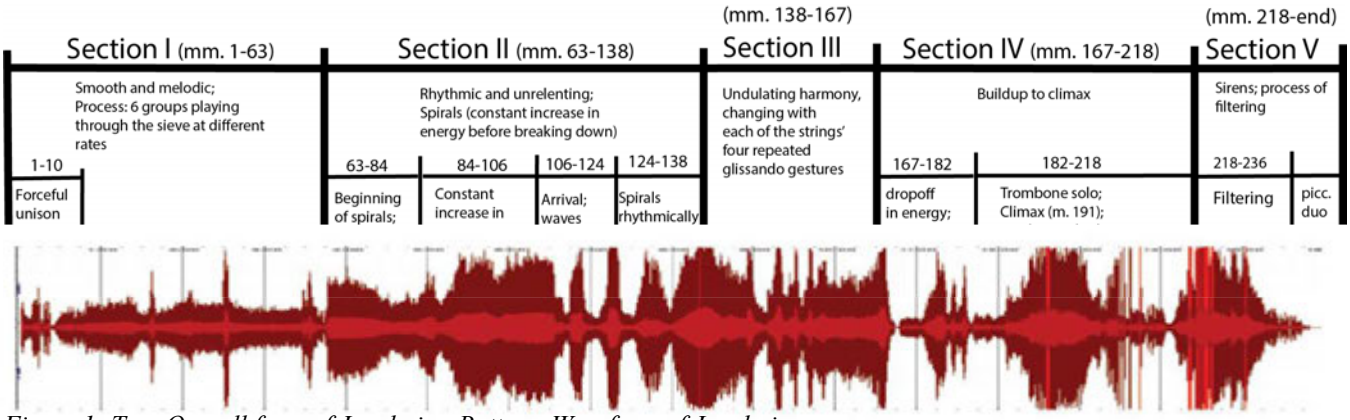


Figure 1: Top: Overall form of Jonchaies. Bottom: Waveform of Jonchaies

21 Jonchaies Section I

Jonchaies is composed of highly contrasting musical characters. Some of these characters are foreshadowed in the opening ten measures.

Xenakis captures our attention at the very beginning with the forceful string glissando in mm. 1-3. This gesture typifies Xenakis's music, which is abundant both in glissandi (Iliesu 1996, 137) and in forceful ecstatic gestures. This outburst of physical energy sets the stage for a wildly dramatic work, putting the listener immediately on edge. As shown in Figure 2a, the strings overshoot their goal by more than an octave before settling on a high B in m. 3 and emphatically re-articulating it at a regular pulsating rhythm (mm. 4-5). The first ten measures foreshadow several other themes of the piece: 1) insistent pulsation, 2) high repeated notes (also prevalent in *La légende d'Eer*), 3) swells and 4) glissando melodies. Figures 2a and 2c summarize this foreshadowing:

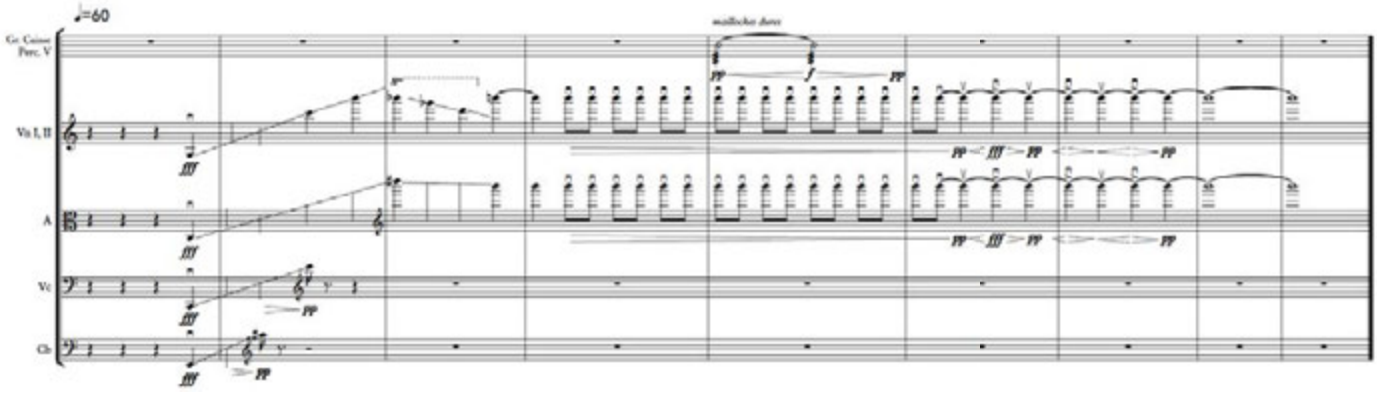
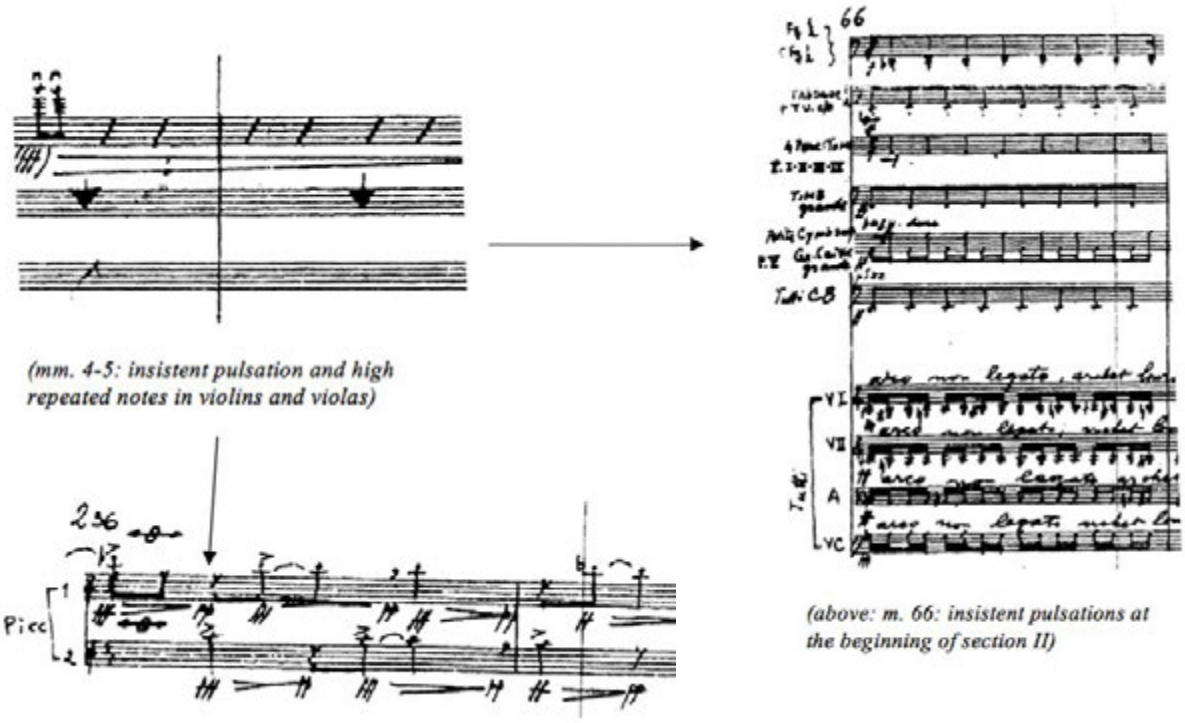


Figure 2a: mm. 1-10

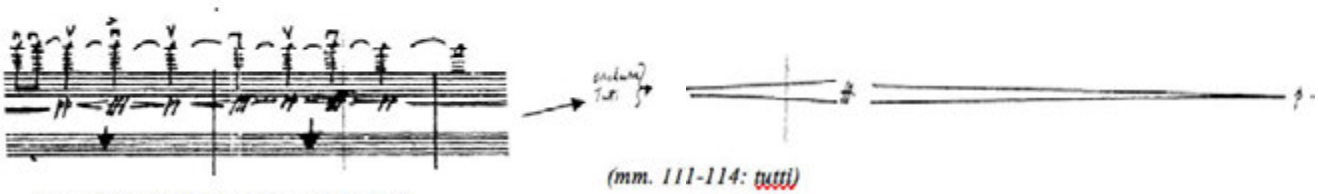


(mm. 4-5: insistent pulsation and high repeated notes in violins and viola)

(above: m. 66: insistent pulsations at the beginning of section II)

(above: m. 236: high, repeated notes in piccolos at the end of the piece)

Figure 2b: mm. 4-5 foreshadowing forceful pulsations of section II beginning at m. 66 and high repeated notes in piccolos at m. 236



(mm. 5-7: swells in violins and violas)

(mm. 111-114: tutti)

Figure 2c: mm. 5-7 foreshadowing orchestral swells in mm. 109-124

The section from mm. 11-6[illegible]s been extensively analyzed in other papers (such as Harley [illegible]and [illegible]Paires [illegible]). It features a common process in *Jonchaies*: beginning with one unified gesture and gradually expanding that gesture to many layers until it becomes a sound mass. The opening seven measures are even more meaningful for this reason; before Xenakis expands the music to extreme density, he begins with the complete opposite: a strong unified glissando in the strings. This is an important point to which I will return.

Following the opening gesture of the first ten measures, in mm. 10-21 we are presented with the melodic cell that gets extensively expanded and multiplied until m. 62. James Harley calls this section "without a doubt, one of the most melodically expressive passages in all of Xenakis's output" (Harley 2004, 108). The pitch collection, or *sieve*, that Xenakis chose for this passage is quite memorable and evocative of a modal quality. Seeking a departure from traditional western scales, Xenakis constructed this sieve, shown in Figure 3, with the goal of "creating a new type of scale in relation to the inner symmetries produced by the intervals…" (Xenakis 1996, 149) and of imitating gamelan music (Harley 2004, 108). As noted by Harley, the intervallic structure lends the sieve its "modal, Indonesian character." He points out that the "interlocking fourths of the pentatonic scale (e.g., F#-B, G-C), with the two semitones acting in some sense like leading tones"… were an inspiration for Xenakis (Harley 2004, 108). The sieve is made of periods of 7 semitones and is non-octaviating:

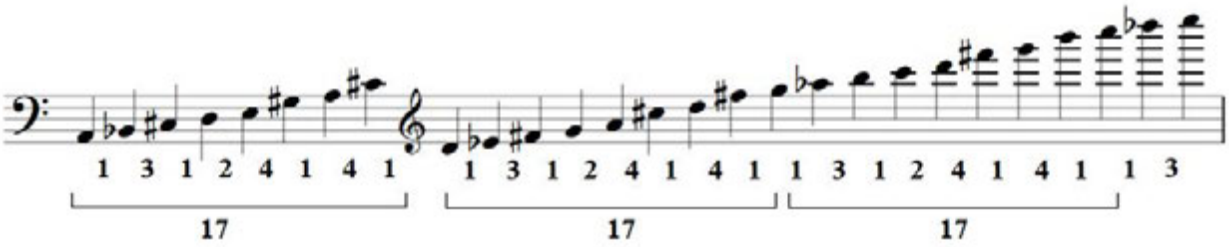


Figure 3: The sieve used in section I of Jonchaies (intervals are indicated in semitones)

Iliesu (1996) and Harbreich (1988) further discusses the role of sieves in Xenakis's music and their tendency towards harmonic modalities. Iliesu points to Xenakis's rejection of modalism and his discontent at the modal result that plays out in the first section of *Jonchaies* (Iliesu 1996, 38). Regardless of how Xenakis felt after the fact, his intuition to use a scale with distinctive characters proved effective in giving the entire passage a particular character and creating a reference for the listener. As the number of layers increases, the recognizable quality of the pitch collection renders the music perceptually cohesive.

From m. 10, the string section is divided into six groups of mixed instruments. Until m. 12, the melodic pattern is played in unison by violins and violas in the extreme high register. Half of the instruments play the melody sliding from note to note with glissandos and the other half articulate each note separately, creating a heterophony that is to expand over the course of this section. Beginning to break at m. 12, group II breaks off into their own pattern using the same pitch collection. In m. 13, group III breaks off as well and we hear the first instances of certain instruments playing the pattern with pizzicati. Groups IV, V and VI break off as well in mm. 15, 16 and 17 respectively. By measure 17, we hear an immense density of string groups playing material that is quasi-imitative of the other five groups. By m. 14, each of the six groups is further divided into three subgroups, each playing the melody using different techniques: 1) glissando, 2) discretely articulated pitches and 3) pizzicato. The pizzicato groups are occasionally supported by brief appearances of mallet percussion instruments. For example, in m. 23, the temple blocks appear briefly, imitating the plucking sound of the strings. Each of the six groups actually performs the same pattern of pitches from the sieve presented in Figure 3, but at differing rates. The specific pattern of pitches (Fig. 4) as well as the rhythmic material for each group is determined by Xenakis using probabilistic processes, namely Brownian motion. The result is an imitative sound mass that nonetheless remains perceptually coherent because of the recognizable characteristics of the sieve.

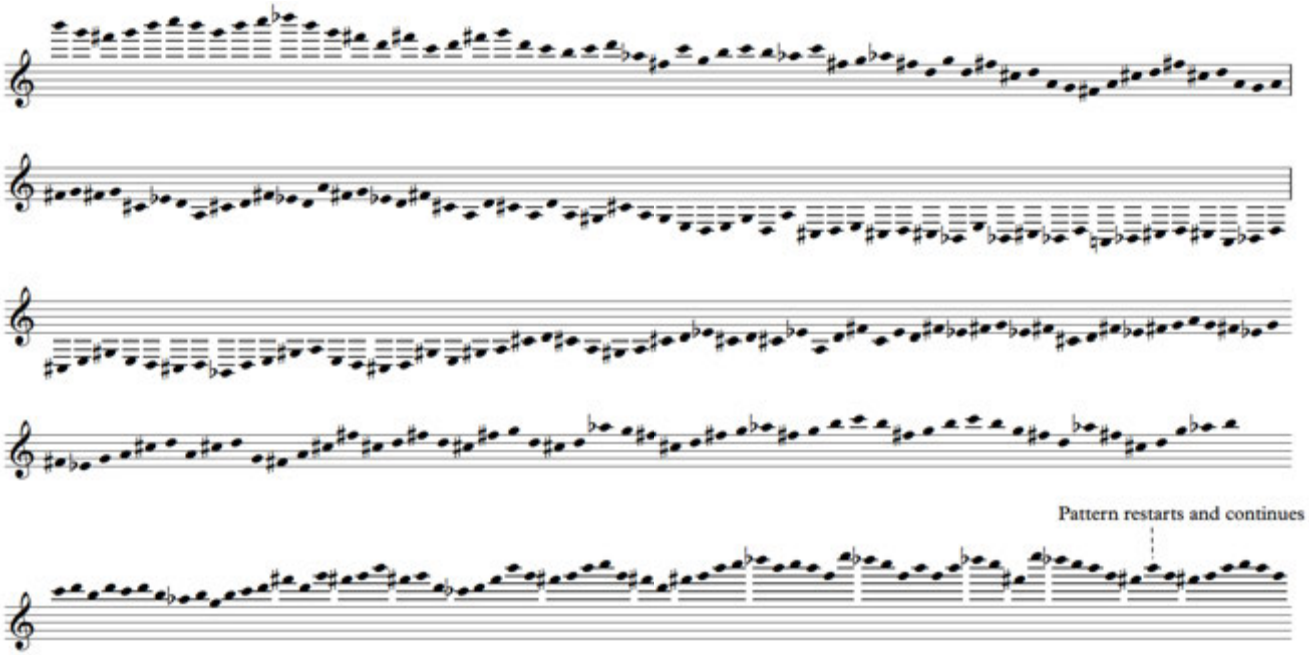


Figure 4: Melodic pattern performed by the six groups of the string section in mm. 10-62.

22.C ontour andR eg ister al Separation

The fact that each group makes its way thrg the melodic pattern at its own rate means that the g oups inevitably separate registrallyO ne o more g oups will b gin playig n the h gher register again in the latter half of the pattern while other groups will still be playing in the lower register, such as startig at m. 30T herefore, the passage progresses from being a homogenous cloud of legato string sound in one register to the g oups separatig p erceptually b se dr egister. As the passage continues, the listener is able then to aurally parse three or so separate lines thanks to the registral separation. Figure 5 d monstrates the process of registral divergence of the six groups v r the course of the melodic p ttern.

Throughout the p ssage, the listener's attentio is g ded back adf orth between hearig he entire string section as one texture, and h arig several streams perceptually distinguished r egister. For example, as the strig section collectively descends to the lower register aroud m . 22, the groups' lines seemingly fuse into one mass. In m. 32, group II, which p ays the p tch pattern at a faster rate than the o hers, ascends and is separated from the others groups r egister. At this moment, two auditory streams are perceivable: one beig group II, ad he o her b ig the remainig groups still fused as a mass. However, m . 36, as the other groups also ascend in pitch, it becomes difficult once again to distinguish separate g oups. By mm. 40-41, groups II adV I are in completely different registers and while the g oups are still v ry much entangled, it is easier to distinguish particular g oups for seconds at a time. At the eb the section at m. 61, with some effort, the listener is able to parse several streams thanks to the divergent registers. However, f irst o second listen and without tryig o pinpoint o e p rticular grp he aural result is still a dense sound mass of many lines. Clearly, the recording and performance themselves influence the ability to distinguish some g oups from others. In different recordings, particular groups stick out at different moments. Regardless, register is an important parameter in auditory stream segregation (Bregma 9 ad he thresholds b tween sd m ass ad he perceptio of individual groups p ay a significant role in the development of this passage.

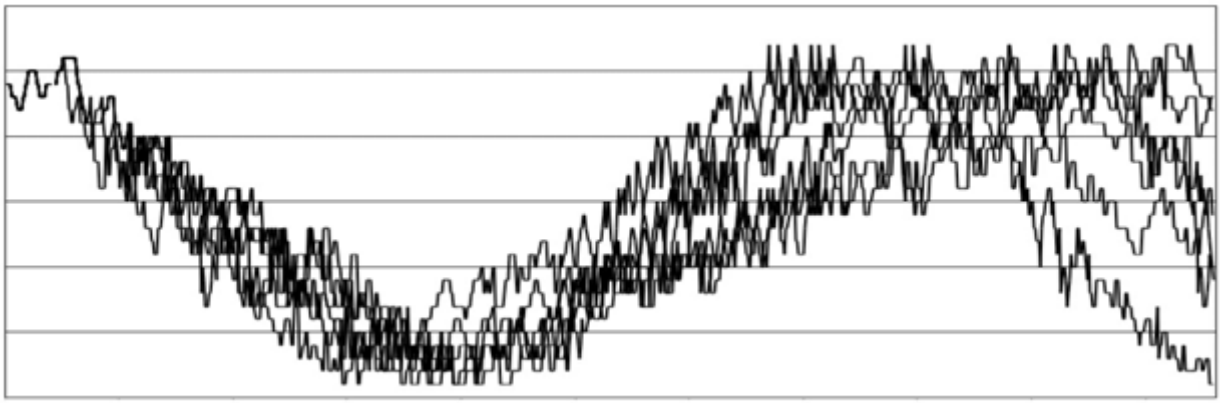


Figure 5: Contour and gradual registral separation of the six groups in section I (with permission, Harley 2004)

3. *Jonchaies Section II*

Following the p w erful crescendo at m. 65, the music takes a thunderous turn reminiscent f the i ng second sectif *Le Sacre du printemps*. The insistent sixteenth notes foreshadowed in mm. 8 -65 return, this time without interruption. The strings are joined b ow b ass, timpani and bass d um on the first and third sixteenths f each beat, while h ssoons, tom-toms and small suspended cymbal play the second adf ourth sixteenths f each beat, which sd ike f fbeats. A process similar to that of the first sectit akes p ace v r a slightly longer p rid f time. The music b gins in a clear ad forceful manner p ayed b a i ied group and slowly disperses into maj ayers that b come an enormous sd m ass, this time played by the entire o chestra. The

music embarks on “a game of rhythmic displacement that sometimes accelerates and sometimes decelerates” (Xenakis 1992, 38). Over the course of this section, the listener has the impression of infinitely ascending in pitch while also accelerating and becoming progressively more chaotic. The orchestra is divided into five groups, each ascending at different rates and each seemingly have their own tempo. To use Xenakis’s term, the result is a rhythmic “entanglement” (*enchevêtrement*) difficult to perform because of its highly polyrhythmic nature.

3.1. *MM. 66-81, Introduction to Section II; Regularity vs. Irregularity*

Referring to section I, before the passage truly begins in m. 11, Xenakis provides a musical introduction in mm. 1-10 (see Fig. 2). He provides a similar type of introduction at the beginning of section II in mm. 66-81. Similar to the very beginning of the piece, the bombastic first few measures starting at m. 66 provide clarity in preparation for the sudden mass that is to gradually ensue; the first three measures are shown in Fig. 6a. After beginning with a regular pulse, Xenakis slowly introduces polyrhythmic fragments that hinder the rhythmic flow, throwing the listener off balance. The first instance occurs in m. 69 as the offbeat groups become a bit delayed, but this hint of jaggedness lasts for only one measure; in m. 70, stability and regularity returns. Another instance of irregularity comes in the following measure (71); the strings drop out leaving the low bass, timpani, bass drum and double bass playing seven eighth notes in the time of eight (7:8) while the others still perform eighth notes. In the very next measure, the ensemble returns to playing 8:8 (either on the beat or as offbeats, as before) while some of the winds stealthily begin playing the first instance of a chromatically ascending line at the same rhythm as the other instruments. Because of the low registers and *p* dynamic, the winds are almost inaudible at first. As the winds continue to ascend, growing to *ff,* the same pattern occurs again in mm. 74-75: one measure of instability followed by the return of stability. When the stability returns in m. 75, the first violins play high C’s on the offbeats. The sharpness of the violins’ high register in contrast with the lumbering sounds of the drums and low brass creates an increased sense of forward motion.

The disappearance of the strings in m. 71 has a significant impact on the overall texture. When the strings are present, they play every sixteenth note resulting in a feeling of propulsion. When the strings drop out, the momentum and intensity noticeably declines. The strings return in m. 76 for one measure, thrusting the music forward before disappearing again one measure later.

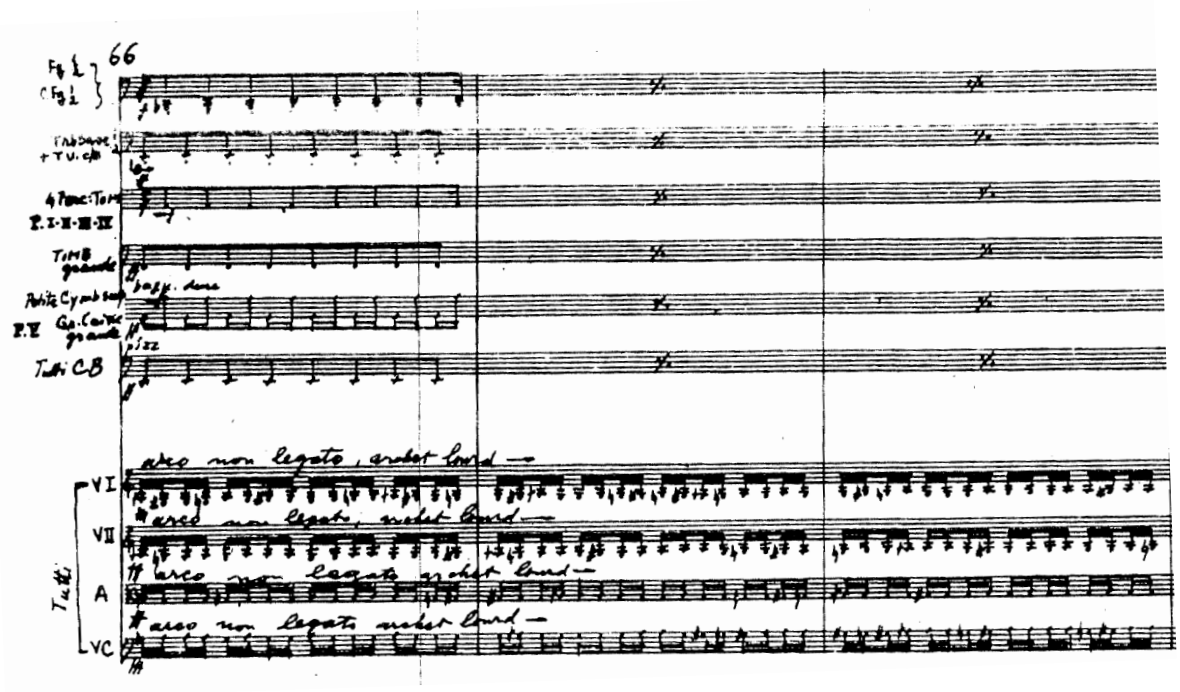


Figure 6a: First measures of section II

Once the strings disappear again, the chromatically ascending line in the winds, previously concealed by the strings in m. 71, sounds suddenly more present than before. The strings make their final appearance playing the driving sixteenth notes in mm. 80-81 before disappearing again in m. 82, leaving the music to slowly unravel. The rhythmic reduction in Figure 6b demonstrates the alternation between stability and irregularity.

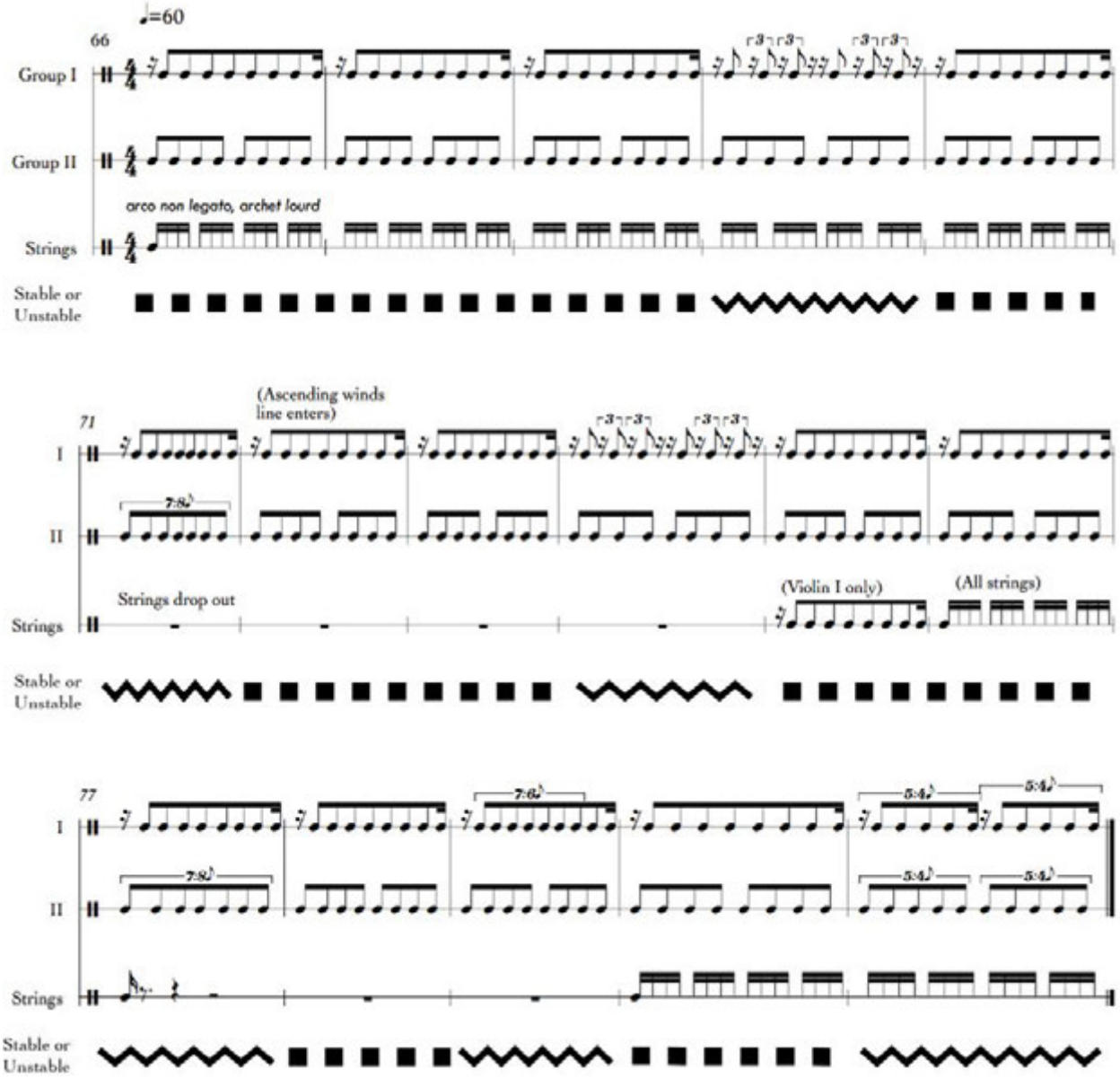


Figure 6b: Reduction of mm. 66-81: Solid dashed lines represent measures that feel rhythmically stable; zigzag lines represent measures that feel rhythmically unstable.

3.2. *Spirals in Section II*

An illusion of infinite ascent commences following the final appearance of the sixteenth notes in the strings in m. 81. Similar to section I, imitative lines are superimposed onto one another to create sound mass. The primary motivic cell in this section is the chromatic ascent performed at differing rates as shown in Fig. 7. As one line continues to ascend, another ascending line enters in a different register and obscures the termination of the first line, and so on, creating the illusion of an infinite ascent. Discussing the undeniable resemblance between this section of *Jonchaies* and its complimentary section in *La légende d'Eer,* Solomos describes this section as "swirling" and says that the infinite ascent arouses a feeling of "spirals" (Solomos 2006, 174). Over time, the orchestra

is divided in five groups, each progressing through their own chromatically ascending line at its own rate.

As the section progresses towards maximal chaos, not only do the rhythms of each group accelerate, but the rate of rhythmic change of each group accelerates. Once the climactic point is reached around mm. 102-4, the five orchestral groups gradually converge and once again perform sixteenth notes in unison beginning in m. 107. The convergence of the groups produces a feeling of a room full of desynchronized clocks suddenly sounding in unison after ticking at different rates. This phenomenon recalls Ligeti's *Poème Symphonique* for 100 metronomes and the process of their convergence. Fittingly, about this process in *Jonchaies,* Solomos writes, "for its mechanical side, this Xenakian way of composing, partly instrumental, partly electronic, evokes an activity of machines" (Solomos 2006, 174). Just before the rhythmic convergence at m. 104, the overall median pitch of the ensemble actually begins to descend. The chart in Figure 8 reveals the rhythmic progression of each of the five groups from m. 81 until the re-unification. On the left are the rhythmic ratios ordered from fast (top) to slow (bottom). The rate of change accelerates beginning around m. 102 at the same time that the pitch begins to descend.

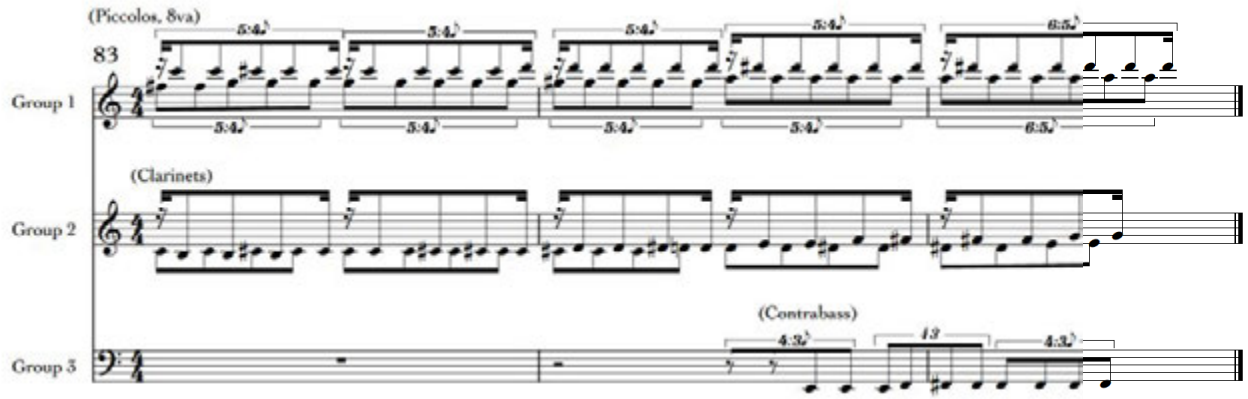


Figure 7: Reduction of mm. 83-85: Ascending chromatic lines played at various rates.

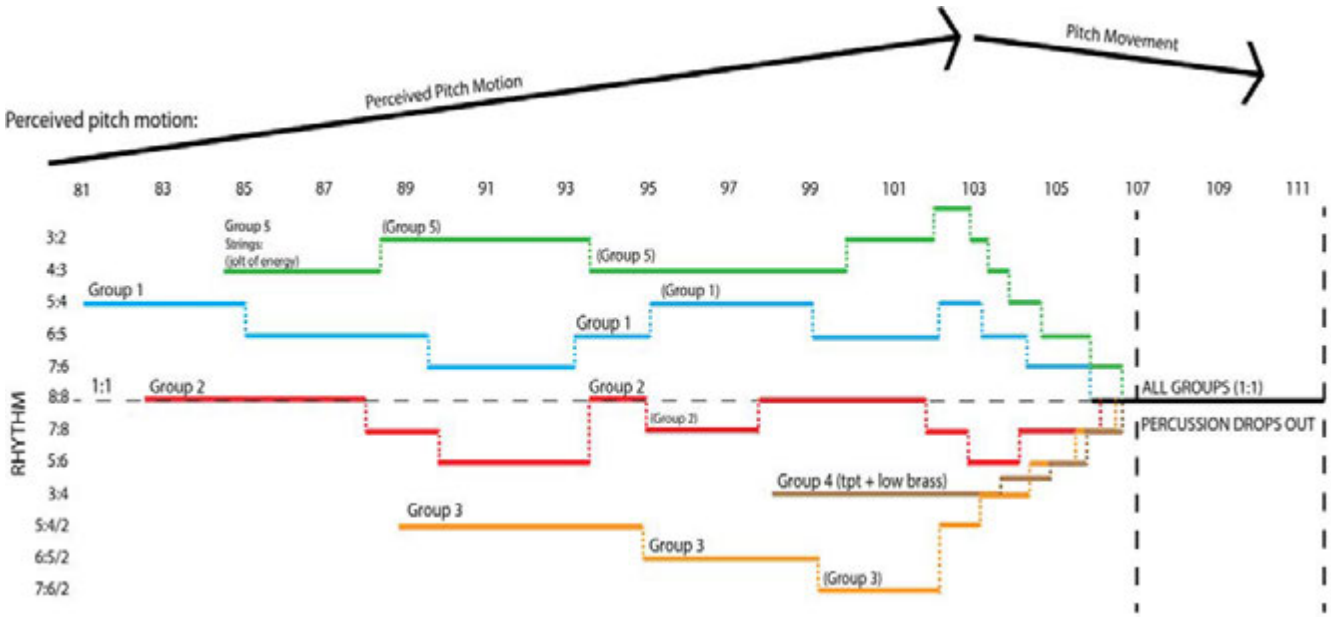


Figure 8: Rhythmic progressions of each of the five orchestral groups in mm. 81-106.

3.3. *Register, Timbre and the Perception of Groups in mm. 81-106*

Register and timbre play important roles in helping the listener parse the five orchestral groups that emerge leading to m. 106. In section I, the aural threshold between sound mass and polyphony is repeatedly crossed as a result of the gradual separation of melodic lines by register (see Figure 5). In mm. 81-106, a similar phenomenon occurs: the listener's attention is guided to different parts of the orchestra because of the unique registral space and timbral characteristics of each group. Although certain groups do occasionally descend in pitch during this section, the listener perceives the illusion of infinite ascent. Xenakis creates this illusion by distracting the listener's attention away from any descent in pitch through: 1) the ascent in pitch of other groups, 2) the sudden rhythmic change of other groups and 3) the introduction of a new orchestral group not previously present.

A simple example can be seen in mm. 87-89: the descent of the first group of winds beginning in m. 87 is concealed by the constant ascent of the two other groups in addition to the sudden rhythmic acceleration of the strings group from 4:3 to 3:2 in m. 88. To further distract the listener's attention, a new orchestral group of low brass and percussion enters at the end of m. 88. A reduction of these measures is presented in Figure 9.

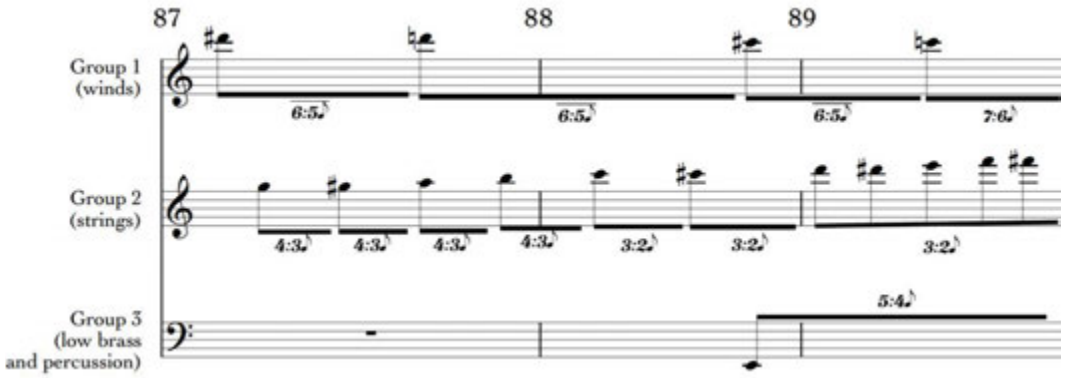


Figure 9: Reduction of mm. 87-89: While one group descends in pitch, the listener's attention is brought to the ascent and rhythmic changes of other groups in addition to new groups' entrances.

Figure 10 shows the registral movement of the five orchestral groups from mm. 82-106. The registral and timbral separation of the groups guides the listener's attention to different parts of the orchestra and allows them to aurally parse the groups.

3.4. Percussion Waves and Consistent Pulse in mm. 106-124

In m. 106 the percussion drops out before all five groups converge and return to the regular sixteenth-note pulse of the beginning of section II (see Figure 8). Unlike the beginning of section II (m. 66) where the strings and percussion play all sixteenth notes, at m. 106 some groups play on the beat and some play off the beat. The syncopation of the winds and bass, in addition to the harmonic dissonance, results in a sonority resembling a marching band in a frenzied parade. The dynamic hairpins create the sense that the band gets repeatedly closer or further away. From mm. 106-124 Xenakis repeats a pattern of three textures as shown in Figure 11: A) Sixteenth note pulse while some groups chromatically descend in pitch and some ascend, B) Sixteenth note pulse with no change in pitch, and C) Percussion entrances while the entire orchestra performs a crescendo without change in pitch. The repetition of these three textures is a stark contrast from the first six minutes of *Jonchaies.* Until this point, the piece consists of complex polyphonic textures gradually expanding to sound mass. The return to rhythmic insobriety brings the listener's attention to the dynamic hairpins and chromatic pitch movement.

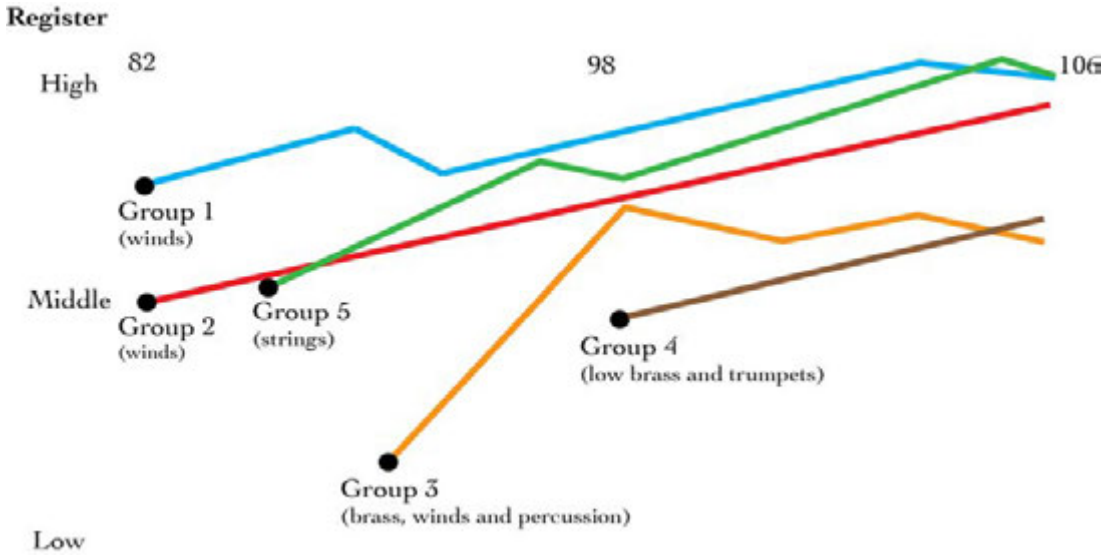


Figure 10: Registral separation of orchestral groups in mm. 82-106.

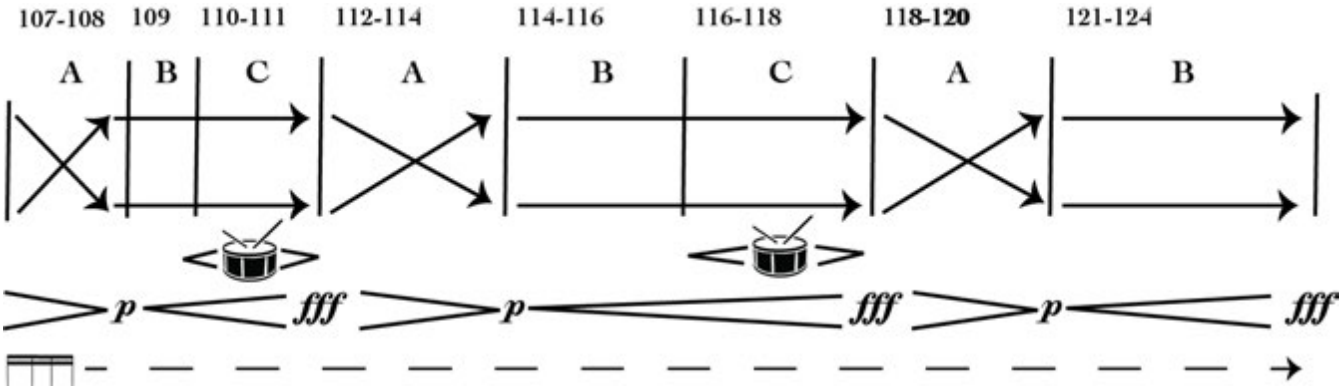


Figure 11: Pattern of textures in mm. 106-124: A) Sixteenth note pulse while some groups chromatically descend in pitch and some ascend, B) Sixteenth note pulse with no change in pitch, and C) Percussion enters and the entire orchestra performs a crescendo with no change in pitch.

3.5. Rhythmic Breakdown in mm. 124-140

Thanks to its limping and stilted rhythms, the last subsection of Section II (mm. 124-140) recalls a machine breaking down. Following the three-texture pattern (Fig. 11), a large part of the orchestra drops out leaving an ensemble of one clarinet, brass, bass drum, timpani and tom-toms. The ensemble is split into three groups: 1) Clarinet and mostly horns, 2) Trumpets, trombones and tuba, and 3) percussion. Like in mm. 81-106 – but repeating the same chord instead of chromatically ascending – each of the two brass groups plays their own rhythmic progression, while the percussion plays a background of eighth-notes and tremolos. In contrast to the feeling of off-beats driving the music forward in most of section II, Xenakis omits the off-beats in this final subsection, resulting in a feeling of limping and asymmetry. For example, compare mm. 86-88 to mm. 127-128. In mm. 86-88, Group I plays at a rate of 6:5 both on and off the beat (e.g. Piccolo I plays off the beat and Piccolo II plays on the beat, shown in Fig. 7). Compare that with mm. 127-128, where the new Group I play at a rate of 6:5, but no group plays the off-beats. While the two brass groups stumble through their rhythmic progressions, the tom-toms play consistent eight-notes. Xenakis describes the role of the percussion in this passage: “The regular rhythm of the percussion is there to render the rhythmic displacement audible; it is essentially the equivalent of a clock that gives the

tempo and underscores the rhythmic interplay" (Xenakis 1988, 134). Figure 12 shows the hobbling rhythmic progression of the two brass groups in mm. 124-140.

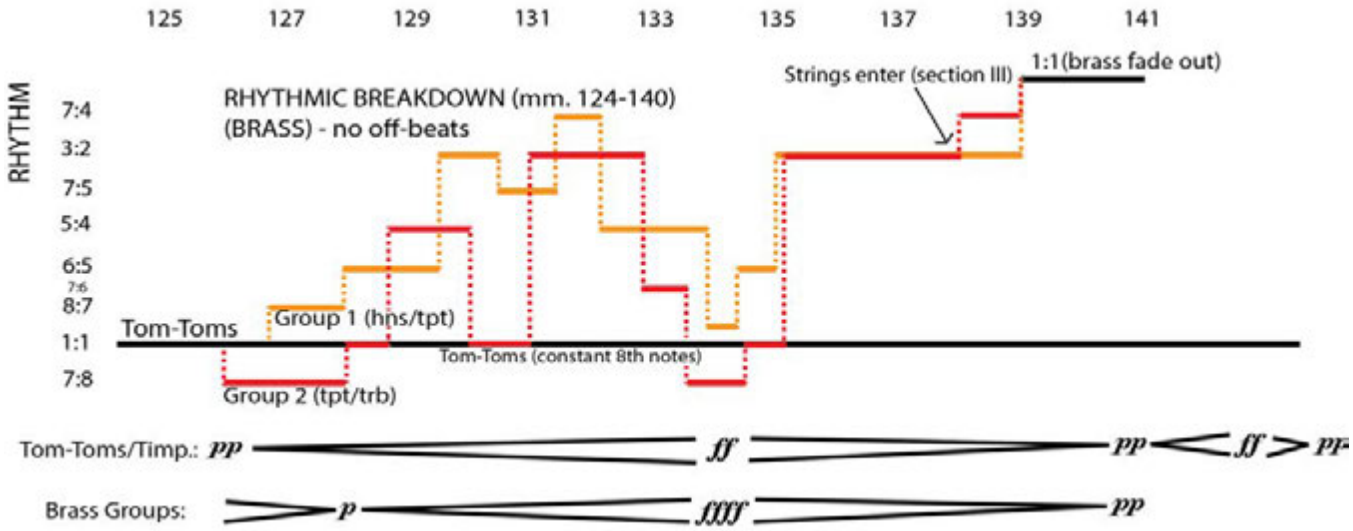


Figure 12: Rhythmic progressions of both brass groups in mm. 124-140. The tom-toms play eighth notes throughout the passage.

3.6. Closure in Section II

At the end of Section I (mm. 63-66), the lush melodic music is abruptly interrupted by the brutal pounding of Section II. The sudden ending generates a feeling of unfulfilled expectations. Does Section II end in the same way? Before the music becomes overwhelming sound mass in both of the first two sections, Xenakis prepares the listener by beginning with a simple and unified gesture: the string glissando and unison melody in mm. 1-12, and the aggressive pulsations in mm. 66-81. Whereas Section I is brusquely cut off, Xenakis returns to clarity and simplicity in mm. 106-140. Even though the texture is entirely different from the beginning of Section II, the return to rhythmic unison in m. 106 (see Fig. 8) provides a sense of reflection and closure. That is not to say that the listener feels the end of the piece approaching; the music continues forward to Section III. But the clear pattern in mm. 106-124 (Fig. 11) and the rhythmic breakdown until mm. 140 (Fig. 12) that follow the preceding chaos lead to a feeling of culmination.

Although Section II feels complete to a certain extent, the interruption of Section I in mm. 63-66 still leaves a feeling of incompleteness. When speaking about completeness and closure, Meyer discusses the potential to have multiple levels of completeness within one musical work: "…completeness and closure exhibit the same architectonic order as the music itself. That is, what is felt to be a completed process on one level may appear to be incomplete on a higher architectonic level" (Meyer 1958, 130). After the first two sections of *Jonchaies,* I propose that there are multiple

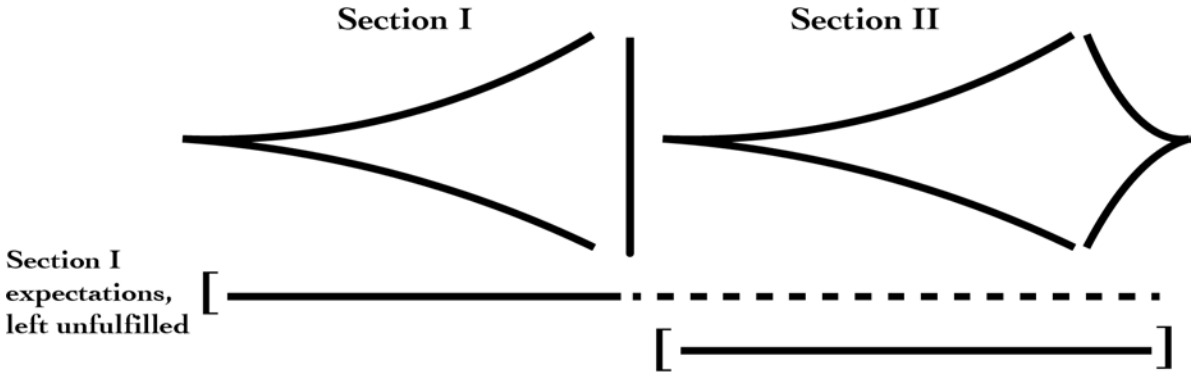


Figure 13: Even after Section II ends with a feeling of closure, the feeling of incompleteness after Section I lingers.

levels of expectations because of the vastly contrasted music. Figure 13 demonstrates that while we may feel a sense of fruition after Section II, the incompleteness of Section I continues to linger.

4. Concluding Remarks

In *Jonchaies,* Xenakis works with variations in orchestrational density and sound mass to shape the dramatic form of the work. In each of the first two sections of the work, Xenakis begins with simple material before allowing it to descend into chaos. He works with register to create clear perceptual distinctions between orchestral subgroups that dramatically converge and diverge. This paper is a beginning approach to understanding how Xenakis uses many musical parameters in tandem, such as register, orchestrational density, the contrast between rhythmic stability and instability, among others, to manipulate the listener's sense of direction and expectations for what is to follow. A comprehensive analysis in this vein of the entire work is necessary to fully understand the dramatic power of Xenakis' techniques and the importance of approaching an analysis of his works from a perceptual point of view.

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Nomos alpha by Iannis Xenakis and the problem of death and destiny

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> 'As for myself, I wanted to deal with the chasms which surround us and among which we live. The most formidable are those of our destiny, of life and death...' Xenakis, *Le diatope: geste de lumiére et de son*, 1978.

Abstract

Performing Xenakis provokes questions on many levels such as reading the score, instrumental techniques and 'expression', physicality of playing and communication with the listener. At the same time, the process of mastering his works brings to light many important extra- musical issues related to the composer's personal struggles, experiences of facing death in war, and his life-long search for artistic truth. In his conversation about the compositions dedicated to the subject of death *Aïs* (1980) and *Nekuia* (1981), Xenakis remarks: 'it was a period when the problem of death was more vivid than at other times. Death, however, is something I think about all the time' (Varga 1996, 166). In my practice research of *Nomos alpha* (1966) I explore the dialectic tension between the abstract concept of the composition and the nature of live performance: a rigorous form that demands a singular technical precision and intensity of emotional involvement, spontaneity of gestures and intuitive insight. I interpret the processes activated in performing *Nomos alpha* as the forces within the two- tiered structure that progress inexorably towards the final stage of their life cycle where the two scalic strands converge and divaricate finally receding into the realm of 'nothingness' or death. My search towards understanding and realising Xenakis' intent involves the interdisciplinary domain that encompasses philosophy, anthropology, cinema and literature. In my paper I will reflect on the subject of death in Xenakis' music drawing on the thoughts of André Malraux (1901-1976) – the writer, politician, Resistance fighter and philosopher of art – who, over the course of the twentieth century, interrogated the fundamental problem of the human condition and irrevocable finality of life asserting 'l'art est un anti-destin'. Focusing on my experiences of performing *Nomos alpha*, I will discuss the resonances and correlations in the two artists' enquiry into questions of human destiny, death and transcendence, and the way my exploration of Malraux's insight into 'human mystery' illuminates an additional dimension in interpreting this work.

1. Introduction

As an example of Xenakis' original approach to the cello and the compositional concept, *Nomos alpha* continues to attract much attention from musicologists, composers and performers. The work has been extensively analysed from structural, mathematical and conceptual perspectives; the

problems of interpretation and technique have also been addressed.1 Xenakis' music embodies the dynamic relationship between opposite forces, such as the rational and intuitive, the scientific and the 'raw' (elemental), measured detachment and fierce passion. In regard to this particular tension, the parameters of *Nomos alpha* are finely calculated by the composer who indicates in the score the fine details for execution of the piece including fingerings in some problematic instances; on the other hand, he decisively abandons the boundaries of the established norms of cello sound and the corresponding physicality of playing. Thus, the performer must find his/her orientation in *Nomos alpha*'s vertiginous territory in search for direction in their individual approach to the piece. For myself, one of the references in this exploratory space is the extra-musical dimension that extends the interpretative space by enlivening associative and intuitive pathways. (To clarify, this approach eschews direct imposition of simplistic programmatic ideas and images on the composition). In conversations and interviews, Xenakis insists on the abstract nature of his music rejecting the programmatic approach and direct links with a particular imagery in interpretation of his works. 2 In the process of developing a relationship with Xenakis' music, I have been drawn to the aesthetic and philosophical problems outside the domain of pure musical ideas – such as death, nothingness and destiny – that, in my subjective perception, touch the core of Xenakis' music, at times in an indirect and, in other cases, in an openly expressive way. Exploring these themes, I expanded my research towards the territories of literature and philosophy – namely, the French and Russian literature of the first half of the twentieth century, focusing on the ideas of André Malraux and some of his literary influences. Turning to Dostoevsky and Shakespeare, Malraux defines their writings as 'immense questions marks', rather then 'prophetic or revelatory text'. 'These texts are great art – art sacré – to the extent that they cannot be explained solely in artistic terms' (Brombert 1970, 190).

2. Xenakis and Malraux: the spirit of *le sacré*

Iannis Xenakis and André Malraux are two major French artists and cultural figures of the twentieth century whose lives and works are marked by the spirit of defiance – in their involvement in political activism and wars, and in their respective arts. Facing and challenging the reality of death, Malraux and Xenakis strived to evince the notion of unconditional resistance illuminating the power of transcendence through sound and words. Both artists extend significant influence in literature, theory of art and music (composition and performance) beyond the twentieth century. Affected by experiences of personal traumas, their creative thinking intersects on a profound level radiating a particular intensity in their interrogation of the notion of death. Indeed, the theme of death underlies their individual artistic search evolving through their respective mediums. The artists' backgrounds also resonate in many ways – Malraux, 'a formidable stylist and an accomplished weaver of ideas' is known as an autodidact who forged an influential presence as a prolific writer, a Resistance fighter, philosopher of arts and a political figure in his role as the Minister of Culture in the Charles De Gaulle government.3 As a committed political activist, Malraux was drawn to the ideals of communism and spirit of fraternity among the people united by a common goal.4 Xenakis was not

1 See for example, Vandenbogaerde 1968, Vriend 1981, DeLio 1980, Solomos 1997, Lai 2001, & Nakipbekova 2019.

2 Varga, 1996, *Conversations with Iannis Xenakis*. London: Faber and Faber, p.138, comments on these issues: 'We were really crossing swords over the old-age question whether or not music means anything beyond the actual notes. I remain convinced that very often it does, but I nonetheless respect the composer's position, based on a combination of aesthetic, psychological and temperamental reasons, that it does not'.

3 See Jean-Paul, V. M. Hérubel, 'André Malraux and the French Ministry of Cultural Affairs: A Bibliographic Essay' [Review of *Mona Lisa's Escort: André Malraux and the Reinvention of French Culture; La Grande Pitié des monuments de France: André Malraux, débats parlementaires (1960/1968)*, by H. Lebovics & M. Lantelme]. *Libraries & Culture*, 2000, 35.4, 557-575 (561).

4 David James Fisher affirms: 'Malraux transformed the Communist ideal into a life-affirming myth which substituted revolutionary activity for the West's disorientation and paralysis.[...]. Above all, the revolutionary movement offers a

formally educated in composition (trained as an engineer he made a significant contribution in the domain of architectural design working for Le Corbusier), yet, his pioneering musical ideas have impacted and still continue proliferating in the twenty-first century giving birth to multiple musical 'shoots'. Xenakis' commitment to the communist ideology, as the means for fighting against oppression, evolved into artistic quest beyond any ideological tenets and direct political activism.[5]

The works of Malraux and Xenakis share the singular qualities of *intensity* and the extraordinary vitality that continue to invigorate contemporary culture. Both artists were committed to interrogating the laws that underline the universal condition, and ways of revealing this power through their creative practice. As atheists, Xenakis and Malraux found spirituality in their respective spheres of artistic expression; both were deeply drawn to the question of mystery of existence, the irrational and transcendental.

Mihu Iliescu (2011) defines Xenakis' creative outlook as 'mythical thinking':

> Xenakis' musical approach is founded on a mythical thinking which tends to deny the notion of time and implicitly that of history. According to it, historical changes do not affect the essential true contained in mythical narratives and expressed in archetypal forms. [...]. Mythical thinking is in fact omnipresent in Xenakis' musical approach. It allows understanding his demiurgic posture, his manner of conceiving the musical creation as sonic cosmogony, his interest for archetypal morphologies.[6]

As stated by Hérubel (2000, 561-562), Malraux's rejection of his Christian heritage and his persistent search for answers posed by the problem of human destiny, shaped his 'aesthetic spirituality', and that Malraux's artistic activity 'formed the crucible that allowed humanity a degree of significance'.

> Malraux's spiritual sensibility was such that it did not adhere to any recognizable theological system but was a sensibility that derived from a visceral feeling of the sacred in existence. Malraux's novels and art commentaries were predicated upon the conception of *le sacré*; neither a rigid philosophical or theological concept, *le sacré* represented Malraux's view of the mystery of man's place in the universe.

In the midst of the twentieth-century wars, ideological struggle and human tragedy on a vast scale, Xenakis and Malraux questioned fundamental problems of death as the key to understanding human predicament within the limitless realm of universal existence. Malraux's views on the transformative power of the arts are expressed in his novels, interviews, speeches and his writings on art. He believes that 'on this earth of ours where everything is subject to the passing of time, one thing only is both subject to time and yet victorious over it: the work of art' (Malraux 1975, cited in Allan 2005, 303). This transformation is inextricably bound with the human condition and inevitability of suffering in facing destiny. 'Art, according to Malraux, is about the mystery of this

political solution to individual isolation and despair. The fellowship and principles of the collective political movement are what finally allow men face death'. David James Fisher, 'Malraux: Left Politics and Anti-Fascism in the 1930's', *Twentieth Century Literature*, 24. 3, 1978, 290-302 (295).

[5] The Greek poet Yannis Ritsos (1909-1990), who experienced formidable physical and spiritual suffering as a political activist in war time Greece, underwent a similar transformation in his political views. In the analysis of the existentialist influences in Ritsos' monologue *Orestes* (1962-1966), Vayos Liapis states: 'Can 'Orestes' really be shown to rely on existentialist underpinnings, as I suggest, or is this notion an illusion? It is on the latter assumption, it would seem, that several interpreters have taken 'Orestes' to be largely an autobiographical monologue, in which Ritsos grapples with his own secretly ambivalent attitude towards his communist ideology. V. Liapis, 'Orestes and Nothingness: Yiannis Ritsos' "Orestes", Greek Tragedy, and Existentialism. *International Journal of the Classical Tradition*, 2014, 2.2, 121-158 (124). Peter Green comments: 'Yet it was, precisely, the formidable pressures to which he was subject that elicited his finest, most deeply felt poetry, just as carbon atoms, under an inconceivable intensity of force and heat, will coalesce to form a diamond'. P. Green, 'Myth, Tradition, and Ideology in the Greek Literary Revival: The Paradoxical Case of Yannis Ritsos', *Arion: A Journal of Humanities and the Classics*, 1996, 4. 2, 88-111 (105).

[6] Discussing the nature of myth, Iliescu cites Lévi-Strauss' idea: 'the myths think themselves through the humans and without their knowledge'. (Lévi-Strauss, Claude. 1964. *Le cru et le cuit*, Paris, Plon, p. 30).

awareness of man's condition. But it is suffering that bestows the meaning. "Every human life [...] becomes mystery when questioned by pain".' (Brombert 1970, 190).

3. The question of death, destiny and transformation

Xenakis faced and challenged his destiny in the time of the World War II. As a student at the Polytechnic School in Athens, he first joined the nationalist movement, but was soon drawn to the ideals and courageous spirit of the Greek communists. Xenakis joined the Communist Party and began actively participating in underground activities and mass demonstrations protesting against occupation. Witnessing colossal gatherings of people united by the spirit of resistance made a profound impact on him – these impressions remained as memories that were later transformed into a rich source of ideas in his artistic laboratory. In his conversation with Varga, he asserts: 'The experience was to be of major importance for my music'. (Varga 1996, p.17). Xenakis came close to death when he was in charge of defending a block of houses in Athens and was hit by a shell from a Sherman tank: 'We heard mortars firing and there must have been an explosion that hit us. Two of the people, one a girl, died instantly. One had his brain scattered on the wall. I fell unconscious'. He describes the details of his wounds: 'Ah...A catastrophe. My palace was pierced, there were bits of teeth, flesh, blood, holes, my jawbone was broken. My left eye has burst [...]'. Recalling his experience in the war hospital where he had to endure three operations in primitive conditions (some procedures were performed without anaesthetics), he reveals: 'I was still convinced that I should die. I was reading Charles Morgan's *Sparkenbroke* while I was in hospital. Love, art, death. It seemed the perfect trinity for me'. (Matossian 2005, 36-37).7

Malraux's writings concern the problem of violence, the mindset that leads to degradation of human beings and redemption. As asserted by Brombert (1970, 188),

> Antitheses and paradoxes, tensions that cannot be resolved, and above all a taste for extreme situations are at the heart of Malraux's work [...]. The violence of battle: grenades thrown into rooms filled with wounded men, shell-torn bodies, blood-spattered walls, flame throwers directed against human bodies, mass execution of prisoners -these are the familiar images of his novels [...] images of madness and disintegration occur everywhere [...] Images of death do, however, strangely slide into images of metamorphosis and survival.

The physical and emotional trauma, and the nature of Xenakis' injury generated major ramifications in his life and his identity and, it might be argued, strongly influenced his creative direction in music: 'in effect, he continued the fight, only changing the means'. (Iliescu 2000, 85)8

The singer Spyros Sakkas relates his collaboration with Xenakis on his vocal works, noting that the composer insisted that the performer should distance himself from the 'hero' in his vocal pieces. 'Sometimes he would correct me as I was singing, asking me to expert my own personal thoughts and emotions in order to keep the voice 'free' and with an independent colouring and ethos'. This desire for radical distancing from expressing emotions signifies the will to transform the limitations of human perceptions into the timelessness within the unfathomable processes of the Universe. Sakkas asserts that 'Aesthetics in Xenakis's case would be his absolute need through his own

7 See the details of this period in Nouritza Matossian, *Xenakis* (Lefkosia: Moufflon Publications) pp.28-43.

8 Xenakis elucidates the significance of this experience for his pivotal composition Metastasis (1954): 'Metastasis, that starting point of my life as a composer, was inspired not by music but rather the impressions gained during the Nazi occupation of Greece. The Germans tried to take Greek workers to the Third Reich – and we staged huge demonstrations against this and managed to prevent it. I listened to the sound of the masses marching towards the centre of Athens, the shouting of slogans and then, when they came upon Nazi tanks, the intermitting shooting of the machine guns, the chaos. I shall never forget the transformation of the regular, rhythmic noise of a hundred thousand people into some fantastic disorder... I would never have thought that one day all that would surface again and become music: Metastasis'. Varga, *Conversations*, p.52.

personal, cultural background, his personal physical and intellectual necessities to translate into sound his experiences'. In relation to the vocal works based on the ancient Greek text, such as *Aïs*, he adds: 'and what happened with certainly [*sic*] was that his body attempted to contact the bodies of the ancient Greeks'. (Vagopoulou 2007, 211). This spirit Malraux defines as 'will to transform': 'Whatever he might say, [the artist] never submits to the world, and always submits the world to that which he substitutes for it. His will to transform is inseparable from his nature as artist' (Malraux, 1948).

Xenakis' landmark composition *Metastasis* might be thought of as a meditation on the idea and the process of transformation. Malraux contemplates the limitations of the heroic action as being in juxtaposition with the idea of transformation: 'The real tension lies deeper: it comes from the basic rift between the temptation of the apocalypse and the temptation of metamorphosis, which is to say survival'. (Brombert 1970, 189). In Jean-Marie Domenach's interpretation

> Malraux's life and work can only be understood against this background of death, death rejected, avoided, and finally tamed and transcended in the fraternity of revolutionary commitment and the dangers of battle. "All that matters to me is what can stand against the fascination of nothingness." And later, when the time of fighting was over, "culture" came to represent for him the sum of forces, which can resist the appeal of death. (Domenach 1977).

Xenakis' creative thought confronts 'the fascination of nothingness' with the 'sum of forces' that affirms life and living; in his struggle to fathom the 'appeal of death' he frequently refers to the notion of *nothing* in compositional and universal contexts.

Aïs and Nekuia: the poems of death

Two works composed in close succession – *Aïs* (1980) for amplified baritone, solo percussion and large orchestra and *Nekuia* (1981) for mixed chorus and orchestra – are explicitly concerned with the subject of death. In *Nekuia*, Xenakis evokes the visceral sensation of immersion into the realm of death, or the image of death. *Aïs* is based on the ancient Greek texts by Homer and Sappho – *Aïs* was the name used in Greek poetry for Hades, the domain of the dead. In the introduction to the score, Jacques Lonchampt (Lonchampt, 1988), comments: 'rarely one had this almost physical impression of a hand to hand combat with death'.9 The idea of *Aïs* was conceived on a desert island

[9] See also, Varga, *Conversations*, p.162.
Xenakis elaborates on the literary sources for the composition in the introduction to the score:
'Aïs – the domain of the dead, Hades of the shadows. I have taken in the Odyssey two fragments of Ulyssess' visit to the land of the dead. (Odyssey, chant XI, verses 36.37)

> into the pit: the blood was flowing like black clouds, and from the depths
> of Erebos gathered the souls of the definitely dead.

(Odyssey, chant XI, verses 205-208)

> To embrace the soul of my definitely dead mother. Three times I hurled
> myself; all my heart longed for that. But three times from my hands
> like a shadow or like a dream, her soul flew away: and in my heart
> more sharp the distress became.

These fragments express the irreversibility of death and they are even more terrible since the being most cherished by Ulysses, his mother, is impalpable, the dream that flies away despite of three vain attempts to take her into his arms. Then I took the fragment of Sapho in that beautiful Aeolian dialect where the desire to live is mixed with the nostalgia for death as if to conjure it.
(Sapho, fragment 95)

> To die, a longing holds me, and to see the shores of Acheron
> full of lotuses and dew.

Finally, a fragment of the Iliad, the ignominious death of the beautiful and valiant Petroclos, struck

in the Aegean See where the composer spent the night listening to the cries of particular birds inhabiting the locality. As described by Xenakis,

> it's a kind of petrel or seagull still to be found in the Mediterranean [...]. Sometimes at night they gather above the nests [...], fly around and give out cries, which sound as if children were being assassinated. [...]. I have used something similar to these cries also because the bird has a mysterious quality in mythology and folklore – as if it were the voice of destiny. (Varga 1996, 162-163).

In Homer, birds appear as complex symbols: 'They fly like ghosts and mediate between gods and humans. [...] Birds in religious symbolism figure as epithets, vehicles, contexts, and metamorphoses of gods'. (Friedrich 1997, 316). Birds might also be associated with fleeting memories and a sense of instability of perceptions – on the border between the rational mind and a dream-like state.[10]

Xenakis rejects the idea of programmatising his music;[11] in his response to the interviewer's suggestion that this work might be thought of as a requiem for his mother, he diverts the conversation towards the sound and the symbolic aspect of the birds. (Varga 1996, 162). Their cries interest him – a particular sonority, a pure sound – perhaps as part of his exploration of noises and sounds captured from the environment, and yet, in these cries he also hears violence and death. His extensive introductory notes in the score illuminate the aspects of death that are transmuted into music – an ambiguous vision of the land of the dead as the dark pit 'where the blood was flowing like black clouds' and in a contrast, as the land 'full of lotuses and dew' (as praised by Sappho); the irreversibility of death; the tragedy of dying young; and the ambivalent feelings in the face of these sorrows –'the desire to live is mixed with the nostalgia for death as if to conjure it'. At the beginning of the composition the listener is confronted with a 'death cry' as if these multihued dimensions of death are condensed into one instance of paroxysmal cry; in the score, this sound in the vocal part is indicated as *cri horrible* (bar 6). For *Nekuia*, Xenakis also offers the introductory notes referring to the ceremony of necromancy.[12] In the way the composer delineates the general concept of the piece, it is apparent that his mind is directed to the condition of chaos and struggle on a cosmic scale, as if observing the battleground of the conflicting ideologies and forces enveloped in the luminosity of colours on Earth from a cosmic perspective – the ethereal beauty unaffected by human violence. Xenakis introduces in the theme of *nekuia* (a death ritual) his deeply personal associations with war, demonstrations, explosions and cries of the dying. The composer creates an effect of a sound perceived from some distance as if distorted and delayed by 'travelling' through

down in his youth and ardor by the conjugated wills of the gods and men: (Iliad, chant XVI, verses 855-857)

> as soon as he ceased speaking the death end covered him
> The soul flew away from the limbs and went to Hades
> weeping for its destiny, having abandoned force and youth'.

[10] Ritsos encapsulates this moment in the three-line poem:

> 'And suddenly
> a memory of birds
> that sank into the unknown'.

Yannis Ritsos, 2020. *Diaries of Exile*, 'January 4', trans. Karen Emmerich and Edmund Keeley (Brooklin, NY: Archipelago Books), p.78.

[11] Xenakis elucidates his attitude on this matter: 'all this symbolism of course loses its appeal when it is revealed and explained [...] Yes, I am afraid it would lose its charm and value. I believe that in art there must always be a threshold of mystery'. Xenakis interviewed by Costas Parlas, To Βήμα (17.09.1978), cited in Ioannis Tsagkarakis, 2013. 'The Politics of Culture: Historical Moments in Greek Musical Modernism', PhD, Royal Holloway University of London, p.216.

[12] 'Funeral ceremony. Also necromancy, magical rite by which ghosts were called up and questioned the future. The general idea of this music, the background, is the remarkable crisis of crisscrossing ideologies in the ether, on the planet's surface, often accompanied by street demonstration sounds, the battle-field explosions and cries, beneath the now gloomy light of the sky, the now bright blue light'. *Nekuia*, score. Introductory notes. Édition SALABERT.

vast space – as an imaginary domain where the dead, the dying and the living co-exist in a perpetual flux, or as violent memories that haunt humans like 'ghosts'.

Nomos alpha: the ineffable space of death and nothingness

'Derrière tout chef-d'oeuvre rôde et gronde un destin dompté'.
Malraux, *Les Voix du silence*, Paris: Gallimard, 1951, p.628.

Composed fifteen years earlier, *Nomos alpha* is known as a singular example of writing for cello within the framework of abstract concepts, and as a case of musical 'alchemy' – a transformation of mathematical processes into an intense visceral experience intensified by the dynamics in the interplay of multiple spaces.[13]

The interpreter of *Nomos alpha* confronts the task of discerning the path(s) in these spaces towards the heart of the composition. At the first stage of working on the piece, the attempts to understand the elegant mathematical system employed by Xenakis and realise its principles in sound, motivates the search for appropriate physical (instrumental) training. In this effort of combining awareness of the abstract models underpinning the composition with the technical work, the interpreter may descry the third dimension – the domain of the intuitive and sensual within Xenakis' mystical 'space'. Approaching *Nomos alpha* from the perspective of the direct expression beyond rational thought animates the experience of physicality of playing – on the planes of the sensual and tactile.[14]

Differentiating between the tactile dimensions of Deleuzian categories of 'smooth' and 'striated' in the composition's textures extends the listening faculty – 'listening' through the fingers – in search for the dynamic balance between the two planes. This could be a starting point in the *Nomos alpha* performer's engagement with principles and dichotomies, such as rhythm and sound, intellect and intuition. The piece comes to life through the interplay between and within these elements, and the performer's application of the ideas of 'embroidering' and 'patching'.[15] In this extended space of thought, physical sensations, imagery and subjective associations, Xenakis' 'chasms' of death and destiny are communicated by the interpreter's mastery of the rhythm and his/her intuitive distribution of the energy and space within the body of the work. This can be achieved through focusing on the interactive layers of rhythm and pulse – on the surface of the musical fabric and in the deep recesses of the structure as a 'tectonic' layer that control and shape the outer processes. Distinguishing between these two layers by emphasising particular junctions in the group of *events* creates the multidimensionality of sound and a sense of the irrevocability in the flow towards the

[13] In relation to the idea of the abstract spaces in Xenakis' music, Solomos asserts: 'the most radical utilization of a geometrical space can be found in *Nomos alpha* [...] where Xenakis uses the group model (in a mathematical sense) of a cube and its 23 rotations'. (Solomos, 2014, 7). Makis Solomos 'The Complexity of Xenakis's Notion of Space', in Martha Brech and Ralph Paland (eds), *Kompositionfürhrbaren Raum. Die frühe elektroakustische Musik und ihre Kontexte / Compositions for Audible Space. The Early Electroacoustic Music and its Contexts* (Bilefeld: transcript Verlag), 2015, pp. 323-337.

[14] Solomos affirms the 'Dionysian' element in Xenakis' music: '[X]enakian sonorities are directly addressed to the listener's senses. [...]. This music has an immediate impact on listeners, without leaning on language, figuration, code: in a way, by directly addressing the senses, its impact is the impact of a natural phenomenon'. Makis Solomos, 'Xenakis' Thought through his Writings', *Journal of New Music Research*, 2004, 33.2, 125-136 (132). Ritsos articulates his view on the power of arts primarily experienced through the senses: 'another means of evaluating a work of art is by measuring its degree of sensuality which exists in the work of art. Human beings develop through the senses. They don't develop through their brain. Our senses feedback the brain, not the opposite'. "Yannis Ritsos talks about Prudishness in Art". Filmed 7 December 2011. Video, 1:34.https://www.youtube.com/watch?v=v1q05ukl9t4&t=3s

[15] For discussion regarding these principles in relation to musical performance, see Caleb Faul, 'Voyagers in Sound: On the Smooth and the Striated in Musical Interpretation and Performance'. *Revista Portuguesa de Filosofia*, 74. 4, 2018, 1437-1464.

concluding progression of the two lines that dissipate into the 'nothingness'. Xenakis' references to 'nothing' and 'nothingness' concern the issues of creative originality (creating from nothing) and the philosophical questions of life and death.[16]

Performing *Nomos alpha* challenges the (perceived) limitations of hearing by the urgency in discerning the infinitesimal nuances in the oscillations of sound across all registers of the cello and the microtonal writing – in the double stops, *glissandi* and a singular effect of the 'beats' – that must be accomplished with uncompromising precision.[17] The two distinct sonorities generated by *glissandi* and *scordatura* can affect the performer and listener's senses directly as a pure sound and indirectly, by eliciting associations with matters of an extra-musical nature. The rich soundscape generated by the family of *glissandi* invariably invokes the sounds and noises from the environment concurrently with associative responses in the subjective space of symbolic meanings.[18] As the audial configurations of patterns with their own characteristics of directions, densities and velocities, *glissandi* in *Nomos alpha* could be imagined as the composer's 'memory of the future' – the vision of birds above the metaphysical island with the cries of 'assassinated children' that exude a 'mysterious quality [...] as if it were the voice of destiny' – the cries that inspired *Aïs*, the poem of death. In subjective terms, the *glissandi* embody ascending and descending trajectories and the shapes of 'thoughts–birds' in the inner mind. The *scordatura* in *Nomos alpha* – a violent detuning of the gut C string down an octave as if 'plunging' into the domain of Hades – challenges the cellist with the 'fight' against the eruptive temper of the setup as if it were a 'mythical beast'.

Depicted by Solomos as a 'composition in composition', the concluding part of *Nomos alpha* (bb. 365-386) is formed by the ethereal progression of fragile sound-entities.[19] This section might be subjectively interpreted as a point of departure, an inscrutable 'utterance', a question mark on the borderline between awareness and oblivion, the dynamic and static – a momentous experience within a meshwork of imaginary threads of *nothing*, *nothingness* and *death*. Within these spaces, there are degrees and levels of intensities and states – death is not an unfluctuating monochrome reality but a parallel experience with its own logic and drama. As stated by Iliescu, for Xenakis, the idea of nothing relates to *re*-building musical foundation,[20] which means, this 'nothing' contains the links to that which existed before and, it might be thought, is a degree of 'nothingness' – the domain beyond death inaccessible to human comprehension. Alien to human corporeality, the concept of this realm is ungraspable neither by the rational mind nor imagination but could be approached through the faculty of extended *listening*. Xenakis' music demands a particular quality

[16] Iliescu elaborates on the question of 'building the musical edifice from nothing' in Xenakis' ethos: According to Mircea Eliade, the idea of violently rejecting the traditions of the past, which is characteristic of the modern art, reasserts a mythical need: that to periodically destroy the world in order to better recreate it from nothing. Xenakis' commitment to rebuild the whole musical edifice starting from a completely new foundation manifests this mythical necessity. The dialectic of destruction and construction is visible in the xenakian interpretation of the dotted line as a metaphor of the unending succession of life and death'. Iliescu 2011, 3. Xenakis questions the problem of originality: 'To say the universe was born out of nothing is to posit a case of absolute originality, for something has come from nothing. If, however, there was something, and you have obtained something different, you are speaking of a causality, a link which reduces the degree of originality'. Varga, *Conversations*, p. 168.

[17] As stated by Solomos, this particular effect is employed in *Nomos alpha* as a way of 'entering the sound.' 'The 'beats', Xenakis instructs the musician, are achieved by: 'slightly raising or lowering (respectively) the note thus marked so that it 'beats' against the second note, at a rhythm indicated by the figure, which expresses beats per second. (Xenakis 1967b)'.'Nomos alpha. Remarks on performance', in Alfia Nakipbekova (ed.), *Exploring Xenakis. Performance, Practice, Philosophy* (Delaware: Vernon Press, 2019), pp. 109-128 (p.113).

[18] For example, in *La Légende d'Eer* (1977-1978), 'glissandi take on a mimetic role, in its evocation of unhuman life-forms and environments'. Hope, C.A., & Terren, 'The Possibilities of a Line : Marking The Glissando in Western Art Music', 2016.

[19] 'In this passage, there's a scale of 96 pitches spread over 8.5 octaves, consisting of three movements: a whole tone scale ascending or descending; a three-quarter tone scale ascending or descending; a one and one quarter tone scale ascending only'. Makis Solomos, 'Nomos alpha. Remarks on performance', pp.114-115.

[20] See footnote 16.

of listening that is motivated by the urgent desire for completeness – the state of being that is resonating with vibrations of the 'virtualities of thought' and, simultaneously, the 'unthinking' mind.21 For the performer, the path towards the ungraspable can be found in this kind of listening attuned to Xenakis' 'listening' and to his 'thinking'.

Malraux describes the heightened intensity of listening and hearing at the moment in the life of a man facing imminent torture and death. The imprisoned protagonist Kassner's hearing becomes extraordinarily sensitive and attuned to every sound around him. Immersed in the darkness of his cell, he distinguishes a careful tapping on the wall of his comrade in the adjoining cell from other subtle noises inside and outside; judging the distance and the direction of the guards' steps in the corridors becomes a matter of survival.22 Malraux, who experienced imprisonment, mock execution and escape, interrogates these themes through the lives of the protagonists of his novels and as metaphors of the human condition; he believes that 'the greatest mystery is not that we have been flung at random between the profusion of matter and of the stars, but that within this prison we draw from ourselves images powerful enough to deny nothingness'. (Malraux 1968, 24). Malraux turns to the subjects of imprisonment and escape in his persistent attempt to grasp the essence of human fate. In the end, his tragic vision of the human condition is not final but is open to hope and change – resisting nothingness and re-building from nothing. *Nomos alpha* embodies the spirit of metamorphosis, the transformational journey that has no completion, as Xenakis chooses to end the process by 'escaping' through the metaphysical 'door' into another realm – in the labyrinths of destiny, beyond sound and thought.

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21 In Xenakis' words, 'Music is 'a sonorous fixation of virtualities of thought, of cosmological, philosophical theses' (Xenakis, 1969, Structures universelles de la pense musicale, 173). Cited in Makis Solomos 'Xenakis' Thought through his Writings', *Journal of New Music Research*, 2004, 33.2, 125-136 (126).

22 'Blow after blow. He hardly dared to listen. [...] While he listened with all his might, he was afraid to hear: would not these knocks cease once more? Once already he had thought he heard the guard's step and he had been mistaken. Hope itself was a form of suffering'. *Days of Wrath* ('Le temps du mépris'), trans. Haakon M.Chevalier (New York City: Random House, 1936), p. 82.

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Ekphrasis in the work of Iannis Xenakis

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Abstract

This paper explores aspects of Xenakis's work through the Ancient Greek concept of 'ekphrasis'. The concept of ekphrasis is defined by Michael Squire (2021) as 'refer[ring] to the literary and rhetorical trope of summoning up – through words – an impression of a visual stimulus, object, or scene'. Early examples include Homer's description of the shield of Achilles in the Iliad, with a more modern, well-known example being Keats' Ode to a Grecian Urn (1819). Ekphrasis is a concept bound up with the representation of one medium in another, and subsequent research has expanded study to incorporate other forms of art, including music. Siglind Bruhn's 'musical ekphrasis' describes the ekphrastic process of 'transmedialisation' as 'the musical representation of a text created in a non-musical sign system' (Bruhn, 2008). It is here where applications to Xenakis's work become apparent, particularly with respect to my own work on 'graphical ekphrasis', which goes further in decentralizing concepts of 'artwork' to encompass any visual text.

This initial part of the paper focuses on Xenakis's famously 'graphic' works, which utilise techniques such as ruled surfaces and arborescences (e.g. *Metastasis*, *Erikhthon*, *Evryali* etc.) to posit notions of ekphrasis in his work, and the exhibition of this 'transmedial' discipline. As Bruhn notes, two components of a transmedialisation are 'depiction' (the formal features) and 'reference' (the cultural context). Xenakis's work is interesting in that it relies heavily on depiction - i.e. sounding out the specific graphical construction - at the cost of 'reference'. This radical thinking is at once the most divisive and inspiring aspect of Xenakis's work, and has led to the redefinition of fundamental musical techniques (e.g. glissando) and ideas. Some brief and novel ideas on *Erikhthon* as an ecological work will demonstrate how meaning can be structured when applying an ekphrastic framework to traversing Xenakis's music.

This drive for 'depiction' is where the schism between sonification (e.g. Scaletti 2011) and ekphrasis (and indeed representation and abstraction) is laid bare and, in Section 4, I propose an aesthetics of Xenakis's music as ekphrasis in terms he often used himself: that of logic. The recent publication of Hans-Werner Heister's *Music and Fuzzy Logic* (2021) is an ideal starting point to probe this wider transmedial spectrum in Xenakis's music. This is explored with reference to Jean-Jacques Nattiez's Music and Discourse (1990) in referring to the listener- and composer-centric models for transmedial aesthetics.

This survey concludes the importance of the interdisciplinary in the aesthetics of Xenakis's work, echoing Daniel Albright's (2014) notion of Xenakis's 'intermedial perfection', articulated through notions of ekphrasis, paying particular attention to Xenakis's own commentary on transmediality in his writings to build a picture of how these came to define new narratives of the man and music, and what they can teach practicing transmedialists today. Moreover, the frameworks explored can allow for further engagement with the larger body of Xenakis's work, encompassing electroacoustic and computer music, thus supporting further aesthetic research.

1. Introduction

A common theme in much of Xenakis's writing is the notion that music should aim to represent certain

phenomena, things, or ideas. As such, one might attempt to situate him in the realm of other composers who allude to extra-musical ideas within their work, such as in much programme music – but this would be a false relation. Indeed, his approach hinges more upon the notion of translation of such ideas in a very direct sense, treating the extra-musical as the real 'musical' text. This is outlined in a reflective moment in his conversations with Vargas:

> That's my contribution to the development of music: I use ideas in composing that are completely alien to music. (2003: 79)

This equivalency of the non-musical and musical texts allows us to view Xenakis's work with respect to the concept of 'ekphrasis', which is defined by Michael Squire (2021) as 'refer[ring] to the literary and rhetorical trope of summoning up – through words – an impression of a visual stimulus, object, or scene' - a notable example being Keats' *Ode on a Grecian Urn* (1819). Siglind Bruhn has contributed greatly to the expansion of the concept of 'musical ekphrasis', defining the term as 'the musical representation of a text created in a non-musical sign system' and describing this act as 'transmedialisation' (2000: 8). In this way, we might consider Xenakis's creative practice as being centred on this 'transmedialisation' of, often visual, stimuli. My own contribution to this field, graphical ekphrasis,[1] privileges the specifically spatial properties in the act of transmedialisation, positing a decentralisation of the 'artwork' to encompass any visual representation as having transmedial potential, echoing Daniel Albright's position that '[a]nything is an artwork to the extent that it looks made.' (Alrbight, 2014: 4) This has further currency in aiding a reading of Xenakis's works - particularly when considering the often abstract, and self-designed subjects which create this visual/musical equivalency. This enquiry feels apt when considering Xenakis's disposition towards ancient Greek concepts, describing himself as 'a Classical Greek living in the twentieth–century' (in Matossian, 1986: 11), with pianist Claude Helffer describing a 'specific feature' of Xeankis's aesthetics as:

> [H]is Pythagorean concept of the interpenetration between all domains; for example, what is beautiful on a mathematical level will maintain this aesthetic character when transposed into other sectors of knowledge or art. The beauty of his arborescences drawn on graph paper will also be beautiful when transposed into Evryali or Erikhthon. (in Kanach 2010: 114-115)

This notion of self-design (i.e. drawing his own ekphrastic subjects) is one of the most interesting aspects of Xenakis's practice. It would seem that, unlike a traditional approach to ekphrasis, Xenakis was unable to find pre-existing representation of the music he sought to compose. In a later passage in his conversations with Vargas he claims that, '[t]he drawing and thinking of the sound-image go hand in hand, the two can't be separated … we have also to be able to find on paper the visual equivalent of the musical idea' (2003: 90). This clearly shows how the relationship between the visual and music is not unidirectional, and operates as a holistic 'whole' of a process. This can be confirmed with interpretations of Xenakis's work outside of music, with Sharon Kanach noting that 'Iannis Xenakis' architecture can be regarded as a transposition in space of what occurs in his music in time and pitch' (2008: xii), which neatly shows Albright's notion of an 'intermedial perfection' in Xenakis's philosophy (2014: 265).

The methodology behind this paper will focus on a component of Bruhn's framework in musical ekphrasis, that of the categories of 'depiction' and 'reference':

1 See T. Metcalf, Graphical Ekphrasis in Contmporary Music, PhD Thesis, Oxford University, 2021; or for a brief introduction, T. Metcalf, 'Graphical Ekphrasis: Translating Graphical Spaces into Music', Question, AHRC, 2020, pp. 78-91.

> I wish to argue that what and how music communicates about any extra-musical stimulus does indeed fall into the two categories that can be seen as analogous with those pertinent in the context of painting and poetry: depiction and reference. I use depiction by musical means as encompassing not only instances of mimicry … but also sensual impressions of hues, shapes, and spatiality. Correspondingly, reference by musical means … will be understood as relying on cultural and historical conventions. (2000: 11)

It is clear that depiction is pertinent to the formal aspects of an extra-musical source; in essence allowing the music to 'mimic' it. In this category, one may designate musical structures, and relationships between musical parameters as preserving the minutia of relationships that make the source work identifiable, and thus the ekphrasis clear. Contrastingly, 'reference' invokes an aspect of style that situates the work in a cultural or historical convention; it is not the relationship of materials that aids ekphrasis, but rather their presentation through a stylistic lens. This concerns aspects of instrumentation, musical tropes, and the contextualisation of the 'depiction' within a wider musical context. Through an initial examination of Xenakis' works which have illuminating sketches (and thus a very clear relationship to the visual), I will discuss how ekphrasis could be applied, and provide useful insights into better understanding Xenakis's transmedial practice, and suggest that his prolific mentions of 'intuition' in the creative process can create a schism between ekphrasis and tangential concepts of sonification and fuzzy logic.

2. Revisiting 'ruled surfaces': *Metastasis* and the glissando

Metastasis (1953-54), for orchestra, is perhaps the most well-known example of Xenakis' initial experiments in transmediality, whereby the music has a link to architecture, more specifically the Phillips Pavilion. The oft-cited sketches make clear the creation of hyperbolic paraboloid curves constructed of straight lines, or 'ruled surfaces', which serve to create to create a similarity in the design of the music with that of the architecture. Indeed, Xenakis comments that:

> 'In my composition Metastaseis … the role of architecture is direct and fundamental by virtue of the Modulor. The Modulor was applied in the very essence of the musical development' (in Kanach 2008)

A transmedial link is created not only on a visual sense, but by virtue of using the Modulor, a design tool developed by architect Le Corbusier (relating to anthropometric proportions). We see the non-musical influencing the musical, and thus can claim that this is a holistic incorporation of the architectural design (rather than a mere allusion), and the beginnings of a move towards a 'general morphology', defined by Elizabeth Sikiardi as: 'research concerned with the understanding of form and its generation … an interdisciplinary effort, corresponding to Xenakis's universal thinking and 'transfer' practice' (2006: 203). This 'transfer practice', or indeed one might say 'transmedial practice', is at the heart of applying ekphrasis to Xenakis's work.

Through an ekphrastic reading, one might argue that the scrupulous level of detail for the vast number of players ensures a high level of 'depiction' within the transmedialisation process: the rendering from visual to audio is clear, and easy to follow. However, when considering 'reference' (cultural or historical aspects) we see no resemblance; it creates a totally novel sound. Kanach claims that the use of glissandi in *Metastasis* (the most accurate continuous representation of any two given linear points in a pitch time space) is a 'signature contribution to the evolution of musical thinking in the second half of the twentieth century' (2010: 113-114). Its referential lack can explain the response of the serialist movement, themselves a group with a fierce predilection towards musical organicism, denouncing the Donaueschingen premiere as 'full of protoplasm' and 'crammed with glissandos' (Kim, 2000). The glissando would come to define much of Xenakis's later music, a kind of aural

signifier in the sense of both a compositional 'style' but also a gesture towards transmediality itself, and its underlying creative principles (which link to more historic, ancient Greek aspects). Theoretically, this piece could be considered an example of graphical ekphrasis, and in this sense its referentially in the present day is self-fulfilling: one hears such extensive glissandi, and its new status as transmedial signifier creates the historic and cultural reference point. One wonders how *Metastasis* as ballet, choreographed by George Balanchine in 1968, might provide further thoughts when considering the extra transmedial step.

3. Arborescences

3.1 Arborescence as struggle: Evryali

The arborescence is another heavily visual feature which can be said to be transmedialised in Xenakis's music, a notable example being *Evryali* (1973), for solo piano. Described by James Harley as 'both more poetic and enigmatic' (2004: 79) than earlier pieces which exhibited characteristics of arborescences (such as *Synaphaï* (1969)), *Evryali* very clearly demonstrates the possibilities (and indeed, limits) of the form. Indeed, one might consider it a 'proof of concept' work when considering its exceptional nature within the solo piano works, with Ronald Squibbs noting that the work is 'unique' in its utilisation of a single unit of duration is adopted almost entirely throughout (semiquavers at minim = 60) (1996: 147).

Evryali has been written on extensively, so I will not delve into its specific details, but rather pick up on the phenomenal aspect of the work, in the fact that in its first iteration, it is impossible to play: the 'off the keyboard' C-sharps being a prime example (which were corrected in later versions). This demonstrates the incredibly heightened aspect of graphically ekphrastic 'depiction': the system is followed through with total fidelity, rather than compromise. Indeed, on compromise, pianists writing on this work note the necessity of 'struggling' with the work, creating reductions to enable it to be played:

> Supreme challenge: he asks us to take risks and overwhelming responsibilities. I find it wonderful that instead of saying to the performer 'I have written this piece for you, and you are going to play it,' he said to me 'Here is the piece. Look at it, and if you think you can do something with it, play it' (Bucquet 1981 in Harley 2004: 80).

Therefore, the transmedialisation of the arborescence patterns manifest challenges both in theory (the score) and practice (performance). The use of the title, which effectively 'frames' the ekphrastic process therein, alludes to this struggle (fighting the Medusa, Gorgon, etc.) and conveniently rationalises the depictive nature of the ekphrasis by placing it within a referential cultural context of the Greek myth and also the sea, aided by what Harley describes as 'wavelike contours' found within the music. It is noteworthy that the piece originally had no title when Bucquet confronted it, and that Evryali came a month and a half later after Xenakis heard the first few pages. (Bucquet in Kanach 210: 67) Indeed, Xenakis uses similar language of 'struggle' in the context of art and abstraction:

> When the artist works, he may think that he is composing with sensibility because he is attracted by some ideas or by some other things. That might be the starting point sometimes, but in the course of the work, things start 'living' and he's fighting with these things all the times, changing them and being changed by them, so the starting point of his feelings becomes very remote. What remains finally can be expressed in a much more abstract ay because it's the result of that thought'. (Zaplinty & Xenakis, 1975: 91)

This supplements Xenakis's comments relating to the 'inner richness of the hand' when creating his graphic sketches, and the balance between 'intuition' and realisation of forms, somewhat refuting Sven Sterken's comments that '[h]is interest was not in the technically 'correct' translation of such models into music or architecture but in their expressive potential' (Sterken, 2008: 34), at least in the initial case of *Evryali*. It would seem that the expressive potential can be achieved through the framing and rationalisation of the very specific, depictive ekphrastic process, and without wishing to compromise in the transmedialisation process, a title can provide a guiding metaphor for this hermeneutic reading, which in itself strengthens both formal and poetic aspects of the work. One wonders whether a parallel can be drawn between the idea of 'successive approximation', as stated by Helffer (who was referring to the performative aspect of Evryali) and this aesthetic schism between representation and abstraction through the visual-musical transmedialisation. (in Kanach 2010: 100).

3.2. Arborescence, Eco-criticism, and Bricolage in Erikhthon

The two ekphrastic innovations found in *Metastasis* and works such as *Evryali* find their synthesis in *Erikhthon* for piano and orchestra, described as one of Xenakis's 'most graphic' scores (Harley 2004: 83), whereby Xenakis sketched the piano and orchestra parts on two different sheets. This heightened graphic aspect of the music perhaps adds rationale to Helffer's statement that 'Xenakis's technique of arborescences is most highly accomplished in this work'. (in Kanach 2009). Indeed, in the preface to the score, Maurice Fleuret describes Xenakis's process as an 'ideal laboratory' – pertinent to use such language of experiment when considering the concurrent exploration of arborescences in *Evryali* as a proof of concept, as suggested above. Here, like in *Evryali*, we see the role of the title and hermeneutics at play again, which bear upon a reading of the text:

> I did not so much recognize the workshop diagrams as the wonderful burst of vegetal forces, in the music's accelerated growth, the sonorous jungle in which everything flow from the irresistible thrust of nature's sap. The piece well bears its name: ERIKHTHON means 'The strength of the earth'. (Fleuret, 1974)

Readings that invoke this 'natural' aesthetic can further help to provide referential points to the depictive aspects of the arborescence transmedialisation. For example, bar 5 launches a section in the piano that centres on an A_{4p} pitch in a neurotic, almost out of character manner (contrasting with the initial presentation of arborescence in bars 1-4). This is the pitch to which orchestral instruments tune: it is the 'natural' or initial sound of the orchestra for any meaningful rehearsal or performance to be possible. The use of microtonal deviations from this pitch, in the orchestra, serve to create a dialogue between orchestra and piano that bears out in a larger sense through the use of continuous glissando vs. discrete pitch. Indeed, the division of the sketches into two parts (for piano and orchestra) further consolidates this dialogue, the realisation of which follows and modifies past musical/graphical experiments, e.g. the use of glissando in *Metastasis*, perhaps most recognisable at b. 72 of *Erikhthon*, to launch new ones, e.g. the use of breath and key sounds in the woodwinds and brass from bb.bb.-80 which utilise a graphic notation. It is also notable that, like *Evryali*, a metronome marking of 60bpm is used - at once allowing for co-ordination, but adding a further layer of 'natural' time in the matching of chronometric time units (i.e. a second).

The piece is thus experienced as the dialogue between these two sonic events, traceable not only to the depiction of arborescence form and other graphic derivatives, but to its referential understanding as a possible piece of 'eco-criticism': being 'of the Earth'. This piece could be a good example of what Dimitris Exarchos describes as technical 'bricolage' in Xenakis's work which 'introduced new compositional tools, such as graphics, whereby the composer either freely composed graphic schemata, or created these via probabilistic computational processes, before transcribing them into musical ideas and notation' (2019: 24). I would go further, however, and claim that it shows not only a technical bricolage, but a bricolage of transmedial tendencies which project beyond the technical,

and begin to more explicitly consider the dramaturgy and narrative of the piece from an ekphrastic perspective, framed by the evocative and guiding title, amidst the groundwork laid out concurrently in *Evryali*. Indeed, Exarchos relates bricolage to Benoit Gibson's (2011) study of self-borrowing in Xenakis's work, and this is a fertile area for further study with respect to the interaction of texts, particularly when considering the similarly titled ballet *Antikhthon* (1971), commissioned by Balanchine (coincidentally referenced above with respect to the choreography of *Metastasis*). This tying together of technique, poetics, and form, could give credence to Gibson's summation that in *Erikhthon*, 'Xenakis gives his imagination free reign' (2011: 43).

4. Transmedial Aesthetics

The heightened sense of ekphrastic depiction in Xenakis's works explored above – which yield both innovation and problems – creates a schism in representation: wanting to find these new forms of sound and music, but at the cost of cultural referentiality, creating what might be deemed a 'lack' in the artwork (as Derrida might argue). One could argue this would place some Xenakis's approach close to the realm of sonification in terms of a transmedial process, described by Carla Scaletti as 'a mapping of numerically represented relations in some domain under study in relations to an acoustic domain for the purposes of interpreting, understanding, or communicating relations in the domain under study' (Scaletti in Worrell (ed.), 2011: 312-313). Xenakis's highly detailed graphs, which can be said to utilise discrete data points and relationships, surely attest to this possibility of absolute depiction. However, in her somewhat polemic article, 'Sonification ≠ Music', tries to highlight the incompatibility of sonification processes with musical ones:

> Sonification is not a mapping from a visualisation to sound; it's a mapping of the original source data to sound. In other words, a sonification is not a map of a map; it's a map of the territory. (Scaletti, 2019: 371-372)

Perhaps Xenakis was sympathetic with this viewpoint, particularly in the years following these initial experiments, when he claimed that '[i]ndustrial means are clean, functional, poor. The hand adds inner richness and charm.' (Xenakis, Brown, Rahn 1987, 23). The development of the UPIC system seems to be a natural embodiment of this position, and the arborescence shapes seen in Mycanae Alpha (1978) show the shared representational concern across media.

Xenakis's rather unique ekphrastic approach can be understood through applications of fuzzy logic: a system designed specifically to grapple with vague or imprecise statements. Like ekphrasis, this seems similarly fitting when considering the rich applications of logic within Xenakis's works such as *Herma* (1961). Unlike Classical logic, in which statements are objectively true or false, fuzzy logic allows for many-valued logics, where truth-values are interpreted as degrees of truth. Taking values [0, 1], where 0 has no place in the fuzzy set, and 1 completely belongs, any value between 0 and 1 implies a degree of uncertainty. Heister has produced a mammoth (and sometimes unclear) work with respect of applying fuzzy logic to music, applying it music from the Renaissance to the present day. His introduction is particularly pertinent with respect to how ekphrasis might operate in this framework, where he states:

> In the light of Fuzzy Logic, relations of music to reality, relations between various layers, between sensorial modalities, and between phases or forms of existence of music, receive new and precise contours during the musical process (2021: 3)

These 'new and precise contours' can be understood as one extreme of the transmedial spectrum, and can align with notions of sonification: a mapping of accurate relationships across data to sound (a value as close to 1 as possible). The 'fuzzy' aspect of this logic should not be confused with 'vagueness', and Zadeh demonstrates the difference between the two:

> [I]n my perception, vague and fuzzy are distinct concepts, with vagueness pertaining to insufficient specificity whereas fuzziness relates to unsharpness of boundaries. For example, "I will see you sometime," is vague and fuzzy while "I will meet you at approximately 5 pm" is fuzzy but not vague. (Zadeh in Heister, 2021: 5)

In a transmedial, ekphrastic framework this fuzziness is possible due to the connection put in place with the source object, e.g. architecture, arborescence, etc., and thus the process of transmedialisation will create a value between 0 and 1. It is the difference between a composition about 'rivers' and 'the River Thames', or a river's 'shape and contour'. Indeed the relationship between the texts in a transmedial process, and indeed their relation to fuzziness and representation, can be usefully explained by Genette's concept of 'hypertextuality' and its categories of 'transformation' and 'imitation', where the former 'transpose[s] a style or subject into another text', and the latter is 'to form a hypertext precisely after the model of the hypotext' (see Genette 1997). In the transmedial framework, imitation would fall under sonification (a truth-value closest to 1), and an transformation would constitute an ekphrasis (between 0 and 1).

Xenakis's evasion of graphic, indeterminate scores creates a discrete set of musical data that can be analysed with respect to it suggested ekphrastic source; this is particularly true of *Metastasis*, *Erikhthon* and other works which have clear graphical sketches publicly available. From an musicologists perspective, much analysis is carried from the view of Nattiez's external poetics, "[the] musicologist takes a poietic document – letters, plans, sketches – as his or her point of departure, and analyses the work in light of this information' (1990: 141). It is these poetics that will determine the perceived truth-value of the work and its degree of fuzziness when performing this specific reading (i.e. one centred on the relationship of the musical and graphic). A visual example might be usefully set up as follows:

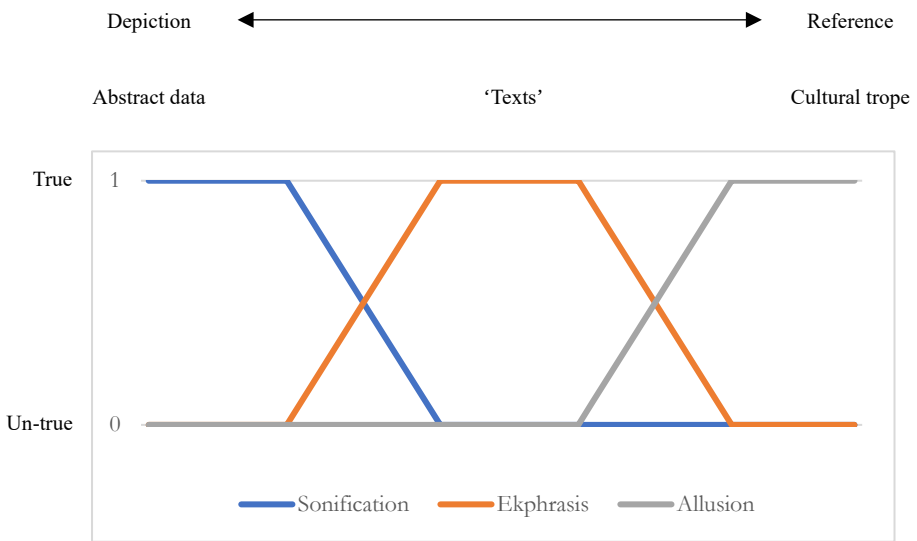

Figure 1. A visualisation of how fuzzy logic may be applied to Xenakis's transmedial music

One could argue that Xenakis's music sits in the area between ekphrasis and sonification, in terms of its aesthetic presentation. The position on this spectrum is largely constructed through the framing of the work itself: what it sets up, what Xenakis alludes to hermeneutically, etc. The cultural aspect of reference here is doubly interesting when considering a temporal aspect, i.e. the differing impact of a work such as *Metastasis* in 2022 vs. 1954, and how/why an aesthetic judgement may change. Arguably, one might see these different representational levels and aesthetics as Xenakis's 'internal conflict' mentioned in *Formalized Music* as the 'opposition between the sonic realization and the symbolic schema which plots its course' (1968/1992: 110) – perhaps the aesthetic implications here form a sort of 'external conflict' between depiction and reference from an ekphrastic perspective, rhyming with Nattiez's external poetics. Nattiez's fifth analytical situation could perhaps be a fruitful new direction of research for music psychologists, and would allow for these aesthetic and perceptive notions to be more empirically explored, when applied within this fuzzy framework. Anecdotal evidence highlights the impact of Xenakis's music on audiences: its 'directness', 'accessibility' etc. - and this resonates with Nattiez's listener-centric means of meaning-making:

> [Music] can evoke the past by means of citations or stylistic borrowings, but it cannot narrate, cannot speak what took place in time past … Literary narrative is an invention, a lie. Music cannot lie. The responsibility for joining character-phantoms with action-shadows lies with me, the listener, since it does not lie with music's capacities to join subject and predicate. (1990: 128)

Having said this, there is tension established with the music's agency to create meaning through a composerly criticism of an ekphrastic subject. The processes of transmedialisation, particularly in the work of Xenakis (which led to profound and meaningful contribution to techniques in contemporary music), alleviates (but does not totally remove) this 'responsibility for joining'. The intermedial aesthetic, redistributes creative agency by virtue of non-programmatic textual interaction:

> [T]he arts themselves have no power to aggregate or to separate–they are neither one nor many but will gladly assume the poses of unity or diversity according to the desire of the artist or thinker (Albright, 2014: 3-4)

5. Conclusion

This returns to questioning the efficacy of applying ekphrasis to Xenakis's works. Of course, there is a limitation within this study, insofar as ekphrastic thinking (or particularly that of graphical ekphrasis) can only be appropriately applied to those works in which there exist highly visual representations (or subjects), present usually though sketches. The re-visiting of the three works with this focus, I hope, demonstrates some utility in this approach: adding new hermeneutic lenses and fields of enquiry that can stimulate further interdisciplinary or intertextual enquiry. This paper does not claim to offer concrete solutions to questions of 'meaning', rather it hopes to contribute to the esoteric field of Xenakian aesthetics: to blur, to problematise, to re-think. Xenakis positioned himself well in his commitment to intermediality, in some ways showing a similar intention to not 'answer' these encompassing questions - such would be perhaps reductive:

> "The role of the musician must be this fundamental research: to find answers to phenomena we don't understand, and to enlarge our powers of conception and action. So, it is a perpetual exploration". (Lohner & Xenakis, 1986: 54)

Interestingly, of the works discussed, it seems that the process of transmedialisation shows that these

are phenomena which Xenakis *does* understand, e.g. in his applications and design of ruled surfaces and arborescences, but his 'perpetual exploration' is to communicate these in a new medium. Through a more diverse situation of Xenakis's works within the aesthetic ideas outlined herein, not only can listeners and critics hone in on a locus on meaning-making, but also composers themselves can begin to think critically on the role of transmediality. I believe this can already be seen in the effect that Xenakis had on his own students, such as Pascal Dusapin (particularly in works of the 1990s, which contain images in their prefaces),[2] and the renewed interest in his UPIC system and its applications.[3] Indeed, the communication of the graphic aspect of many of Xenakis's works is becoming increasingly prominent and widely available, thanks to the work of Pierre Carré and others. [4] Thus, we can see an increasing interest in Xenakis's intermedia, and the frameworks outlined in this paper can be useful for traversing not only the acoustic music (which has been the main focus herein), but also Xenakis's electroacoustic and computational music.

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2 See *Loop* (1996), *String Quartet No. 4* (1997), *Cascando* (1997), *Piano Etudes* (1999-2002).

3 See Weibel, Brümmer, Kanach (eds.), *From Xenakis's UPIC to Graphic Notation Today*, Berlin, Hatje Cantz Verlag, 2020.

4 E.g. P. Carré, 'Pithoprakta (w/ graphical score)', https://www.youtube.com/watch?v=nvH2KYYJg-o (2017)- similar examples can be found online. Indeed, one for *Evryali* exists where the final section of the video visualizes the music in a midi interface, exposing the arborescences, created by user 'allarmunumralla': https://www.youtube.com/watch?v=g3qYqmOD-qU (2012)

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About Iannis Xenakis´ External Conflicts.

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Abstract

Iannis Xenakis starts his project of musical discourses at the end of the fiftieth with DUEL (1959) for two orchestras and their leaders. They enter into an ´external conflict´ beyond the internal relation between composer, score and interpreter. The interaction is formalized as a zero sum game and based on a game matrix fixing the opponents´ actions as ´tactics´ and the results of their coincidences as payments. This game-theoretical frame, valid for STRATÉGIE (1962) and later for the instrumental fight LINAIA AGON (1972) too, can be filled out in different and partly divergent ways, motive for a workshop with proposals, debates and a special focus: The composer has set an extraordinary accent concerning the orchestra games by inviting " the public to evaluate the pairs of tactics of conductors X and Y and to vote immediately on the make-up of the game matrix ". To interpret this challenge and to provide tools for the participants to reflect a realization, the workshop shall be organized around these main topics:

The choice between two principal game types, one with simultaneous moves without knowledge of the adversary´s parallel decision, the other with alternating actions and reactions. Xenakis has calculated all his game matrices after the first model based on imperfect information and mixed strategies, but in the prefaces for the DUEL and the STRATÉGIE scores he demands clearly sequential decisions ´as in chess´.

A qualitative ranking of sound combinations in DUEL relating subjective preferences with game actions, against abstract evaluations in STRATÉGIE without relation between music and payments.

The analysis of DUEL and STRATÉGIE in extensive form, a notation to find equilibria and optimal strategy profiles in sequential games. It can be shown that the composer´s calculations favor always one conductor (the one who plays the matrix rows) independent whether he starts. He has in terms of the theory winning strategies that cannot be crossed out whereas his opponent has none. Xenakis who takes care of the fairness of his games has certainly not intended this structural inferiority, a consequence of different equilibria conditions in simultaneous and sequential games.

A concept to balance the games. Tools like subgames, subgame perfectness, backward and forward inductions shall enable the participants to find new solutions, game constructions with win or at least draw strategies for both conductors. Possibilities shall then be discussed,

to accept Xenakis´ invitation, for example by aggregating assumed or observed preferences or by a collective voting over proposed matrices.

The workshop is focused on theoretical questions rather than organizational tasks, but points like the conductors´ difficulties to find optimal strategy profiles in real time or the communication between all actors shall be kept in mind.

Finally, the thesis shall be debated that Xenakis´ fundamental concept to combine music and strategy has potentials beyond antagonistic conflicts. Game theory investigates a wide specter of interdependent decisions reaching from strictly non-cooperative situations to coordination and cooperation, thus perhaps providing incentives for further compositional experiments.

Participants can get material for the workshop (introductions, algorithms, proposals, references) in advance by contacting the author.

Immersive landscape
recomposing the sound of a public square

3 days Workshop for Xenakis 22 Centenary International Symposium proposed by **Cecile Regnault** architect professor in Lyon architecture school France and
Gilles Paté visual artist, teacher in Versailles Architecture school, (France)

Participants (sound designers, composers, architects, visual artists, acousticians...) : maximum number of **12**

Description : As in Xenakis Diatope sound installation, the workshop will propose experimentations around the idea of a total immersive space, starting from the soundscape of a real public square. The participants will record its atmosphere, edit a sound diagnostic of the space and then realize a projective recomposition of its sound ambiance. The result of the workshop will be an image by image editing film combining the existing atmosphere of the square and its projected ambiance, on the thematic of immersive sound environnement in the city.

An immersive atmosphere includes movements of the pedestrian, changes and transitions, and maybe physical elements of design or architecture to provide specific conditions of attention to sound. A new scenography can be imagined, combining the caracteristics of the existing soundscape and additions for a particular sound journey . This fiction starts from the documentary part of the analysis of the square to develop its thematics.

Sound in the city is already immersive, but usually in an overlapping way : trafic drone, sonic events of construction sites, trains... the projection could emphazise micro-sound events to create an atmosphere, such as textures of the ground, vegetation or birds, but also technical sounds present on site such as climatizers, underground openings, technical sounds of machines... Create an immersive ambiance could also recombine existing sounds in a musical recomposition on the lines of specific paths through the square.

Some examples of outdoor « sound labyrinths » exist like the sound installations of Eliane Radigue that work more on a sound journey than a frontal stereo composition. Xenakis also composed in three dimensions and his orchestral compositions like Jonchaies (1977) developped iwith a full spatial presence. Let's also quote Art of Failure reinjecting sound of specific architectures on site.

The visual part of the video, a diaporama, can be composed of views of the existing square and a projection of an urban renewal of the square, but it can also be made of drawings, animation, 3D or photos of real models... the rythm of the editing, from long frames to stop motion editing, will reinforce the immersive atmosphere of the soundtrack.

The workshop team will provide sound recorders, the participants are invited to bring a computer with an editing sound program such as the freeware audacity, and a video editing program. The organizers could help with a projection room to show the creations in good conditions of image and sound.

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Cv

Cecile Regnault is architect, teacher in Lyon architecture school (France) and its research laboratory evs-Laure umr 5600, she directed different projects on urban soundscape including the realization of permanent sound installations in public space (chime, kiosk).

Gilles Paté is visual artist, teaching art and sound in Versailles architecture school,where he created the sound Studio, an experimental workshop devlopping scale one interactive sound installations.

Insect sound ecology and stochastic models

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Daniel Brown (Intelligent Music Systems, USA)
Natalia Kotsani (NTUA, Greece)
Anastasia Georgaki (NKUA, Greece)

Composers and researchers in acoustic ecology use signal processing tools and techniques to understand the behaviour of insect swarms, their social organization, and how they are divided into groups all over the world.
In this workshop, we will study two different approaches that connect the research fields of the acoustic behaviours of Cicadas from Greece (*Cicada Orni*) and selected Cicada species of the genus *Platypleura* from South Africa, as tools for stochastic composition inspired by Iannis Xenakis' research and compositions. In this way, we connect the science of bioacoustics with the exemplary synthesis of micromodels from microstructure to macrostructure.

The 'composer-technologist' paradigm is a useful departure point for the investigation of compositional process, models, applications and ontologies in the pursuit of understanding and developing compositional techniques in electroacoustic music.
The workshop presentation here, aims to demonstrate some subjective explorations of these processes from the perspective of the presenter and includes inspiration from some of Xenakis's own models adopted as well as from those that have made significant contributions in the fields of cognitive musicology and electroacoustic music analysis.
Of these models, processes and techniques, those that explore task-environment models, problem solving and heuristics, gesture spaces, creative ontologies, bio music and biomimicry will be discussed alongside examples from various electroacoustic compositions by the presenters. Included in this is how analytical data can be used compositionally and how information from analytical tools such as spectro- and spatio-morphology can further inform task environment procedures in the overall process of electroacoustic music composition. As part of the special cases presented in the workshop, data collected from the phonotaxis of insects (cicadas) and also mosquitoes have been used to inform various models useful in compositional task environment applications. Examples of these will be given and demonstrated, where discussion can ensue about further possible applications of cross-border (linking Greece and South Africa) computer music performances using such models.
From this, we are intending to demonstrate and create novel creative outputs from adopting these techniques by drawing on established approaches to creative-problem solving given to us by important figures across electroacoustic music, particularly Xenakis and others that have put-forward interesting methodologies.

In the second part of the workshop, different rhythm levels of cicada behaviour will be analysed, focusing on how specific parameters change in the presence of other singing cicadas, and the overall sound of the produced polyrhythms in a group of cicadas. We will examine a set of parameters corresponding to stochastic deformations of sonic material in order to produce behaviour exhibited by a cicada chorus. A multidimensional lattice model will be used for the spatial arrangement of cicadas, and the resulting dynamics of the cicada chorus will be studied while selected parameters are changed through the MAX/MSP environment.

Perspectives for developing this project which is mainly based on microcomposition and stochasitc modelling of the cicadas, will include spatial applications in augmented aurality as also the creation of a live streaming sound bridge of different species of cicadas in specific geographical sites overpassing the ecological and biological constraints of these species.

Synchronized Spatial Performance of Graphic Scores and Computer Assisted Composition with MaxScore and Drawsocket

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Abstract

During this workshop we will guide participants in the use of new notation software developments in MaxScore and Drawsocket, inspired by Xenakis' formalized compositional approaches and work on the UPIC (Unité Polyagogique Informatique CEMAMu) graphic notation to synthesis system.

MaxScore is a computer aided composition toolset that assists composers and performers in the creation and digital performance of common practice and graphic notation in the multimedia graphical programing environments of Max and Ableton Live.

Drawsocket is a platform for networked score display, for use in coordinating spatially distributed performances and realtime notation creation. By making use of web-browser technology Drawsocket provides a framework for bi-directional communication channels, touchscreen interaction, and poly-temporal synchronizations.

In the context of the Xenakis 22 Symposium, we will lead a hands-on workshop exploring the use of the MaxScore/Drawsocket system for the application of Xenakis' generative and experimental notational approaches. Attendees will have assistance from the authors for using the software for the generation of common practice and graphic notation, from computational models to playable spatially distributed scores.

In conclusion, we will introduce an experimental software called Symbolist, that uses Drawsocket as a front-end GUI. Inspired by the UPIC system, Symbolist is an in-development graphic notation and performance application designed around the principle of bidirectional mapping between graphic and symbolic notation for multimedia composition.

Through the course of the workshop we hope to stimulate discussions on the problems of notation and representation in digital media, and think together into the future of what scores for new forms of spatial and temporal media might look like, and what tools and skills might be required to create them.

16-Track GENDYN: A Multichannel Resynthesis of GENDY3

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Abstract

GENDY3 by Iannis Xenakis (1991) is a pure algorithmic composition generated by Xenakis' original GENDYN program. The idea of this program dates back to the 1950s when Xenakis conceived of a music entirely calculated by computer, i.e. with calculated musical structure and calculated sound. After a few intermediary stations (his Stochos Program of 1962, his 1970s research in stochastic sound generation), this idea culminated in the creation of GENDY3 and ended with the composition of S709 (1994). In 1997, after having been granted access to Xenakis' working place at CEMAMu, I was lucky to regenerate GENDY3 with the help of my New GENDYN Program, a generalized and graphic re-implementation of Xenakis' GENDYN program, originally intended to serve him as a workspace for the composition of more stochastic compositions. Almost 25 years later, and just in time for his 100th birthday, I generated the 16 tracks of GENDY3 as separate sound files for pedagogical and musicological purposes as well as a prerequisite for tentative performances of GENDY3 in space.

1. Introduction

Xenakis' electroacoustic piece GENDY3 (Xenakis1991) is a stereo piece, however, its generating algorithm GENDYN is mono synthesis. The published version of GENDY3 (as well as the original DAT tape for performance) is just a combination of two such mono sound files, with a time delay of about 100 milliseconds between them. For performance, Xenakis suggested 4 loudspeakers around the public with the stereo in front and (reverse) stereo in the back[1]. However, even when projected onto 2 or 4 loudspeakers, the musical artefact as such is still mono.

Internally, however, a GENDYN piece is created by synthesizing 16 tracks (or in the case of S709, 8 tracks) of stochastic sound “in parallel”. Yet, at the end of this “parallel” multi-track computation, the GENDYN algorithm mixes these 16 tracks down to one single mono output[2]. In other words, for each sample of the resulting mono sound file, the contributions of an array of 16 independent “stochastic oscillators” are summed up to yield the resulting mono “master” amplitude value. In order for the master amplitude not to exceed 16 bit PCM amplitude (i. e. 16-bit MAXINT), Xenakis took care to have each of his 16 stochastic oscillators only emit low amplitude values.

The challenge for me was to get the 16 parallel tracks of stochastic sound out of the program in order to create 16 individual GENDY3 track sound files. In other words, the idea was to make the implicit multi-channel GENDYN synthesis explicit. This is of course not possible by trying to “split” the mono sound file into its 16 layers of sound. The only solution is to re-generate, by synthesis, one after one, each of the 16 tracks “solo” by muting all the other ones.

1 Around 1996, I saw a sketch by Xenakis for his suggested spacial performance setting of GENDY3. I do not remember where that was, and I am not able to locate this document. Maybe the reader knows better.

2 A graphical represntation of this procedure is given by Xenakis in [Xenakis1992], p. 299. Sixteen boxes are plugged into one box which is the output of the synthesis.

The first thing I did with these 16 sound files was to mount them one on top of the other in an audio editor and listen to the result in order to be convinced that the result is exactly GENDY3 as we know it. However, as a consequence of the resynthesis procedure, the sum of my 16 tracks differs in some minor details from Xenakis' original mono output.

In this paper, I describe the procedure leading to 16-track-GENDYN in detail. Then, I discuss the differences between GENDY3 on CD (or DAT) and my 16-track-resynthesis. The mission of my project is to hand over my 16 tracks to the public, for study, pedagogy, or tentative spatial performances in the future ([Hoffmann2020]).

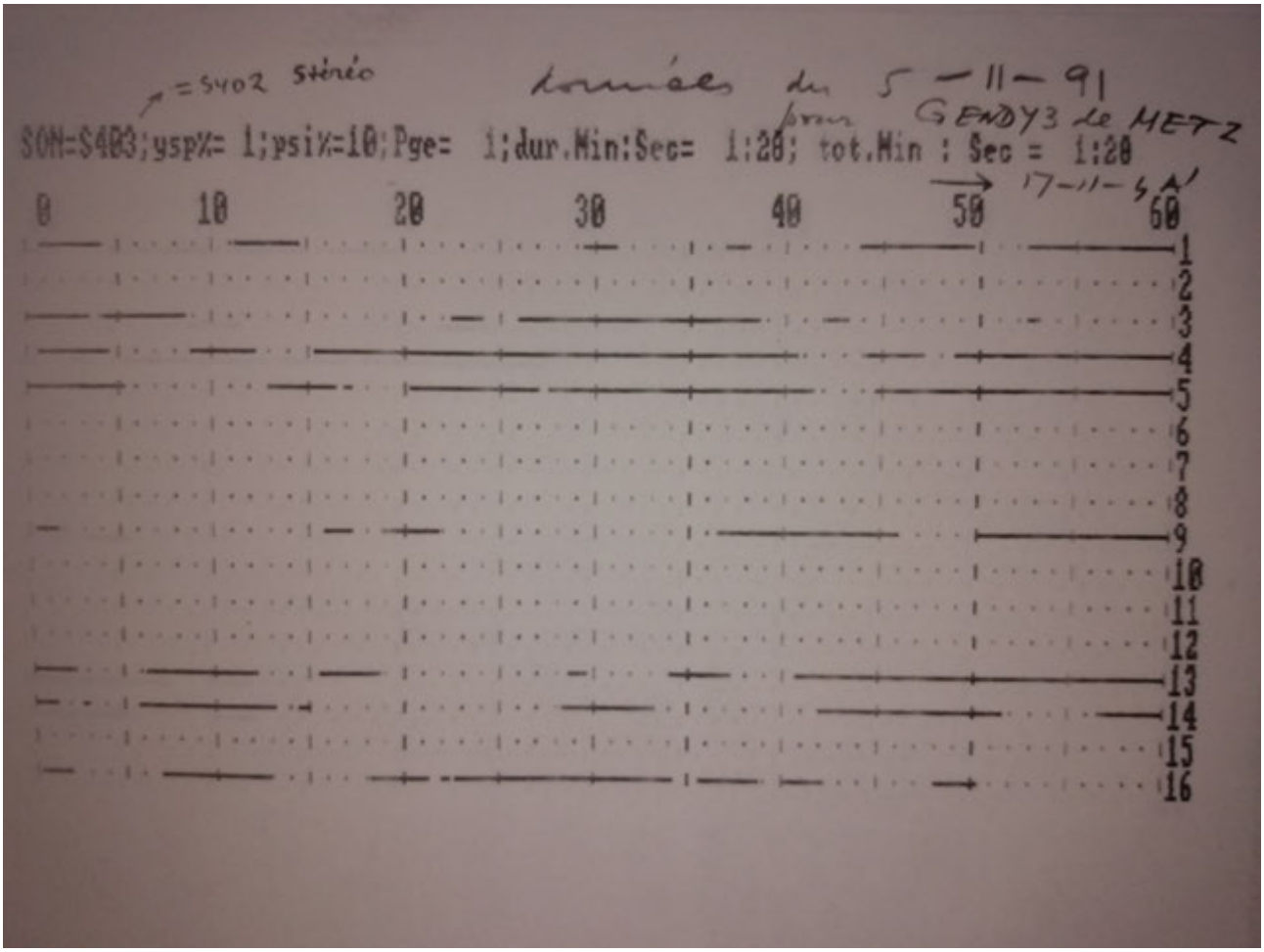

Figure 1: Xenakis' annotations on a printout representing the first 60 seconds of GENDY3

2. Gendy 3 or GENDY3?

On the CD sleeve, Xenakis' 1991 piece is spelled “Gendy 3”. The same spelling is used in the official catalogue of [Salabert2021]. However, in Xenakis' own documentation of the two program runs that created GENDY3 in 1991, he clearly marks GENDY3 as the title chosen (see figure 1). I owe this clarification to Folkmar Hein who understandably asked me how my resynthesis should be spelled for his International Documentation of Electroacoustic Music ([Hein2020]). Without having intended to do so, I think the different spelling is a good discrimination between Xenakis' published version and my resynthesis.

The original spelling GENDY3 by Xenakis is, in my understanding, inspired by the (in)famous limitation of file names under Microsoft's Disk Operation System (DOS) that Xenakis used. It was simply not possible, on a Microsoft system in 1991, to have a file named “Gendy 3”, neither for the small letters nor for the space character. Moreover, a file name was limited to 8 characters maximum, optionally followed by a point and 3 characters of file name extension. This limitation was exhausted

by the file name of Xenakis' program “GENDY301.BAS” which synthesized GENDY3 in 1991. The file name extension “BAS” stands for “(Quick) Basic source code file”. The digits “301” possibly represent a version number (in the world of programming, version numbers often consist of 3 digits). The remaining 5 characters GENDY refer to GENDYN, an acronym for “GENération DYNamique (Stochastique)” (French) or “Dynamic (Stochastic) Synthesis” (English). Xenakis had to sacrifice the N of GENDYN to the file name convention of DOS, and maybe this could be the reason for the shorter spelling “Gendy” in his catalog of works.

In constrast, the spelling of the GENDY3 follow-up-piece S709, in 1994, found its way unaltered into the catalogue and onto CD. With the letter “S” followed by an ordinal number, Xenakis used to denote the current sound file created on his hard disk. GENDY3 is a combination of S402 and S403, as evidenced by Xenakis' notes (see figure 1).

3. Resynthesis

I have stated that my 16-channel version is an alternate resynthesis of Xenakis' GENDY3 piece. But how is it possible to do a resynthesis of such a piece in the first place, given the fact that the music is stochastic in nature, i.e. governed by randomness? Fortunately, Xenakis' GENDYN program is not driven by pure chance but “only” by pseudo-random numbers. Actually, it is rather difficult to simulate perfect chance by numeric means in a computer[3]. Classically, random numbers are created by recursive functions implementing a kind of numerical “fold-and stretch”-algorithm (in the simplest case, multiplication followed by modulo operation). Xenakis used the so-called “Lehmer” formula for the random numbers driving the amplitude modulation[4] in GENDY3:

$X_{n+1} := X_n * a \bmod m$

For the frequency modulation of GENDYN, Xenakis used another, built-in, random number function of his QUICK BASIC PRO runtime system. Both random number generators have to be started with a “seed”, i. e. a first number X_0 from which to continue the random number sequence. Often, programmers choose for this seed the timestamp of the current system time, impossible for a spy like me to recover. Fortunately, Xenakis did not do what regular programmers do but wrote a fixed seed into his program text. Therefore, a program run years later is able to reproduce the same results. (The fact that Xenakis' 1991 version of the program GENDY301.BAS was lost and had to be reconstructed by me from a printout is another story told in [Hoffmann2009]).

In fact, pseudo-randomness is nothing else than chaos, in the scientific sense of a deterministic process that is sensibly dependent on its starting and border conditions. If conditions are exactly the same, the end result will be identical. However, the slightest deviation in starting and / or border conditions will result in dramatically different output. So the challenge of my resynthesis was to provide for the exact same conditions that were governing Xenakis' program run in 1991.

3.1. Step #1: Running Xenakis' original program

The re-run of Xenakis' (reconstructed) original program GENDY301.BAS in 1995 was the first step (see 2nd lower box from left in figure 3). I compared its musical output to the version published on CD, and found it, by musical memory, to be identical. (Only much later, in Jan 2022, for sake of scientific exhaustiveness, I compared both versions side by side and discovered the differences which will be discussed below.)

The next step was to develop a new program that would be able to create the same music but in real time (instead of days of computation), and to have visual and interactive control over the synthesis, in order to better understand the genesis of the composition. It was a combination of CEMAMu's

3 See [Haahr1998] for an entertaining overview and a true random source.

4 For a discussion in how far GENDYN is essentially a combination of (stochastic) amplitude and (stochastic) frequency modulation, see e.g. [Hoffmann2004].

wish for adding a Graphical User Interface (GUI) to Xenakis' program and my own wish to get real-time aural and visual feedback for Stochastic Synthesis. As a result, I was hoping to present Xenakis a refurbished version of his original program and to enable him to compose many more stochastic pieces with it. In 1996, I was able to synthesize a single GENDY3 track in real time on an Intel DX4-86 75 MHz processor. (Xenakis' own computer in CEMAMu had a DX2-86 66 MHz chip.) Later, all of 16-track GENDYN became real-time on a Pentium 4 processor[5]. My GUI interface would allow me to change parameters in real time and also show me the various steps of the stochastic computation in the form of random number distribution graphs and “billiard ball” animations of the various random walks[6]. From that moment on, I worked with the new program which I called “The New GENDYN Program”[7]. This name was an allusion (slightly presumpteous) to the branding of the “New UPIC System” that CEMAMu had created shortly before.

3.2 Step #2: Running the New GENDYN Program

The resynthesis of GENDY3 with the New GENDYN Program (see 3rd lower box from left in figure 3) posed three challenges. The first challenge was that I had to build into the new program all idiosyncracies and even bugs of Xenakis' original programming because I needed to get the same results. (A bug in a composer's program creating a masterwork of art is, from an artistic perspective, not a bug but a feature).

The second challenge was that I had to (re-) define the huge parameter sets that Xenakis had used for each of the 11 sections of GENDY3. Xenakis had written an entire set of auxiliary programs called PARAG.BAS only to define these parameters hard-coded into program text (one can see an excerpt in [Xenakis1992], page 300). I did not want to do the same, so I translated Xenakis' parameter program(s) into a text file that is read on startup of my New GENDYN Program.

The third challenge was that I had to emulate the built-in random number sequence from the QUICK BASIC PRO runtime system in my C++ programming. The only solution that I found in the end was to save to disk, while synthesizing GENDY3 with GENDY301.BAS, one random number file for each of the 16 tracks and for each of the 11 sections of GENDY3. On resynthesis, the New GENDYN Program would read these random number files and therefore reestablish GENDY3's unique random number sequences. If one has no access to these 100 or so random number files one is not able to resynthesize GENDY3 with the help of the New GENDYN Program.[8]

I combined the acoustic result of step #1 with that of step #2 into a stereo sound file and listened to it by headphone. The two channels sound equal except for a glissando pitch movement in the before-last section (starting on 16'46” which corresponds to CD release 15'50”). This glissando slowly gets polyphonic between the left and the right channel, at first by microtonal deviation and then more and more until it splits up into two independent glissando voices, one on the left ear, one on the right. At first, I was very frustrated that I had failed to entirely reproduce Xenakis' masterpiece. Only later I understood how lucky I had been that my resynthesis was distinguished by a birthmark of its own. It makes it evident, while listening, that my resynthesis is a really a resynthesis and not a copy.

5 This is true for all but one section of GENDY3 which was too calculation-intensive for my hardware. One can clearly hear (and see!) this in a video I made of the New GENDYN Program computing GEND3 in real time ([Hoffmann1997]).

6 See, e.g. [Hoffmann2004]. As a matter of fact, Xenakis, too, had visuals in his GENDY301.BAS: it would display the resulting waveform on his computer screen. (The practical value of this waveform display, in my view, was only to show that the program was still running.) He also had a printout of the GENDY3 „score“ in form of a kind of piano roll notation, but only indicating sound duration, not pitch (see figure 1).

7 See [Hoffmann2000] with the same title.

8 Even worse, I also had to read from disk the saved positions of all time random walks at the start of each of the 11 sections. So, to put it bluntly, my resynthesis only works within the time span of a GENDY3 section, i.e. only a few minutes of music.

3. Step 3: Running the New GENDYN Program 16 times in a row

The last step leading to 16-track GENDYN was to run the New GENDYN Program 16 times in a row with the same parameter input except for the “Active Tracks” parameter. At each turn, I changed it in a way that all tracks were muted except for the one I was interested in (see figure 2, imagine that I unchecked all but one “Active Tracks” box). I let the program compute the whole GENDY3 piece (about 20 minutes), writing only the selected track to disk. In sections where, according to the presets of Xenakis, the selected track is not part of the synthesis, only zeros are written to the sound file. As already mentioned, I superposed the 16 tracks in an audio editor and listened to the result in order to check that the sum of these tracks, played simultaneously, equals the mono output of one single program run with all tracks activated.

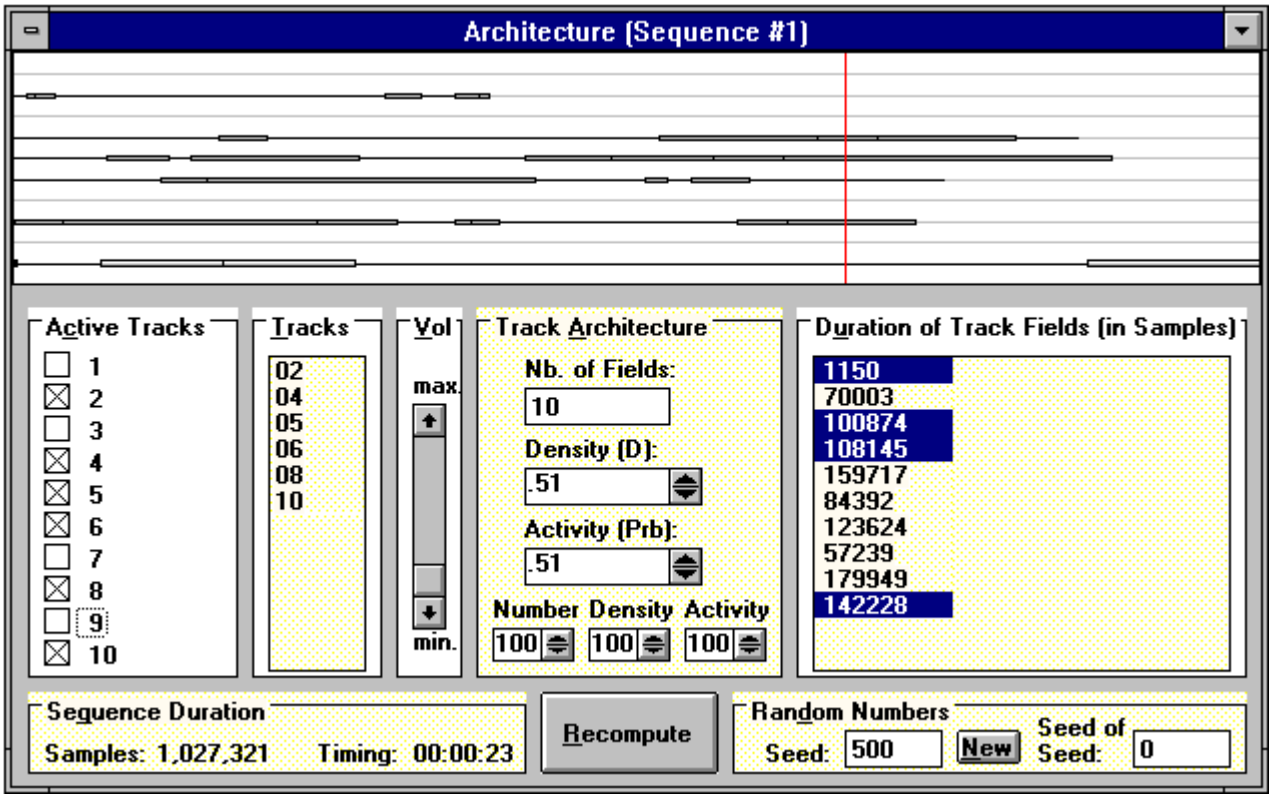

Figure 2: A Screenshot of the New GENDYN Program showing the control panel for a section along with the graphics for sound patch layout (called “sound architecture” by Xenakis). Tracks can be activated or muted in the leftmost column of checkboxes.

4. The Genealogy of 16-track GENDYN

In the following, I describe in detail, following the steps above, how each stage in the genesis of 16-track GENDYN slightly differs from the preceding stage by a specific aspect. In order words, following the genesis of 16-track GENDYN, I show how it is implied by and at the same time deduced from Xenakis' work

4.1. From one GENDY301.BAS program run to the next

To begin with, even the two channels of the CD recording itself are not 100% identical (see the two leftmost arrows in figure 3). There is an unstable sound in sequence #4 (section #7, between 10'00 and 12'00) appearing for the first time at 10'53” and then intermittently, but which eventually dies out on the right channel earlier than on the left channel, creating a stereo panning effect. This is a welcomed proof that Xenakis did not simply copy the mono output of his program onto the two stereo tracks of the released DAT tape (later to be transferred onto CD) but that he combined two subsequent

program runs, as postulated by his own documentation.[9] The starting conditions of the second run must have been different as a result of the first program run, not for the time random walks because pitch movement is identical, but for the amplitude random walks. Maybe the positions of the amplitude random walks were not reset to zero when starting the second run, causing the unstable sound to mute earlier.

4.2. From the GENDY301.BAS program output to the CD release

For more than 20 years I was convinced that GENDY3 as released on CD is the pure combination of two consecutive program runs of Xenakis' original Quick Basic program GENDYN.BAS. I was so convinced that I did even not bother to check. However, when compared side by side, it becomes obvious that there are, on the whole, 75 seconds of sound missing on the CD recording (see 3rd arrow from left in figure 3). This is, compared to the length (20'00") of the original program output, a truncation by 6.25 percent. Xenakis had cut out, here and there, seconds off the generated sound file in order to obtain a tighter timing of the piece. He cut some silences (as he did with his later piece S709[10]) which tend to occur towards the end of sections by design of the GENDYN algorithm. He extended this editing to some isolated sounds towards the section ends. And then there is one big cut: 40 seconds of wonderful noise have been sacrificed by Xenakis from about 4'54" to about 5'34" in spite of the fact that he once called noise "the richest sound"[11]. This big cut, then, is followed by almost no cuts as if the composer had lost interest in editing his music for the rest of the piece.[12]

I have taken the effort of trying to locate and cut the same spots out of the GENDY301.BAS output as Xenakis did back in 1991, so as to align the 93.75 percent of published GENDY3 sound with the original computer sound (the former on the right ear, the latter on the left). The result, then, is 100% identical music on both ears. Even the unstable sound mentioned above aligns on both ears because, by chance, I combined the left CD track to the output of my program run. To sum up, program output and CD recording are identical modulo cuts.

4.3. From GENDY301.BAS resynthesis to New GENDYN resynthesis

In 1997, I combined the output of Xenakis' GENDY301.BAS program (3rd arrow in figure 3) with the output of my New GENDYN Program (4th arrow in figure 3) into a stereo soundfile. The result, when listening with headphones (Xenakis' program output on the left, my program output on the right ear) is identity, with the one exception mentioned above. However, when zooming into the wave forms with an audio editor, they look extremely different. I did not care to reconstruct the exact amplitude random walks, and I even used a different formula for breakpoint interpolation. Therefore, my resynthesis is the same music but is built of completely different sample values.

4.4. From the New GENDYN resynthesis to 16-track GENDYN

23 years after my GENDY3 mono resynthesis of 1997, I finally realized a synthesis of the 16 individual GENDY3 tracks with the same New GENDYN Program (see 4th arrow vs. the rightmost 16 arrows in figure 3). My motivation was to produce sound material that would allow to better understand the making and the fabric of GENDY3 (in its raw, uncut computer version) and to possibly enable a future spatial experience of the GENDYN sound world.

However, a mixdown of the 16 GENDY3 tracks and the mono resynthesis are not identical. 16-track GENDY3 adds another difference to Xenakis' original version. As has already been mentioned, there are two global random number generators for all tracks of GENDY3, one for the frequency and one

9 See [Xenakis1992], page 299, note at the bottom of the chart. This is, to my taste, a wonderful example for the mindset of an artist, as compared to an engineer. I for myself would simply have copied the file.

10 Personal communication by Gerard Pape, director of Les Alteliers UPIC, in 1997.

11 [Varga1996], p. 91.

12 In order to align the rest of the piece, I had to cut out, two or three times, a tiny bit of max.1 second, for which I have no musical nor logical explanation.

for the amplitude random walks. As for the frequency random walks, there is no difference between the mono and the 16-track resynthesis because their random numbers are, as described above, externally fed into the New GENDYN Program, trackwise, so they are exactly the same, regardless if a track is synthesized solo or together with the other tracks.

This is not true, however, for the random numbers driving the amplitude random walks. During mono synthesis, when all 16 tracks are computed “in parallel”, the sequence of random numbers is distributed among all active tracks. The first track gets the first random number, the second track the second, and so on. In contrast, when tracks are synthesized solo, they get all the random numbers of the random number sequence all for themselves, one after the other. Now you could say: so what? What's the difference? Those random numbers are random after all so it should not make a difference which of them are used, it's a big random mess either way.

Now think of what has been said above about the “quality” of random number sequences. As it turns out, the Lehmer formula as used by Xenakis does not provide for good randomness in the scientific sense, as motivated by [Haahr1998]. For the music of GENDY3, this means that amplitude patterns tend to repeat over longer periods of time creating a sensation of spectral pulsation. This becomes even more audible when frequency is fixed, as is the case for many GENDY3 sounds. When sounds appear isolated, mono and 16 track resynthesis behave exactly the same way. Yet as soon as a second track adds to an isolated one, in mono resynthesis, where random numbers are shared between tracks, spectral pulsation gets blurred. There is one moment in mono GENDY3 where such a pulsation in an extended solo sound is completely broken by a competing noisy sound (3'43” to 4'07”)[13]. The same passage in 16-track GENDY3 leaves the pulsating sound unaltered, because it is independent of the noise in terms of synthesis.

To sum up, 16-track GENDY3 is different from Xenakis' published original by 3 aspects (see figure 3):

1. it is uncut, basically featuring some additional 40 seconds of wonderful noise
2. it has a different pitch evolution in one glissando sound towards the end of the piece
3. spectral pulsation in sounds with stable pitch is undisturbed by concurrent sounds

5. Conclusion

16-track GENDYN is a product in the spirit of Iannis Xenakis, however it is not a work by Iannis Xenakis. As we have seen in this paper, even in the case of GEND3, which is the fulfillment of his live long dream of an “Automated Art”, Xenakis reserved to himself the role of the final arbiter (i. e. censor) of the computer synthesis result. Therefore, 16-track GENDY3 cannot be considered as a sibling variant of Xenakis' opus summum GENDY3 because sadly, the final arbiter is not among us anymore. Xenakis even might have opposed to a release of 16-track GENDY3, given the fact that it contains the full program output, including the silences that Xenakis was anxious to suppress.

13 The breaking of periodicity by concurrent randomized random number drawing from a „bad“ random number source could indeed be an efficient method to improve the randomness of that source. In the described GENDY3 example, randomization by concurrent drawing is maximal since it is done by a noisy signal, i.e, the concurrent drawings are maximally random. I could imagine that this method of random number improvement has been proposed in the random number community as some of the readers might know. Or could it be that Xenakis, as a side result of his music, aurally demonstrates a procedure to improve randomness on a computer?

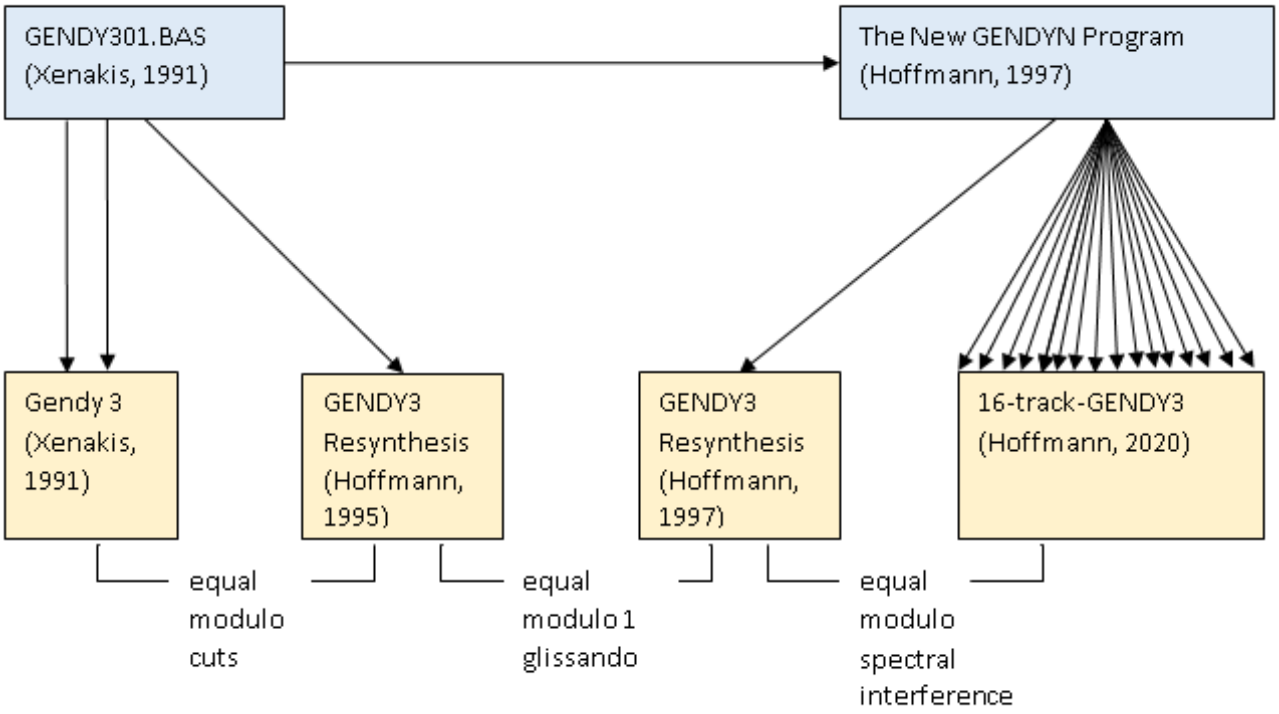

Figure 3: The genealogy of 16-track GENDYN. Upper row: software. Lower row: artefacts.

However, Xenakis might have liked the fact that 16-track-GENDYN is more suitable to projection in space than a double-stereo rendition of a mono sound file. Multi-track productions and performances are typical for Xenakis' electroacoustic practice. Yet, a public performance of 16-track GENDYN is still to come. It could be performed with 16 loudspeakers and a 16-channel playback system, but a performance on an acousmonium setup or even a wave field system could be interesting too.

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The other Room. The influence of Iannis Xenakis on room acoustics

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Abstract

This lecture does not deal with concert situations but exclusively with recordings released on compact disc or vinyl long-playing record. In other words: in this lecture I will exclusively focus on the spatial information or the reverberation pattern of a recording room and the acoustic result when listening to the recordings. There are many different treatises about space and music. As a composer and architect, Xenakis dealt intensively and groundbreakingly with all these facets.

In aesthetic and scientific issues, little or no attention has been paid to room information (reverberation pattern) in acoustic recordings. Not even in the case of (artificial) reverb in electroacoustic music.

The key experience for my questions were these recordings of the compositions for strings of Iannis Xenakis, interpreted by members of the Arditti String Quartet:

Kottos – Mikka – Mikka S – Embellie – Ikhoor

The remarkable thing: They recorded it twice within only 9 years: in 1982 and 1991. A comparison of the two recordings shows a remarkable difference: not in the interpretation but in the technical recording procedures. In short: in the 1982 recording almost no spatial information can be heard, no reverberation pattern. Xenakis was actively involved in the 1982 recording and pushed through to create this extreme dry acoustic for the result.

Within the lecture I will

- mention here my interviews with the Arditti String Quartet about the recordings.

- give acoustic examples for a better understanding.

- give a short excursion into standardized recording techniques.

- give an outlook on how we perceive spaces.

- will touch on other thoughts on room aspects

After these examples with acoustic instruments, I will make a short excursion to Xenakis Electroacoustic Music.

All this combined with the question of what motivated Iannis Xenakis to take this step?

1. Introduction

This lecture does not deal with concert situations but exclusively with recordings released on compact disc or vinyl long-playing record.

In other words: in this lecture I will exclusively focus on the spatial information or the reverberation pattern of a recording room and the acoustic result when listening to the recordings.

There are many different treatises about space and music. The thematic areas could be:

- The positioning of the sound source in space

- The movement of sound in space

- The simulation of architectural spaces and their spatial information (reverberation)

- The acoustic construction of virtual spaces, i.e. spaces hat cannot be built architecturally (reverberation that does not exist in the real world)

- The construction of variable concert halls

- The space as an instrument

As a composer and architect, Xenakis dealt intensively with all these facets. Just think of his spatial compositions such as *Terretektorh* for 88 musicians distributed in the room (1965/66), in *Nomos gamma* for 98 musicians spread out in the audience (1967-68) Xenakis speaks of spatial permutations, his competition entry for a variable concert hall (1984) for the Cité de la Musique in the Parc de la Villette in Paris, which was supposed to allow the most diverse spatial composition concepts and, by means of a variable resonance box, could let the hall itself become a musical instrument. The fact that sound movements make space tangible, that space and time are mutually dependent, this „world“ is virtually a matter of course for Iannis Xenakis.

In aesthetic and scientific issues, little or no attention has been paid to room information (reverberation pattern) in acoustic recordings. Not even in the case of (artificial) reverb in electroacoustic music. The key experience for my questions were these recordings of the compositions of Iannis Xenakis, interpreted by members of the Arditti String Quartet:

Kottos for violoncello (1977)

Mikka for violin (1971)

Mikka S for violin (1976)

Embellie for viola (1981)

Ikhoor for string trio (1978)

The remarkable thing: They recorded it twice within only 9 years: in 1982 and 1991[1]

A comparison of the two recordings shows a remarkable difference: not in the interpretation but in the technical recording procedures. In short: in the 1982 recording almost no spatial information can be heard, no reverberation pattern. This is actually a sacrilege of sound and balance engineering (Tonmeister), since this is never the case with acoustic recordings. To put it casually: on this 1982 release, the colophonium (rosin) of the strings trickles directly out of the loudspeaker.

[1] RCA RS 9009 (RL 25444)
Recorded at The Henry Wood Hall, London June 1982.
In 1991, 9 years later, the above-mentioned compositions were recorded again with the Arditti String Quartet by Westdeutscher Rundfunk Köln (WDR) and Radio France: disques montaignes 782005

How can it be explained that the 1982 recording sounds almost as if it had been recorded in an anechoic room?

Xenakis was actively involved in the 1982 recording and pushed through to create this extreme dry acoustic for the result.

How can it be explained that the recording from 1982 almost sounds as if it was recorded in a so-called anechoic chamber? Xenakis was present and actively involved in this 1982 recording. He worked to create these extremely dry acoustics for the listener at the loudspeaker.

This situation is different with the second recording of the Arditti String Quartet from 1991. Xenakis was not there. The reverberation room information here corresponds to familiar listening habits.

1.2. Excursions about rooms

Before I write further about Xenakis and his handling of reverberation, more precisely, about the reverberation in some record and compact disc productions, here first some excursions about rooms, more precisely, about the acoustics of concert halls, recording rooms and reverberation rooms.

In a sense, I am also writing here about only one of the categories mentioned above, namely „the room as an instrument“. If we look at this category more closely, quite different artists than Iannis Xenakis initially come to mind. For example, the American sound artist Maryanne Amacher (1938-2009). She had considered space as an instrument in her series Music for Sound Joined-Rooms starting in 1980: „In Music for Sound Joined-Rooms, and Mini-Sound Series I use the architectural features of a building to customize sound, visual, and spatial elements, creating multi-dimensional environment-oriented experiences, anticipating virtual immersion environments. As the audience moves through new scenes being created by the “Sound Characters," they navigate the expanded dimensions of a sonic world that is staged throughout the architectural site, an entire building, or its rooms. The idea is to create an atmosphere that gives the drama of being inside a cinematic close-up, a form of “sonic theater" in which architecture magnifies the sensorial presence of experience. Rooms, walls, and corridors that sing. I produce these works in location-based installations/performances that are built from „structure borne“ sound (sound propagated through walls, floors, rooms, corridors), which acousticians distinguish from the „airborne“ sound distributed by loudspeakers only. Creating the detailed sound design is very much like scripting a sonic choreography. In some episodes sound sweeps through the rooms; in others, chords and tonalities are intricately joined between the rooms; in still others, a particular sound shape is emphasized to animate sonic imaging of a distant room. The rooms themselves become speakers producing sound which is felt throughout the body as well as heard.“[2]

Alvin Lucier (1931-2021) first succeeded in considering a given room and its reverberation as a primary and essential parameter with his well-known, processual work *I am sitting in room* for voice and electromagnetic tape (1969/70). This piece shows like no other work how a timbre can be transformed by the acoustic conditions of the room. The score, a written realisation instruction, sets out the process of how I am sitting in room is to be made to sound. Apart from a room, a microphone, two tape recorders, an amplifier and a loudspeaker are necessary for the realisation. It is almost obsolete to mention that in the meantime tape recorders have been replaced by digital recording and playback devices.

A speaker first speaks the given text on tape. His voice - as with all acoustic events in rooms - also excites the given room, so that his voice and the acoustics, the reverberation of the room,

[2] See also: http://www.foundationforcontemporaryarts.org/recipients/maryanne-amacher

are recorded. The recorded text is now played back into the same room through a loudspeaker and again recorded onto a second tape recorder using a microphone. This copying process by means of microphone, loudspeaker and tape recorder is constantly repeated. With each new copying process, the acoustic properties of the room are added to more and more, because with each copy, the room is excited again by the loudspeaker.

And Iannis Xenakis? He simply omits this primary spatial information. Not always. But more on that later. First, a few digressions about spaces.

1.3. Perception of Rooms

How do we hear rooms? Do we hear rooms? Self-evident things are not perceived immediately. We listen to a speaker and later remember the sound of his voice. We listen to the voice and: we do not notice that the voice always acoustically stimulates the room as well and that we thereby hear this room as well. In very large rooms, however, it becomes obvious. For example, during a guided tour in Cologne Cathedral, in St Mark's Basilica (Basilica di San Marco). If the speaker is in front of us, the so-called direct sound predominates. If the speaker moves away from us, the direct sound decreases and the so-called diffuse sound (i.e. the room, or more precisely, the (reverberation of the room) is perceived more strongly. If the speaker crosses the reverberation radius, the line on which direct and diffuse sound have the same loudness, then the sound experience of the room, the „language of the room“, the filter room, finally predominates.

1.4. Excursus on concert halls

For the construction of today's concert halls, a standard has emerged that is valid for architects and is not very suitable for concert performances of new music. Modern concert halls have acoustic properties that are mainly suitable for music of the 19th century. This applies on the one hand to the reverberation time of the room, and on the other hand to the arrangement of the orchestra podium and the seating for the audience: the audience sits as in a theatre room and looks or listens in one direction. In almost all known concert halls, it would therefore not be possible to perform a work like Karlheinz Stockhausen's *Carré* for four orchestras and four choirs (1958/59), which are arranged in a square.

The acoustics of a room are primarily determined by the reverberation time. The Cathedral of Ulm, for example, has a reverberation time of about 12 seconds. However, the room also determines which frequency components of a sound are boosted or attenuated.

The exploration of electroacoustic music and sonic arts and the associated media led to a rediscovery in the direction of the room in the compositional concept.

1.5. Memory

Memories: as a schoolboy, I attended about 50 different concert events in the Beethoven Hall of the Liederhalle in Stuttgart, built in 1955-56 by the architects Rolf Gutbrod and Adolf Abel with the assistance of the acoustician Lothar Cremer. Decades later, I heard a record by the organist Martin Günther Förstemann. Like a dream, listening to it brought back memories of my earlier concert visits, although I had never heard the organ of this concert hall. Not the compositions, not the organ, no, it was the room that produced this memory. In fact, the recordings of this record were made in 1966 in this concert hall, which I did not know while listening to this record.[3] In other words, the famous acoustics of this room not only became present outside the room via recordings and radio broadcasts, but the Yamaha company also set

[3] Long-playing record PHILIPS A04 450 L (stereo 838 700 AY)

up a monument to it, so to speak, because the data for the Hall effect mode of their AV receivers were determined in the Beethoven Hall in Stuttgart.

1.6. Reverberation rooms

Further observations: on compact disc there is the series ACUSMATRIX (BV HAAST RECORDS Amsterdam). ACUSMATRIX 6 (CD 9106), Early Electronic Music, features early electronic compositions realized at WDR in Cologne. Works from the 1950s. Very different composers: Herbert Eimert, Karel Goeyvaerts, Paul Gredinger, Gottfried Michael Koenig, Henri Posseur, Bengt Hambraeus, Franco Evangelisti, György Ligeti, Giselher Klebe, Herbert Brün. In musicological and other seminars listeners always remark that there would be a great similarity between the pieces. Is it true? The compositions are very different. What leads to the perception of similarity? If we listen closely, we can determine that what we perceive as similarity was the reverberation room of the WDR at that time: a tiled cellar room with a loudspeaker mounted in one corner and a microphone diagonally opposite. Robert Bayer comments: „[...] We mostly sent the sound into the reverberation room. There it was emitted by loudspeakers and sent back through microphones.“ [4]

1.7. Excursus on recording procedures

When recording an instrumental ensemble or individual instruments for conventional stereophony, a standard recording procedure is to use a so-called main system: two microphones with omnidirectional characteristics (pressure receivers) that register both the instruments and the spatial information. Often this already sounds very good during playback. However, since the instruments can sound a bit far away when (listening to) the stereophonic recording, behind the speakers so to speak, the usual „correction“ is to assign one more support microphone to each instrument. These support microphones are very close to the instruments and practically register only them and not the room information. The task of the recording engineer is now to bring the main system and the support microphones into an acoustic relationship in such a way that a certain proximity is suggested during stereo reproduction by means of these support microphones. Just as the localization between the two loudspeakers can be determined by means of stereophony: right, left and an infinite number of phantom sources in between, the level ratio between the main system and the supporting microphones can be used to suggest a front and a rear with corresponding intermediate levels.

2. The influence of Xenakis during the recording

In the 1982 recording given above, it seems that the main system was obviously switched off. To use only the spot microphones is actually a sacrilege. However, Xenakis, who was present at this recording, insisted and enforced this dry, „roomless“ recording. So says Levine Andrade, the quartet's violist at the time, in conversation with Martin Supper in Delphie, August 1985 (Centre Acanthes' Xenakis workshop). Levine told me that this led to a considerable conflict with the sound and balance engineer, as he did not want to realize the sound conception of this recording by Xenakis. Since Levine is no longer alive, to be on the safe side for this lecture I asked Irvine Arditti (leader and founder of the Arditti String Quartet) about this recording to verify my assumption and previous information: „[...] Xenakis did want a dry and close sound. He had a very particular idea about how things should sound but they were not always accepted by all [...]“. In 1991, 9 years later, the above mentioned compositions were recorded again by

[4] Marieta Morawska-Büngeler, Schwingende Elektronen. Eine Dokumentation über das Studio für Elektronische Musik des Westdeutschen Rundfunks in Köln 1951-1986, Köln 1988, Tonger, Page 45. Translated into English by the author.

the Westdeutscher Rundfunk Köln (WDR) and Radio France with members of the Arditti String Quartet:

In these recordings the usual spatial information, the reverberation of the room, can be heard again. Xenakis was not present for this recording. Irvine Arditti: „[...] I like a close sound but one also needs some room sound.

By the time we got to make the next recording with WDR technicians Xenakis became less involved.

He trusted us more and also the technicians [...]“[5].

2.1. A similar example, independent of Xenakis

Deliberately ignoring the spatial information of the reverberation pattern in recordings had also occupied quite other artists, as is striking in the later (solo) recordings of the pianist and composer Friedrich Gulda (1930-2000), for example the *Préludes* by Claude Debussy in the 1969 recording. His son Paul Gulda comments: „[...] During the transformation process from analogue to digital, we noticed how close and present the piano is. My father loved, the later the more, to move the microphones very close to it - the so-called close miking. ZEIT online: ‚Is that untypical for classical recordings?' Gulda: Yes, it is very unusual. The room acoustics usually play a greater role in classical recordings [...] Close miking is used more as a support to bring out the bass, the treble or another register that doesn't carry so well. With Gulda, however, this kind of recording was at the centre [...] ZEIT online: ‚[...] an unbelievable analytical sharpness [...] almost with a dissecting knife [...] to the limits of silence [...]'“.[6]

2.2. Reverberation pattern on Xenakis Electroacoustic Music

In contrast to the recordings of instrumental music, in the realization of electroacoustic music the reverb is added artificially. Listening to the electroacoustic oeuvre of Xenakis, i.e. from *Diamorphoses* for two-channel tape (1957)to *S.709* for two-channel tape (1994), shows the following facts: the more independent Xenakis was from a public studio like GRM, the more he renounced reverberation pattern. This independence happened around 1972, the founding of the Centre d'Etudes de Mathématique et Automatique Musicales, or CEMAMu for short. Among others, the compositions *Mycènes Alpha* and *Gendy3* were realised there:

Gendy3 for two-channel tape (1991)

Mycènes Alpha for two-channel tape (1978)

However, this step can be heard very clearly in *Mycènes Alpha* (1978), since - due to digital technology - analogue noise can no longer be heard here (analogue noise is often interpreted as a kind of room by the listener). *Mycènes Alpha* is the first composition by Xenakis that he realised on the UPIC (Unité Polyagogique Informatique CEMAMu) he devised. The roomlessness is most prominent in *Gendy3* (1991).

The following works of Xenakis' electroacoustic music were my references while listening. All have been released on CD, DVD or Vinyl. Some of them also several times with different mixes:

[5] 26. July 2021, Email to Martin Supper.
[6] 11 May 2007, ZEIT online,
https://www.zeit.de/online/2007/21/paul-gulda,
last accessed 23.8.2021. Translated into English by the author.

Diamorphoses for two-channel tape (1957).

Concret PH for two-channel tape (1958)

Analogique B for four-channel tape (1959)

Orient-Occident for two-channel tape (1960)

Bohor for eight-channel tape (1962)

Kraanerg, ballet music for orchestra and four-channel tape (1968/69)

Hibiki Hana Ma for twelve-, eight- or four-channel tape (1969/70)

Persepolis for eight-channel tape (1971)

Polytope de Cluny for eight-channel tape (1972)

La Légende d'Eer (Diatope) for eight-channel tape (1977)

Mycènes Alpha for two-channel tape (1978)

Pour la Paix, 2nd version for gemCh., four speakers and stereo tape; 3rd version for four speakers and stereo tape; 4th version for stereo tape (all 1981)

Taurhiphanie for two-channel tape, music realised with UPIC (CEMAMu Paris) (1987/88)

Voyage absolu des Unari vers Andromède for two-channel tape (1989)

Gendy3 for two-channel tape (1991)

S.709 for two-channel tape (1994)

So that there is no confusion here: I continue to mean - as throughout the text - exclusively the reverberation pattern of a recording, not the stereophonic information, which is undoubtedly always present. Nor do I mean concert situations.

3. Conclusion(s)

I would like to point out here once again the real issue: the elimination of everyday reverberation in the recording process. It invites everyone to think about the fact that for one ore the same instrumental composition the roomless recording or the concert situation (with the spatial experience of the hall) can be chosen.

What moves Iannis Xenakis to take this step in the recording situation? One of several answers could be: the radicality of his thinking shows up here as well. The self-evidence, in a certain respect the tradition, to hear reverberation pattern at every listening of a (recorded) piece of music is also broken by him: he partially avoids it and thus creates new aesthetic directions of view, more precisely listening strategies. For further investigation, it should not be forgotten that Xenakis' „intervention“ in the chamber music mentioned only took place in the recordings. Nevertheless, he also designed concert halls with defined reverberation. During the rehearsals of the chamber music mentioned above with members of the Arditti String Quartet in Delphie in 1985, I was able to observe that the given concert and rehearsal room acoustics did not require any discussion for Xenakis.

Other or further conclusions would still have to be discussed and worked out.

I consciously based my investigations exclusively on hearing and listening. In similar examinations, the sound material is often visualized (e.g. by sonography). In this case, I see the danger that some things are „differently“ by the visualization. The ear is deceived, so to speak, because it „puts things right“ via the visualization.

Revisiting the Gendy model from the perspective of noise transformation as a compositional method

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Abstract

Xenakis' GENDY presents itself as a very elegant and effective implementation of a model that successfully realises how "musical sounds may be described as a function of amplitude over time" (Koenig 1971, p. 93). In their endeavours the authors have not approached it as an original that needs to be respected or emulated. Rather, they have considered GENDY and the underlying thinking a model that invites experimentation, thereby possibly developing it in various directions and—hopefully—finding useful musical results.

This paper, more than anything, can be considered a report on the route the authors travelled which has led us along several experiments and tests that were conducted from a desire to discover extended uses of an extremely simple yet rich principle for creating musical sounds "by generating repeated copies of a line-segment waveform in which the vertices vary at random" (Puckette 2016, p. 4). Following this brief but exhaustive description of GENDY, it becomes clear that the 'varying at random' plays a crucial role and has our full attention. Chapter 1 elaborates on the topic of randomness and noise.

Establishing that the Jeynoise paradigm of noise transformation (Jung, Pabon and Flett 2016, p. 1) spawned rich materials in the context of GENDY formed a starting point. Additionally, various contexts of instruction synthesis were created in which that richness was translated into discernible behaviours from the perspective of complex musical sounds. The experiments have taken place using the Max environment where code was generated using both gendsp and C. The relevant perspectives on complexity and an introduction of Jeynoise are given in chapter 2. The ensuing chapters each explain specificities of how Jeynoise was combined with GENDY.

It should be mentioned that this endeavour was fully informed by the writers' own—and very personal—critical listening to the output of each of the models that they created. This paper can serve as a reflection on what it means to write code in the context of composition with musical sounds created by nonstandard synthesis programs. Inherent in this reflection is the perspective that the code that is. presented in a quasi-fixed form (as a Max object) could in fact be a multitude of versions of code in each of which the development has bifurcated at some point in some different direction. The authors believe that in the context of GENDY, discussing such 'open' approaches to code development is very valuable.

This paper is accompanied with code and sound examples that can be found on the research catalogue (https://www.researchcatalogue.net/view/1565546/1565547). These materials

can be understood to present a practical context in which the current discussion is embedded.

1. Why noise—introducing excessive dynamics and restraining it

Most noise-generators present fluctuations that barely repeat the same pattern, even if the distribution of outcomes is invariable. If the concern is whether the sequence or signal rises and falls irregularly without repeating an identifiable pattern, most random-number-generators or noise-oscillators are satisfactory. White noise is a decent example; it has a great looking flat-spectrum, and every case within the upper and lower boundaries of values or amplitudes has an even chance to occur. Also, in most modern computer implementations, the repetition periods of sequences are incredibly long.

In terms of random numbers as compositional materials, as Paul Berg described concerning "the acknowledgement of a relationship between serialism and aleatoric composition of Gottfried Michael Koenig," it is discernible that "the rate at which intervals occur is more important than their order," and Koenig had put forward this idea "based on his listening experience." (Berg 2009, p. 77-78) In this view, the generated numbers constantly being evenly distributed within the upper and lower boundaries can be seen as a discontent factor because all possible cases have the same rate, so talking about how a rate differs from others in white noise is in vain because everything has equal prominence. Similarly, the white noise spectrum hardly warps, so all frequency components will likely coincide at the same maximum magnitude, constantly being in the most dynamic (energetic) state possible. One would merely hear a monotonous tone when white noise has turned into audio samples directly; the fluctuation is fastest and too random. Therefore, strategies for soothing excessively active random sequences (or signals) are adopted frequently in computer/electronic music composition involving random numbers. Unexceptionally, Iannis Xenakis described "probabilities" as "wild horses." (Luque 2006, p. 25) Xenakis said, 'I have been working like a laborer to obtain interesting things from the [GENDY] program;' then continued, 'I have been obliged to throw away many experimental results and keep only those that interested me.' (Luque 2006, p. 25) The statement may imply that restraining wildness from its maximum is plausible to derive the program's dynamic behaviour that attracts the composer's ear. In this sense, white noise is a valuable source to transform; since it has a flat, everything-is-loudest spectrum and suggests equal rates on samples' occurrences, one would consider the ways to warp and differentiate those.

Often, composers filter or amplitude-modulate white noise signals. Then, some frequency components can disappear or become softer, or the magnitude of fluctuations will not solely stay at the largest. Likewise, the authors have also taken white noise as the beginning point to present bumpy curves moreover arbitrary shapes in distributions of random numbers. Thus, the authors were developing an algorithm to warp real-time the distribution of white-noise-samples to let the resulting noise distribution reflect the arrangements of points designed by the composer. After implementing the probabilistic algorithm, the authors have also developed several methods to transform distributions stochastically. An example is the feedback of arrays; the wave previously a result of a stochastic process determines the current distribution of random numbers and induces the change in the state of the process in turn. Such an approach is the inheritance from the GENDY algorithm; in GENDY, the stochastic modulation is applied to the previously drawn wave. Then, next, the current wave becomes the previous one. Also, in turn, the authors now attempt to project their algorithm and methods through the lens of GENDY.

Seen in this light, the dynamic systems made for the compositional needs of composers, which involve the use of random numbers, such as the GENDY of Xenakis, can be understood as being delicately tailored to the preferences of composers rather than noise by itself navigating its course of change in its behaviour through time. The way guiding/processing random numbers can be complex, such as, as realised in GENDY, a patch consisting of mathematical modules (building blocks) and signal-flows between those. Also, the use of modules-in-series is a brilliant yet straightforward notion in the design of GENDY. The additions of the authors to this complex system design concept are, as

mentioned, a real-time method that turns lists into *probability density function*s *(PDF)*, so-called Noise Transformation, and a paradigm for noise synthesis that incorporates the line-segment approach called Jey-noise. The following chapters will examine the standard operators used in GENDY and the author's adapted GENDY implementations. Also, the authors will explain their idea on feedback as viewpoints to understand Xenakis' work and their control methods for GENDY.

2. Complexity that arises from feedback—GENDY and other synthesis techniques

When discussing complexity, the authors refer to inherent musical complexity. It is beyond the scope of this paper to even start discussing the magnitude of this term, but it can briefly—and vaguely—be expressed as those traces (Döbereiner 2009, p. 5) which spark involved listening.

Musical complexity in sound synthesis environments may emerge due to a large set of possible approaches including the construction of complex data structures, artificial intelligence, analysis through machine listening, etc. In the case of GENDY however, we are confronted with an extremely simple model with very limited control. The development of this model in the way the authors have done, was driven by the belief that a variety of uncharted complex behaviours could emerge even when such a simple model was coupled with non-standard approaches to noise generation as described above.

The complexity that the GENDY model evokes can be identified as a complexity based on recursion or feedback. That is, the current state is an expression of the previous one, available as a number of values in memory, on which some operations have been applied. The procedure of applying operations on the values in memory within the recursive process is what sparked the author's imagination. It is exactly here they believed that something of value was to be found. It meant that effort should go into researching and extending the model, rather than looking at control approaches that function at larger time scales.

2.1. Memory and Feedback

Like the authors suggesting revisiting the immanent mechanism in GENDY, as stated, GENDY can be explained as a model in which recursion defines the emerging of complex musical sounds. Here a connection can be seen with other models—analogue or digital—that incorporate memory in a feedback loop as well as operations on values or signals stored in it. In general, one could call them recursive models, like many various chaotic descriptors. For instance, the work of Jaap Vink in the voltage-controlled studio or David Tudor's Neural Synthesis could be mentioned in this regard.

Worth mentioning in this context too, is a model designed by Dutch synthesiser builder Rob Hordijk, which he coined 'Rungler' and which generates a signal he describes as 'stepped havoc'. The module that makes Rungler so distinct is a shift register in which a reduction of the output of standard wave generator is stored. From these values a signal is derived that feeds back as a control for the frequency of the generator. Indeed, Rungler follows a minimal design but is capable of exhibiting complex behaviours on various time scales simultaneously.

Like Rungler, GENDY links the two aspects of stored values *outside* time, which are used to generate a signal *in* time. A distinct difference between the two is that Rungler does not incorporate randomness and behaves like a traditional chaotic model creating—depending on certain settings—various attractors between which it oscillates. In the case of GENDY, where random is a significant part of the model, Jeynoise was seen to play the role of the interface connecting the state of a GENDY waveform in time and the values in memory on which operations are applied.

An apparent difference, when comparing with Rungler in terms of the sound result, is that the GENDY model does not switch between behaviours, but is capable of moving between them, thereby over time articulating the boundaries that demarcate the space in which it moves and exhibiting a certain rhythm in the reoccurring of distinct sound typologies.

2.2. Noise Transformation

One observation, when generally evaluating generative processes, is that movement based on randomness between boundaries, even when distribution approaches are implemented, over longer time spans easily lead to the perception of an average behaviour that tends around a centre point or centre area. Automating the large-scale change of parameters could provide a solution but in the case of GENDY this could easily lead to a situation of external control defeating the inner workings of growth and decline. A challenge that presented itself was to create the kind of dynamic behaviour that yields a variety of musical results that exhibit distinct identities, which is to a large degree specified in its definition—the code. It is at this point in our deliberation that the idea of combining GENDY and Jeynoise as a noise transformation model came up.

In simple terms, Jeynoise is an approach to generating random values at sample rate, that attempts to offer control on the spectral quality of the produced noise signal. It is named after its designer Jeyong Jung who implemented this idea in a set of objects that function within the 'Max paradigm' (Puckette 2002, p. 31) and is accessible from within Cycling74's Max package manager under the name 'ACToolkit'.

The jeyrand~ object functions as an audio rate random generator that implements probability distribution control. It outputs a signal between 0 and 1 and sample values collected over a certain time (using jeyhisto~) will show a distribution that corresponds to the defined probability distribution at the input. The same signal is made available on a second outlet where it is rescaled according to a minimum and maximum frequency value. This frequency value can be fed directly into a jeynoise~ object, which constructs a concatenation of sine wave periods. Upon each completion of a period a new frequency value is sampled. Although constructed from sine wave periods, the output of jeynoise~ sounds noise-like.

The two Max objects (jeyrand~ and jeynoise~) together offer the creation of coloured noise defined by a list of probability values. The application of jeynoise however is not limited to merely creating an infinite variety of noise colours. It promises functionality in a wide variety of applications in which it is desirable to express musical behaviour through probabilities.

3. Random walk and folding

A key characteristic of the original GENDY definition is the so-called secondary random walk. This aspect represents an important generative element that allows for the modelling of distinct perceivable behaviours. For the sake of rigor; the second-order random walk consists of three components: a stream of randomly generated values, the accumulation of these values constrained within elastic bounds, and the accumulation of the accumulated values, again within elastic bounds. It can be said that the inner accumulator sets the tendency of the direction in which the outer accumulator progresses.

At least three control values can be provided: the folding range for the outer accumulator, the folding range for the inner accumulator and a factor which controls the amplitude of the random values within the inner folding range. Given certain settings, the second-order random walk tends to gravitate around its barriers (Luque 2006, p. 26)—which Xenakis must have identified as interesting behaviour. However, different values for control could make it behave as a first order or regular random walk as well.

In a second-order random walk at least two qualities can be distinguished; the behaviour at its barriers and the way in which the space between them is traversed. The figures shown here help to visualise these qualities. It should be stressed that outside the context of generating GENDY output these figures are rather meaningless.

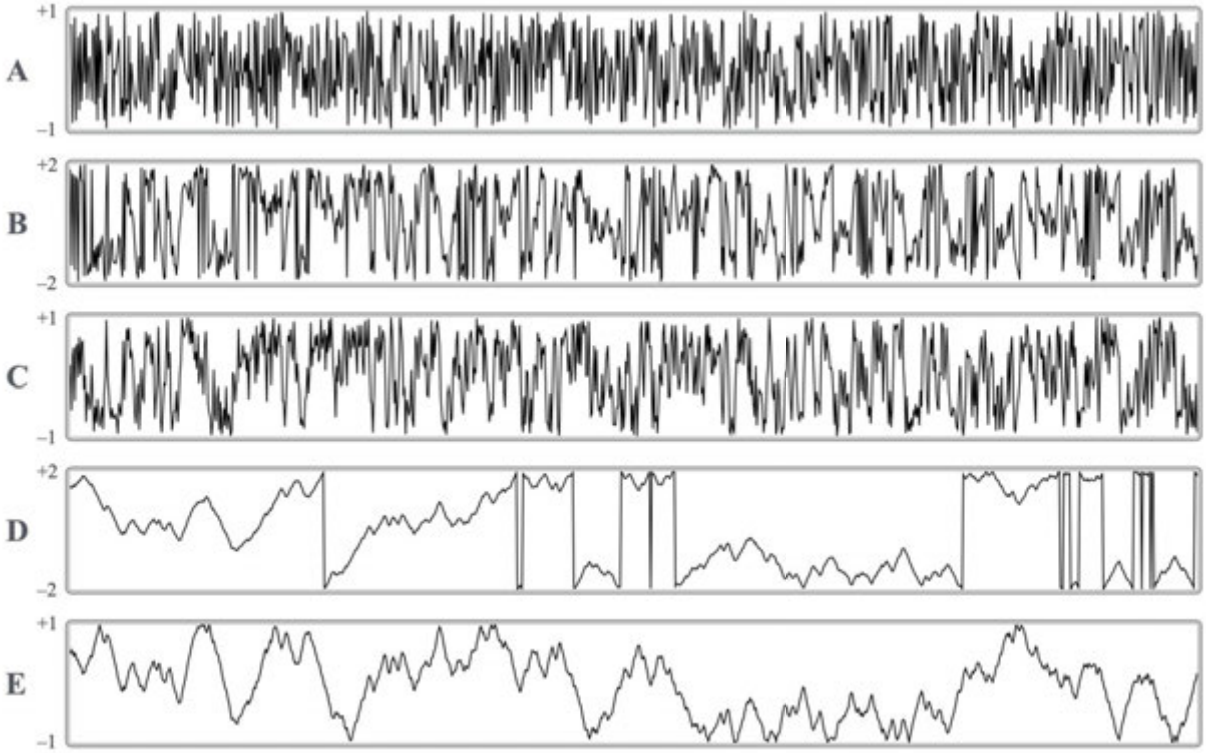

Figure 1: [A] white noise signal in the range –1 to 1; [B] accumulated and wrapped-into-doubled-range A; [C] folded into the range –1 to 1 B; [D] C is divided by 16, accumulated, and wrapped into the range –2 to 2; [E] folded into the range –1 to 1 D.

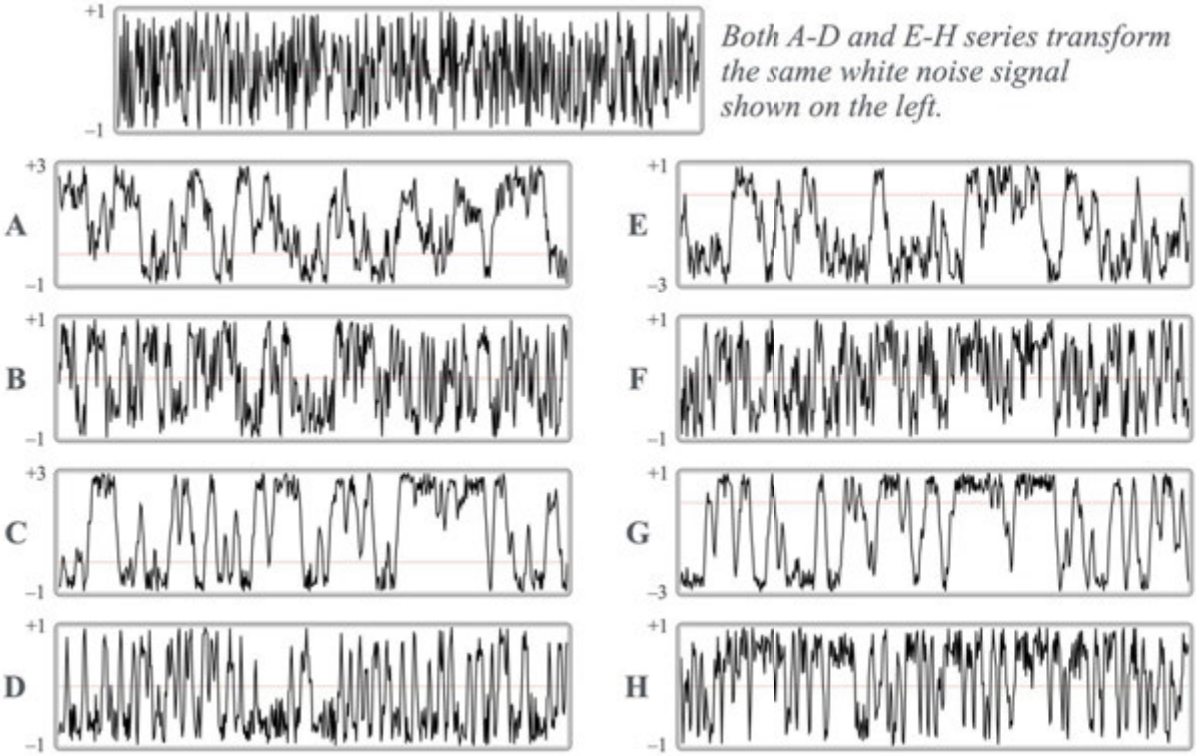

Figure 2: [A and E] accumulated and folded into doubled-and-shifted range white noise signal; [B and F] folded into the range –1 to 1 A and E; [C and G] accumulated and folded into doubled-and-shifted range B and F; [D and H] folded into the range –1 to 1 C and G.

4. Noise transformation as an approach to defining walking tendencies

As explained in the previous chapter, two distinct qualities of the second-order random walk are

behaviour at its barriers and the way in which the field between them is traversed. Concerning this latter quality, applying noise transformation as method to for the generation of random number, introduces the option to distinguish between the growth and decline of the second-order random walk. An uneven distribution in the random values will equally lead to variations in the rate of accumulation.

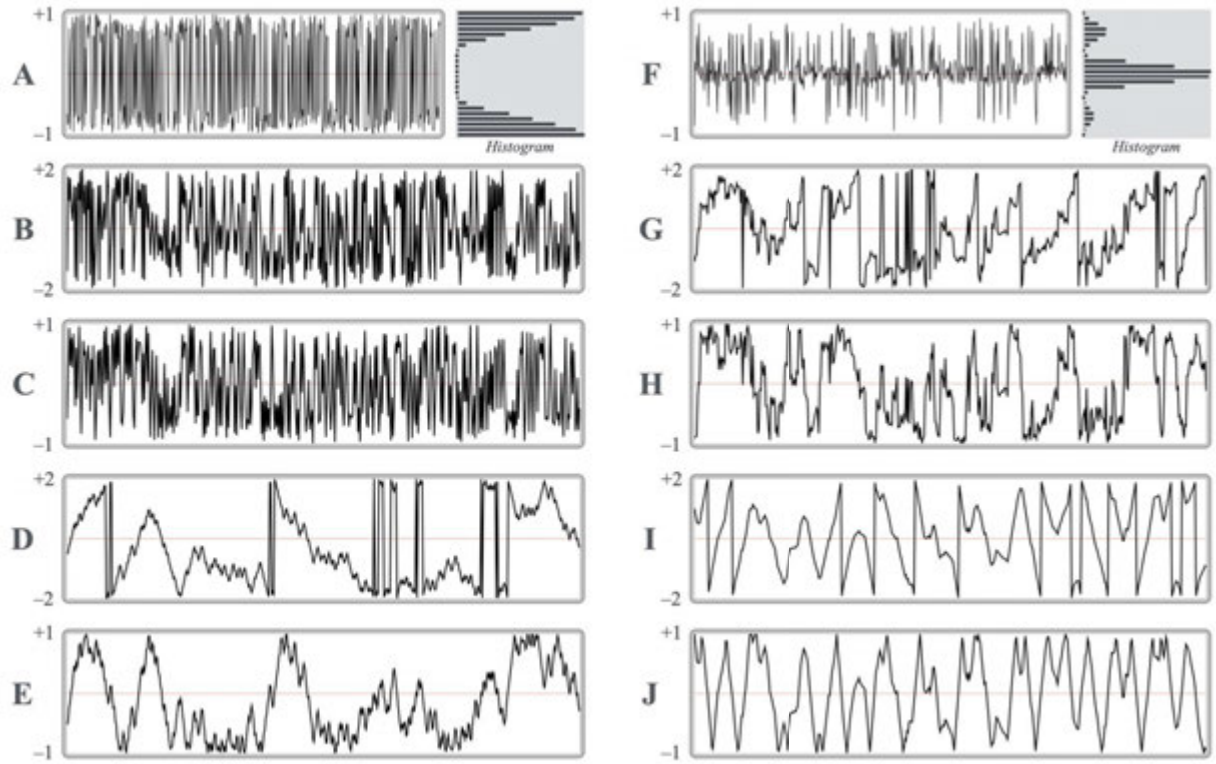

Figure 3: [A and F] random sequences made by the Max-external-object Jeyrand~ reflecting drawn distributions; [B and G] accumulated and wrapped-into-doubled-range A and F; [C and H] folded into the range –1 to 1 B and G; [D and I] C and H are divided by 4, accumulated, and wrapped into the range –2 to 2; [E and J] folded into the range –1 to 1 D and I.

4 *Balanced random walk*

In order to balance the random walk between the barriers and avoid the tending towards one of them, it is possible to measure an average that can be used as a new centre value around which the random values are scaled. Alternatively, there is the option to maintain the unfolded value for calculating the next state of the second-order random walk, which leads to a continuously traversing between the barriers, rather than gravitating around them.

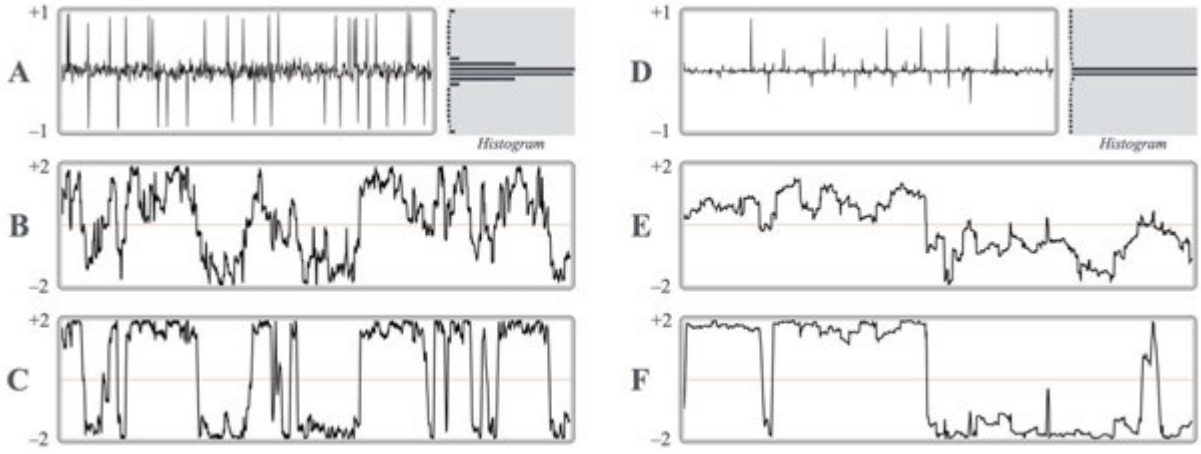

Figure 4: [A and D] symmetrically distributed random sequences made by the Max-external-object Jeyrand~; [B and E] accumulated and folded-into-doubled-range A and D; [C and F] B and E are wrapped into the range –1 to 1 then accumulated and folded into the range –2 and 2.

With these adjustments it became possible to express varying sound characteristics just by changing the distribution of the noise transformation, also when the parameters remained untouched. Such variation in characteristics was best observed when noise transformation was applied to the duration abscissa, as opposite barriers represent opposites in the perceived frequency. Applying it to the amplitude ordinates became meaningful when the organisation of amplitude values was taken into account. This is something which was included in the experimentation. For instance, in one example, the occurrence of certain patterns was mapped to the status of the GENDY generator. Changing the distribution of the noise transformation in this case, translated to a variation in the rate at which certain patterns occur.

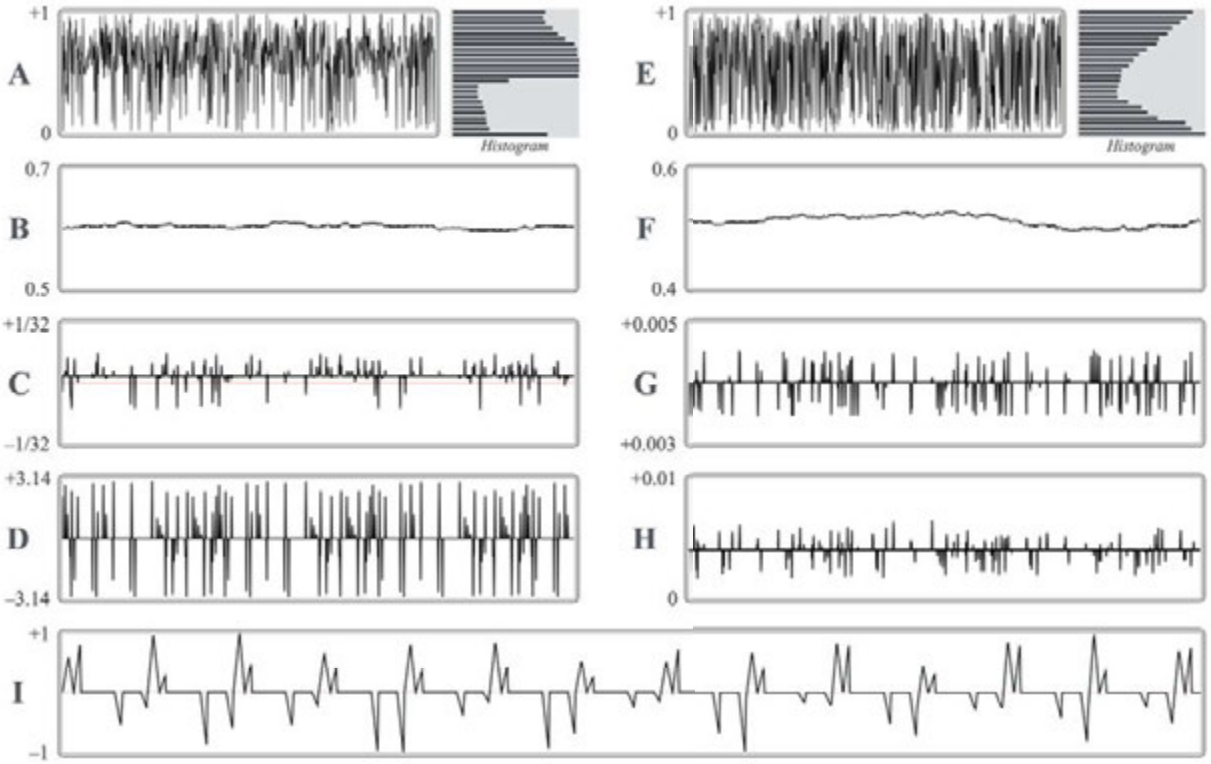

Figure 5: [A and E] random number sequences made by using the Max-external-object Jeyrand~; [B and F] running averages over the past 1,000 samples, derived from A and E respectively; [C and G] sample-by-sample-compared-with-B-and-F and scaled A and E; [D and H] random walks derived from C and G; [I] a wave made based on D (abscissae) and H (ordinates).

2.2 Random walk transformation

The Jeyrand~ noise transformation function defaults to the use of a built-in random generator, which can be identified as white noise, so-called pseudorandom number generator. It provides for an option to feed other signals from external sources. In relation to the discussion of the previous two chapters, such external sources represented options to further model the behaviour of GENDY. With white noise any value could occur at any moment, which translated to the set-up with noise transformation means that the entire distribution would be expressed equally at all times.

However, when a random walk was used as a source for Jeyrand~, the values it produced tended to be in a certain area of the distribution for an extended duration. In the context of a second-order random walk, this led to prolonged moments of exhibiting certain characteristics.

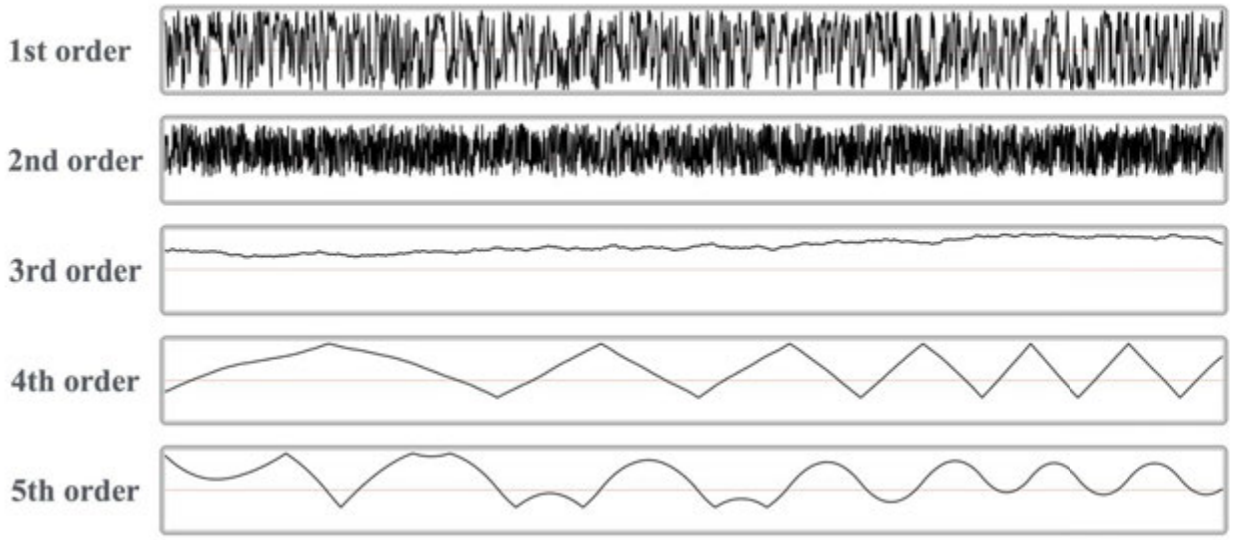

Figure 6: Each wave has been made by accumulating, wrapping, and folding Jeynoise~ signals (in the case of the 1st-order wave) or a one-order-lower wave. The magnitude of random walks has been reduced by five times before being turned into a one-order-higher walk. The 5th-order wave was fed back into the Jeyrand~ object, and the PDF of the object was modulated by slow-rate-sampled random-walks in real-time.

5. Variations of composite systems—differently patching modules in GENDY

The experiments that this paper reports on started with an attempt to reconstruct the original model of GENDY to which Jeynoise was applied. Specifically, Jeynoise introduced the option to apply various distributions of noise to the second-order random walk. In order to test the scope of such application, various combinations of folding and wrapping were examined. It became clear that rather than pursuing a single 'original' approach—the second-order random walk—it made sense to see how different combinations of noise distributions and approaches to wrapping and folding would create variations in output.

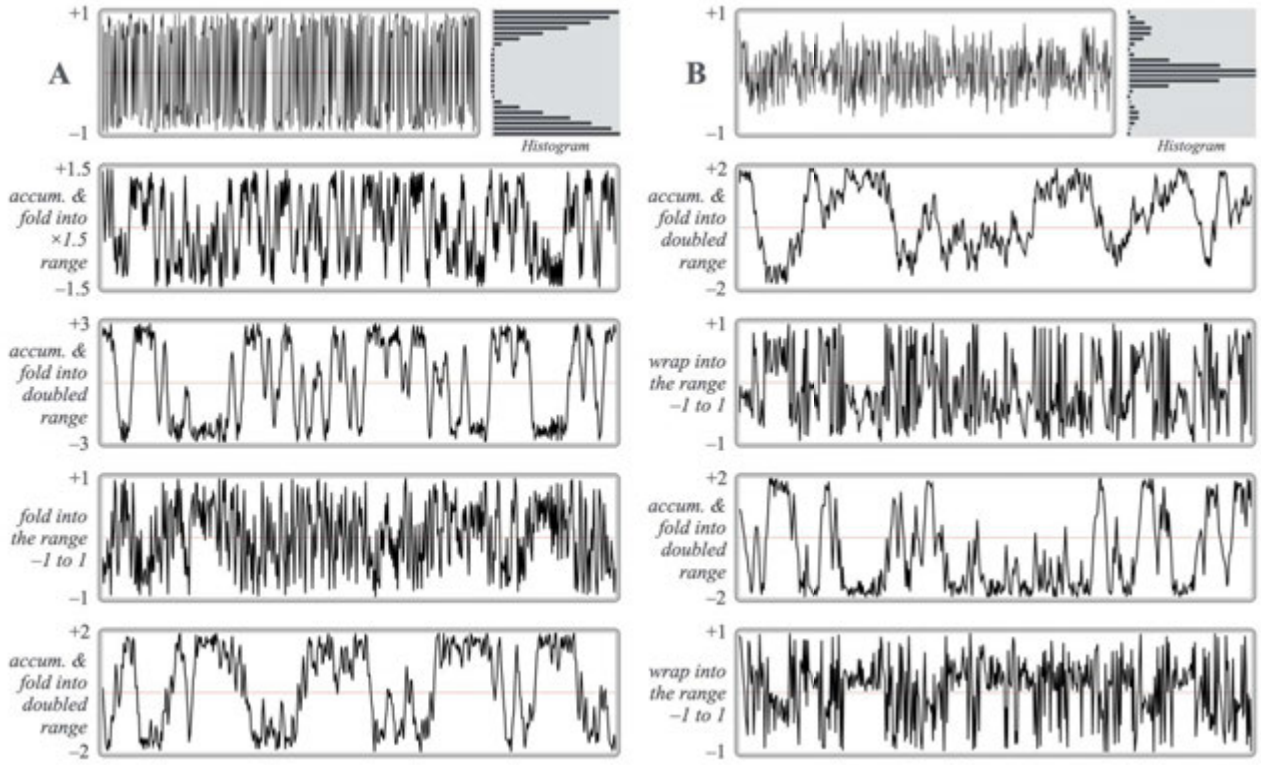

Figure 7: The PDFs of the random sequences A and B are the same as the ones used in A and F of Fig. 3.

6. Line-segment-waveform approaches

In the GENDY algorithm, amplitude ordinates and duration abscissae are the structural elements of the produced wave. As discussed, the random walks modulate the ordinates and abscissae in time. While signals represented as a sequence of samples—following the Nyquist Theorem—only allow for operations applied to the actual values, signals represented in different ways may open options to equally different interactions.

If indeed the GENDY signal is viewed as a sequence of delta durations and amplitude values destinations (the departure value being the previous destination), then it becomes feasible to think of operations that include swapping, skipping, inverting, removing etc. Moreover, such operations, although hardly relevant at the sample level, could be considered meaningful because the result renders alteration or variation in the final sound that can be appreciated and enjoyed as such. In addition, a relation between the description of points and the random fluctuations or other characteristics that determine GENDY's sound can be established. As an example of this, the online repository shows how the status of a GENDY engine is derived from specific sequences of previous amplitude values.

In the current discussion, where interesting connections are searched that link the characteristics of GENDY and Jeyrand, the authors have taken prime interest in the compositional features of non-standard sound generative processes. In this endeavour inspiration came from examples such as PILE or SSP (Berg 2009, p. 76), approaches that take the intrinsic relation of the descriptors of sound and operations as a starting point. Only secondarily, the focus has been on mathematical concerns that are related to the implementation.

Jeyrand can be considered a generator of great variations of noise signals based on probability distributions that can updated in real-time. Such probability distributions can be derived from the sample-by-sample signal output of GENDY but as well from statistical description of various aspects of the representation of GENDY. In the latter case, the GENDY representation serves as a pool of data that can be ordered, searched or measured in order to derive that information that is most suitable or renders most interesting behaviours.

7. Observations and conclusions

Using their own ears as guides, the authors have set out searching for extensions of the GENDY model in order to define complex musical materials. Their intuition was that adding Jeynoise as a method for generating random numbers would open interesting options in such an endeavour. As a first step an implementation was created that was used to verify that variation in noise distributions indeed clearly exposed equal variation in produced sound characteristics, even though sometimes they were variation within rather narrow ranges.

These findings led to the perspective of researching an approach in which an as large as possible set of behaviours would be the result of a model simply acting upon its own noise distribution. It was thought that such extensions of the model adopting feedback, were more worthwhile to pursue than the creation of large-scale options for parameter change. As a first important step Jeynoise was incorporated into various renditions of higher-order random walks as means to generate large varieties in control signals of which the use was verified by the resulting GENDY output.

In an attempt to share code as a means to share our findings, and hence try to come up with a general and complete as possible generator, the authors found that such an attempt was defeated by the intrinsic connection between composition and programming in the context of non-standard synthesis environments. In such environments programming decisions directly turn into compositional materialisations—as it should be. This led to the insight that a large number of models could be equally possible as valuable outcomes, each of which had developed in a different direction because of diverging accumulations of decision-making.

The authors established for themselves the meaning of discussing non-standard approaches from the

combined perspectives of coding and composing. Attempting to avoid the pitfalls of first-the-program-then-the-music or a one-solution-many-musics they believe it more valuable to define an approach to finding programmatic handles to which compositional units can be attached; in simpler terms, a situation in which one is able to "learn that which without the computer would not be learned." (Berg 1979, p. 30).

What is shared by the authors therefore should mostly be considered a toolbox which allows for certain experiments and experiencing the richness of certain behaviours.

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Non-standard possibilities in sonification and machine learning at audio rate

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Abstract

Xenakis's implementation of dynamical stochastic synthesis has been described as an example of non-standard synthesis where parameters do not correspond to acoustic or perceptual features. The paper considers how his premise of creating music "out of nothing" at the level of digital audio samples and beyond may be informative in considering creative uses of sonification and machine learning techniques at the level of digital audio samples. Thoughts on the topic, along with a description of work underway are outlined.

1. Sonification and algorithmic composition

Sonification is the presentation of data by non-speech auditory means in the broader context of auditory display (Kramer 1994). It has been suggested that Iannis Xenakis is perhaps the composer who best exemplifies the point of contact between sonification and algorithmic composition (Worrall 2018). Xenakis's works clearly belong to the realm of music rather than auditory display. Alongside passages based on his use of theories which were usually mathematical models, a large proportion of his works also depended on his intuition (Solomos 2016). However, Xenakis made frequent references to the use of theories in his compositional process in his writings and interviews. Indeed, one could perhaps argue that the listener being aware that the music had been generated by some process or other was of importance for Xenakis, regardless of the extent to which the underlying process or data could be perceived. Whether a sound may be considered as sonification could depend on the intention of the composer, or its function (Barrass and Vickers 2011), the perspective of the listener (Hogg and Vickers 2006) or the circumstances of listening (Grond and Hermann 2012). From his use of Brownian motion in works such as *Mikka* and *Pithoprakta* and Markov chains in *Analogique*, to the architectural design for the Philips Pavilion informing his string glissandi in *Metastaseis*, sonification is an apt description for much of Xenakis' output.

Algorithmic composition is the equivalent of parameter mapping sonification which usually operates at the time-scale of individual notes. It is comparable to sonification at control rate. Many works by Xenakis may be described as algorithmic composition, employing methods comparable to the parameter mapping sonification of mathematical models.

2. Audification and non-standard synthesis

2.1. Non-standard synthesis

Xenakis also explored the use of processes at audio rate through his implementation of dynamical stochastic synthesis, a process where probability distributions are used to continually transform breakpoints in a waveform. It has previously been described as an example of non-standard synthesis, where parameters do not correspond to acoustic or perceptual features (Holtzman 1979; Laske 1989).

In standard synthesis methods, the resulting sound may be predicted to a certain extent from the parameters e.g. frequency and amplitude for a sine wave, or even for a more complex process such as frequency modulation. Indeed, more often than not, the parameters are decided precisely in order to produce a specific sound e.g. by setting frequency and amplitude values to obtain the desired pitch and loudness. In contrast, it is often difficult to predict the precise characteristics of the resulting sound from the parameters with non-standard synthesis. The relation between the parameters and perceptual attributes may be non-linear. In addition, by working at audio rate (via "microcomposition"), Xenakis was very much aware of the possibilities of producing sonorities of higher-orders (Xenakis 1992) in a process described as "sonological emergence" (Di Scipio 1994), where timbre and pitch emerge from sample-level processes (Hoffmann 2004). One could argue that non-standard methods are implemented precisely in order to listen to the possibility of such outcomes.

2.2. Audification

Audification is the direct translation of data to the audible range and it is a form of sonification at audio rate. It could be considered as an analogous technique to non-standard synthesis. As such, the sound produced may also be difficult to predict. But in the most effective implementations, there is also a similar capacity for the emergence of higher-level features (and to an even greater extent than is evident in parameter mapping sonification). In the audification of seismic data, timbre is a good indicator of the material e.g. metallic sounds indicate sediments whereas wooden sounds indicate bedrocks. Its tectonic source mechanism can also be inferred from its amplitude envelope e.g. a sharp hard beat indicates one plate subducting the other and a 'plop' indicates two plates moving apart (Dombois 2002).

As with sonification in general, one listens to audifications in order to ascertain features of the data used. Whether an understanding of the underlying mathematical model is necessary to fully experience Xenakis's works is open to debate, but it is nonetheless one possible way of accessing the music. With recent debates on how aesthetic considerations should be an integral rather than a distinct element within auditory display (Vickers, Hogg and Worrall 2017), Xenakis' use of non-standard synthesis may be considered as examples of audification.

Although not fully realised, Xenakis envisaged how features may emerge on the level of microstructure (timbre), ministructure (note), mesostructure (polyrhythm, melodic scales of intensities) and macrostructure (global evolution on the order of some tens of minutes) (Xenakis and Brown 1989). Audification design informed by Xenakis' aims would lead to an effective form of sonification.

3. Artificial neural networks

An artificial neural network (ANN) is a simplified computational model of neurons in a brain. We are currently witnessing a resurgence of interest and development in machine learning (ML) using multiple layers of ANN, or deep learning (DL). Whilst the basic ideas behind ANN are not new, the development of Graphics Processing Units and their capacity for parallel matrix and vector computations has enabled unprecedented growth in the field in recent years. It may be seen in a wide variety of applications including art and music.

The majority of uses of ANN for training and generating music until recently have been based on higher-level features and time-scales i.e. they may be considered as equivalent to algorithmic composition or parameter mapping sonification, operating at the level of notes. However, recent work using NN at lower-levels may be observed at the level of FFT time slices or even digital audio samples e.g. Wavenet (Oord *et al* 2016).

Another general observation is that the goal of most research into creative uses of ANN is the reproduction or the imitation of features, styles or entire pieces found in existing works and artforms. This is no different in the case of music. The situation is understandable as its most financially viable

use currently is perhaps automation e.g. of time-consuming tasks within the work flow of composing and arranging on a DAW, or of the production of entire musical pieces in specific styles. Whilst it could be argued that related research may offer new insight into existing artforms as a form of practice-led research and may also be of use in fields such as computational creativity, it is not conducive towards the creation of new art, or research-led practice.

3.1. Audio rate and non-standard possibilities

The primary goal of the aforementioned Wavenet is the generation of speech as a text-to-speech (TTS) system where the desired text along with the previous audio samples are used to predict the next sample. If the network is trained without a sequence of desired text, it generates sounds which are curiously speech-like but sounding like non-sensical made-up words. In a similar manner, a dataset of classical piano music was used to train a network and without conditioning it on an input sequence. When left to generate sounds, the results are again a curious concoction, reminiscent of early 20th century piano music.

There are several implications. The first is that the real possibility of working at the low-level time-scale of raw audio with ANN. Dealing with amplitude values of each audio sample is far removed from higher-level perceptual features of audio. But Wavenet has demonstrated the possibility of ANN to operate at this abstract level and create perceptually coherent higher-level results. In addition, the ability to generate audio without conditioning the network on a sequence of desired text or score, working with raw audio samples offers possibilities comparable to non-standard use. The second more general observation concerns the opaque nature of how audio is encoded using ANN. Usually in DL, information is reduced to numerous multi-dimensional vectors and matrices. What the values they contain represent remains a mystery. A non-standard approach may be a productive way of working with such a blackbox-like structure which could be described as a form of audification of ANN.

4. Future work

The next step will be the practical implementation of the ideas mentioned which is underway. Additionally, although the ML techniques mentioned in this paper are only several years old, the resurgence of the use of ANN has seen unprecedented development in the field and new optimisations are already evident which require further evaluation.

There are also additional considerations. Wavenet uses an autoregressive model with a fully convolutional neural network (CNN), normally used with images. With the temporal dimension processed in place of the usual spatial dimension in an approach reminiscent of Xenakis' discussions concerning space and time (Xenakis and Brown 1989), working with ML may provide another avenue for exploring the space-time relation on a conceptual level and beyond.

Aside from long training times from working on raw audio which recent developments attempt to address (e.g. Paine et al 2016; Oord et al 2018; Kalchbrenner 2018), ANN methods in general have difficulties in learning and generating structures at longer time-scales. Generating sound at audio rate leading to a form of sonological emergence is a possibility which deserves further attention.

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Analysing Mikka "S": from Micro to Macrocomposition and Perception Features

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Abstract

Iannis Xenakis always questioned traditional music theories, and acoustic theories applied to music, particularly. Based on Xenakis' writings, it is possible to notice a critical position to the Fourier series, natural harmony, and serialism, among other points. Anchored in such viewpoint, in the 1970s, Xenakis created a synthesis method using finite juxtaposed elements to model the stochastic variations in the sound level pressure. In parallel, he used this method as a sonification strategy to be applied to instrumental composition resulting in a series of works including *Mikka "S"* (1976), for solo violin. In this article, we analysed *Mikka "S"* based on two hypotheses: 1) Xenakis's viewpoint dialogue with complex dynamic systems theory correlated to the multidimensionality of musical parameters and their complex inter-relation; and 2) *Mikka "S*" can be analysed by the evolution of the psychoacoustic feature of roughness, which is a perceptual sensation also dependent on multiple musical variables. We argue that the compositional and instrumental techniques employed in this work such as polyphony, microintervals, different types of glissandi, intensities, modes of attack, durations are Xenakis's strategies employed to control the roughness evolution during the piece. We conclude by observing a general tendency of the *Mikka "S"* musical texture to increase the roughness in time. In addition, we point out that the multidimensionality of the roughness perception opens the possibility of a large exploration of the musical material producing stimuli to different sensorial responses.

1. Introduction

We introduce our study describing how Xenakis's questioning of Fourier Analysis and Synthesis converged to his development of a new method of sound synthesis.

He seems to always have questioned traditional music theories and acoustic theories applied to music. Based on his writings, and also in his compositions, one can rapidly observe that had a critical position concerning this musical conception founded on the Fourier analysis-synthesis approach, natural harmony, and serialism (Xenakis, 1971, p. 242). Xenakis's position can be attributed to multiple factors, but maybe one passage in an interview with François Delalande could resume his viewpoint: "One must always cultivate a new view, that is to say the distancing. One should be constantly an immigrant"[1] (Delalande, 1997, p. 123).

[1] « C'est à dire qu'il faut cultiver constamment le regard neuf. C'est-à-dire la distanciation. Il faut être constamment un immigré » (Delalande, 1997, p. 123).

Starting upon such Xenakis's concept of dynamicity and change over time, we can also highlight his interest in complexity and interdisciplinarity, concerning the mathematization of musical parameters and the construction of abstract relations between sounds and concepts, leading to the formalization of composition processes (Gibson, 1994, p. 9).

In "*La crise de la musique sérielle*" (1955), the main points of Xenakis's criticism of serialism are that the principal materials of such music are frequency, intensity, and timbre, although the frequency has a preponderance in dodecaphonism as the linear arrangement of the twelve tones. Besides the row, another issue is the use of a polyphonic arrangement to organise the pitch material in serial music. Given that, in polyphony, a complex passage, with a considerable number of voices, results in amalgams of pitches in different registers. Xenakis identifies such use as a contradiction of serial music. It is because the polyphonic amalgam results in a perception of sound masses due to the saturation of auditory perception, and therefore one cannot identify the voices separately (Xenakis, 1994, p. 39-41).

Starting upon such viewpoint, Xenakis created the principles of stochastic music, where polyphony disappears, and sounds are independent. Its organization is based on the statistical mean of the isolated states of transformation in time. Thus, we have the introduction of the notions of probability and combinatorial calculation in musical composition. Another crucial issue is that macroscopic perception (that can be the perception of sound objects or the perception of macroform) is controlled by the mean of the internal movement of sounds (Xenakis, 1994, p. 42). Then, the abandonment of the traditional notions of harmony and counterpoint would result in the notion of time-varying frequencies density, which could be vertical aggregates or horizontal sequences of sounds (Xenakis, 1994, p. 45). Just such characteristics of the sonic aggregation created by Xenakis, inspire us to use a model of Roughness to analyse the musical texture of *Mikka "S"*.

During the end of the 1960s, Iannis Xenakis had worked at Bloomington, using computers to work on sound synthesis. Normally, at this time, synthesis was conceived as a superposition of harmonic or inharmonic partials, as a kind of additive synthesis (Solomos, 1996, p. 47). For Xenakis, sounds produced by simple sinusoidal oscillators were marked by a simplistic sonority, moreover, the serial approach utilized in electronic music could not improve the sound result. Xenakis enumerated a few problems related to such synthesis method used in electronic music, as follows: 1) Studies of Meyer Eppler have shown that orchestral sounds present spectral variations in frequency and amplitude in their stationary parts that give "life" to sounds. These variations should be approached by new theories with different acoustic and harmony conceptions. 2) The importance of the transient part of the sound for timbre recognition. 3) The inexistence (until the beginning of the 1970s) of a pattern and form recognition theory to translate synthesized curves in the perception of forms and configurations (Xenakis, 1992, p. 243-244).

As an attempt to solve those problems identified in microcomposition, Xenakis proposed the synthesis method of finite juxtaposed elements by taking the atmospheric pressure as a control parameter of sound variation as a function of time, therefore he expected to obtain a complex curve with increasing irregularity, in a quasi-periodic manner approximating the sound result to noise. Xenakis pointed out that this strategy did not pretend to simulate already-known sounds but to produce unexpected and interesting "new" sounds. Also, the start point, different from additive synthesis, was an order-disorder concept, combined with means to increase or decrease it. Xenakis's idea was not to construct a complex sound from unity discontinuous elements (similar to the additive synthesis partials) but to generate sounds with continuous variations controlled using a stochastic approach (Xenakis, 1992, p. 245-246).

As Solomos (1996, p. 47) explains, Xenakis's method of sound recomposition (or sonification) was based on the most complex state of sound, the noise. On one hand, the sound pressure curves were directly generated using the vertical axis (Y) for sound amplitude and the horizontal axis (X) for time. Those aleatory curves are obtained with Brownian movements (chaotic displacement processes of

suspended particles in a liquid or gas, which are the result of their collision with the molecules of the environment).

In this article, our analytical perspective is that Xenakis's method for sound synthesis dialogue with the theories of Complex Dynamic Systems. As we can understand from Solomos's statements above, the process of recomposition engaged by Xenakis deals with the multidimensionality of musical parameters and their inter-relation, conceiving them as a system of multiple variables evolving in time: e.g. the inter-relation of sound pressure curves with other musical parameters such as pitch, noise, time, musical intensity, density, and instrumental techniques. In addition, we observe the attention given by Xenakis to the transient part of the sound, which is very complex in comparison with the other parts of the sound envelope, presenting an irregular and unpredicted behaviour that is very difficult to be modelled by traditional synthesis methods.

Complex dynamic systems are normally unstable and formed by a large number of variables or isolated states. Moreover, in those systems, time is considered an independent dimension that evolves in a "one-way direction" (Prigogine, 1995, p. 26). In our view, music can be understood based on these notions (Rossetti & Manzolli, 2019; Rossetti et al., 2020). On the other hand, music theory historically gave more importance to one variable, the pitch, and many examples of this fact can be found. One of them is in Schoenberg's *Theory of Harmony* (1983, p. 421), where he affirmed that musical sounds have three operatory dimensions, pitch, timbre, and intensity, however, up to now the most largely expanded was the pitch.

Therefore, we present an analysis of *Mikka "S"* (1976), a violin solo work by Xenakis that deals with the theoretical background presented above and, at the same time, with technical issues of the violin. In the first moment, the sounds of *Mikka "S"* are produced by the interaction of two independent voices that interfere with each other in a polyphony constructed with large and continuous *glissandi* with microtone intervals. In the second moment, Xenakis used abrupt attacks *au talon,* and fast and discontinuous *glissandi* of different directions and sizes. As already pointed out, this kind of amalgam sonority can be analysed by a model of the psychoacoustic phenomenon of roughness, which is linked to this sensation of harshness. The roughness was first described by Helmholtz (1954) and more details of this psychoacoustic feature will be presented next. We highlight that although the roughness sensation was explained by Helmholtz in terms of traditional acoustic and psychoacoustic theories based on the Fourier approach, it is also a multidimensional phenomenon linked to complexity, and is dependent on multiple variables such as pitch intervals, intensity, and different modes of attack of the musical instruments. Moreover, this sound material is very prominent in *Mikka "S"*, and we hypothesize that it was explored by Xenakis in different ways in the composition process of this work.

2. Roughness definition

Roughness produces a type of harsh aural sensation and was introduced in psychoacoustics literature by Helmholtz (1954). This harshness sensation is perceived when a sound signal contains amplitude fluctuation rates between 20 and 150 fluctuations per second, depending on the pitch register. By the end of the 19th Century, Helmholtz defined the basis of psychoacoustics considering the Fourier law, which enunciated that "any given regular periodic form of vibration can always be produced by the addition of simple variations, having pitch numbers that are once, twice, thrice, four times, etc., as great as the pitch numbers of the given motion" (Helmholtz, 1954, p. 34). Analogously, the ear performs the inverse operation to perceive pitch: "musical tones could be resolved into a series of partial tones corresponding to the simple pendular vibrations in a mass of air", as Ohm's acoustical law indicated (Helmholtz, 1954, p. 49).

Traditionally, in Western music, roughness is also related to consonance and dissonance, and a clear example of a roughness sensation is achieved by a minor second interval performed by any instruments or voices. The reason that harmonic intervals different from unisons exhibit amplitude fluctuations are linked to the phenomenon of interference, and the reason that some of those intervals correspond to rough sounds is related to the mechanical properties of the inner ear. Roughness sensation

is usually understood in terms of the sine-component interaction between the same frequency band and the critical band[2] (Vassilakis, 2005, p. 119-122).

The roughness model is related to the sense of very fast amplitude variations of the sound. It is partially conditioned by the physical characteristics of the sound signal (mainly pitch and intensity), and by the properties of the inner ear (Vassilakis, 2001). For the audio-feature roughness analysis and its graphs elaboration, an implementation of the descriptor using Vassilakis's model (2001) in a Python environment was performed by Antunes; Feulo; Manzolli, 2021 and will be used in the analysis presented here.

The roughness calculation is commonly anchored in the parametrization of the dissonance curve in the function of the critical bandwidth (Vassilakis, 2001), as introduced by Plomp and Levelt's experiment (Plomp; Levelt, 1965). The roughness, as proposed by Vassilakis (2001), is calculated as a sum of the local roughness for each pair of partials of the spectra, as follow:

$$R(f_1, f_2, A_1, A_2) = \frac{1}{2}(A_1 * A_2)^{0,1}\left(\frac{2A_2}{A_1+A_2}\right)^{3,11}\left[e^{-b_1 s(f_2-f_1)} - e^{-b_2 s(f_2-f_1)}\right] \quad (1)$$

where f e A are the partials frequency and amplitude, and $b_1 = 3{,}5$, $b_2 = 5{,}75$, $s = \frac{0{,}24}{s_1 f_1 + s_2}$, $s_1 = 0{,}0207$ e $s_2 = 18{,}96$, parameters deduced by the approximation of Plomp and Levelt's experimental curve. We used in this analysis a python implementation of the Vassilakis roughness model, as introduced by Antunes; Feulo; Manzolli, 2021.

3. Analysis of Mikka "S"

In the mid-1970s, Xenakis could not realize his new synthesis technique by lack of means. Instead, he applied the principle to instrumental music, resulting in a series of works including *Mikka* (1971), for solo violin, *N'Shima* (1975), for two sopranos and instrumental quintet, *Theraps* (1975-76) for solo double bass, and *Mikka"S"* (1976), for solo violin. In those works, continuous and non-linear (discontinuous) *glissandi* are largely found, varying from tiny to large registers, resembling random walks (Solomos, 1996, p. 49). As Luque (2009, p. 79) asserts, in *Mikka*, *N'Shimma*, and *Mikka "S"*, Xenakis generated stochastic synthesis curves in a graphic plot to define the pitches and *glissandi*'s durations, mapping the horizontal axis is time and vertical axis into a grid of quarter tone pitch values.

Mikka "S", for solo violin, is a work of around four minutes, which is dedicated to Mica Salabert. The *glissando* is a preponderant instrumental technique in this piece, consisting of two basic types: long and slow *glissandi* with overlapping entrances, resulting in a two-voice texture; and short, cut-off disconnected gestures by upward strokes at the heel (*au talon*) of the bow. An important role between continuity and discontinuity textures is linked to the structure of this work. Continuous contact between the bow and strings is maintained in the first 60 measures (with a duration around 2'40''), with tempo unity of half note equal (or faster) to 54. The last 16 measures, on the other hand (Ca. 1'20''), mostly consist of brief and disconnected *glissandi*, interleaved with sustained pitches (Squibbs, 1996, p. 243).

The analysis presented here consists of two procedures: a) the first that uses the material from the music score, we define as "symbolic analysis", and b) the second, that uses an audio recording of the piece, we define "audio analysis". In the first, we plotted pitch, duration, and intensity information in two graphics: 1) a plot of the duration (X-axis) and pitch (Y-axis), and 2) a plot of the duration (X-axis) and intensity (Y-axis). Additionally, these two graphics were compared to an audio-feature extraction of the roughness evolution in time, from an audio recording of *Mikka "S"*.

[2] The term critical band was introduced by Fletcher in the 1940s and refers to basilar membrane area that vibrates in resonance to an incoming sine wave (Vassilakis, 2005, p. 122).

3.1. Analytical hypothesis

Our hypothesis is that when listening to *Mikka "S"*, one can identify the presence of different levels of roughness produced by the interaction of the 2 voices performed by the violinist, also in the discontinuous gestures of *glissandi* played *au talon*. We will search to identify which excerpts of the work can produce higher and lower roughness sensations, relating them with the intervals written in the score. After finding those regions with prominent roughness values, we will seek to propose a formal segmentation of the piece based on the information collected by the analysis methods utilized.

3.2. Symbolic analysis

For the analysis of the score, we first plotted the information of pitch and duration of the notes in the score in a 2-dimension graphic having the durations in the X-axis and pitches in the Y-axis. The unity of the durations are the measures and their subdivisions, and the unity of the pitches are pitch-class numbers, with middle C = 60 (quarter tones are defined in *midicents*, e.g. *C4* a quarter tone higher = 60,5). Then, similarly, we plotted the intensities information (Y-axis) also in function of time (X-axis). To define a scale of intensities, these specific values from 0 to 90 were chosen, corresponding to dynamics notation (from *ppp* to *ffff*): silence = 0, *ppp* = 10, *pp* = 20, *p* = 30, *mp* = 40, *mf* = 50, *f* = 60, *ff* = 70, *fff* = *80*, and *ffff* = 90. Figure 1 shows the resulting graphics.

Observing the higher part of Figure 1[3], the durations X pitches graphic, one can visualise the behaviour of the pitches in both voices and their *glissandi* in time. From measure 1 to 19, voice 1 and voice 2 maintain a distance approximately of an interval of a sixth, except for measures 11 and 12 when the interval decreases and approximates to a second interval. Measures 19 to 21 have only one voice descending to a lower register (around G3). In measures 22 to 27 the voices behave similarly to the beginning of the piece in terms of intervals; however, the movement of the voices increases. From measure 30 to 47, voice 2 remains in A4 pitch (69), while voice 1 moves below and above this pitch. From measure 36 to 40, voice 1 performs a continuous *glissando* from F4 a quarter tone higher to A4, continuously approximating to the unison that is achieved in the second beat of measure 40. This unison quickly ends with a descending *glissando* in voice 1.

In measure 47 a new design begins. Voice 1 performs *glissandi* in higher regions (from B5 to E5, measures 47 to 53, and from E4 a quarter tone higher to C#6 a quarter tone higher), while voice 2 moves to a lower register, between G3 and D4). Then, in measure 54 an extremely high descending *glissando* begins in voice 4, from E7 achieving C#5 at the end of measure 60. In the same excerpt, voice 1 performs a *glissando* from measure 55 to the end of measure 60, beginning in A#6 and descending until E5. It is very important to highlight that both *glissandi* cross each other, resulting in a very intricate passage. Then, from measure 61 to 76, the piece evolves to a single voice, mostly in *ffff*, with the presence of several fast and discontinuous *glissandi au talon*, sometimes separated by long notes, such as in measures 66, 67, 68, 69, 72, 74 and 75. It's a different part of the piece in terms of character, possibly composed using a different process. Here, we can infer that Xenakis developed aleatory curves obtained with Brownian movements.

In terms of dynamics over time, which can be observed in the lower part of Figure 1, most of the time the dynamics of the two voices evolve similarly. We find differences in measures 25 and 26 where voice 2 is maintained in *fff* , while voice 1 decreases from *fff* to *p*. From measures 47 to 53 there are also differences. In measures 47 and 48, voice 1 dynamics increases from *p* to *fff*, and voice 2 remains in *fff*. In measures 50 to 52, a "canon" of dynamics is observed: voice 2 increases from *p* to *fff* from the middle of measure 50 to the beginning of measure 51. The same behaviour in voice 1 is found in voice 1 from the second beat of measure 51 to the beginning of measure 52. At the middle of measure 52, both voices return to *p*.

[3] The data used to elaborate the graphic is available at https://gitlab.com/micael_antunes/mikka_s_roughness/.

Based on the behaviour of the voices, we deduced 4 musical textures, leading to 4 segments of the piece. Segment A (bars 0 – 26) exhibits a texture of oscillatory patterns in both voices. The major characteristic of segment B (bars 26 – 47) is the static note of the voice 2. Segment C (47 – 61) displays an expansion of the register and complex behaviour of the 2 voices in texture. Finally, segment D presents only one voice (Voice 1) in the musical texture. The formal subdivision of *Mikka "S"* in four sections is presented in Figure 2

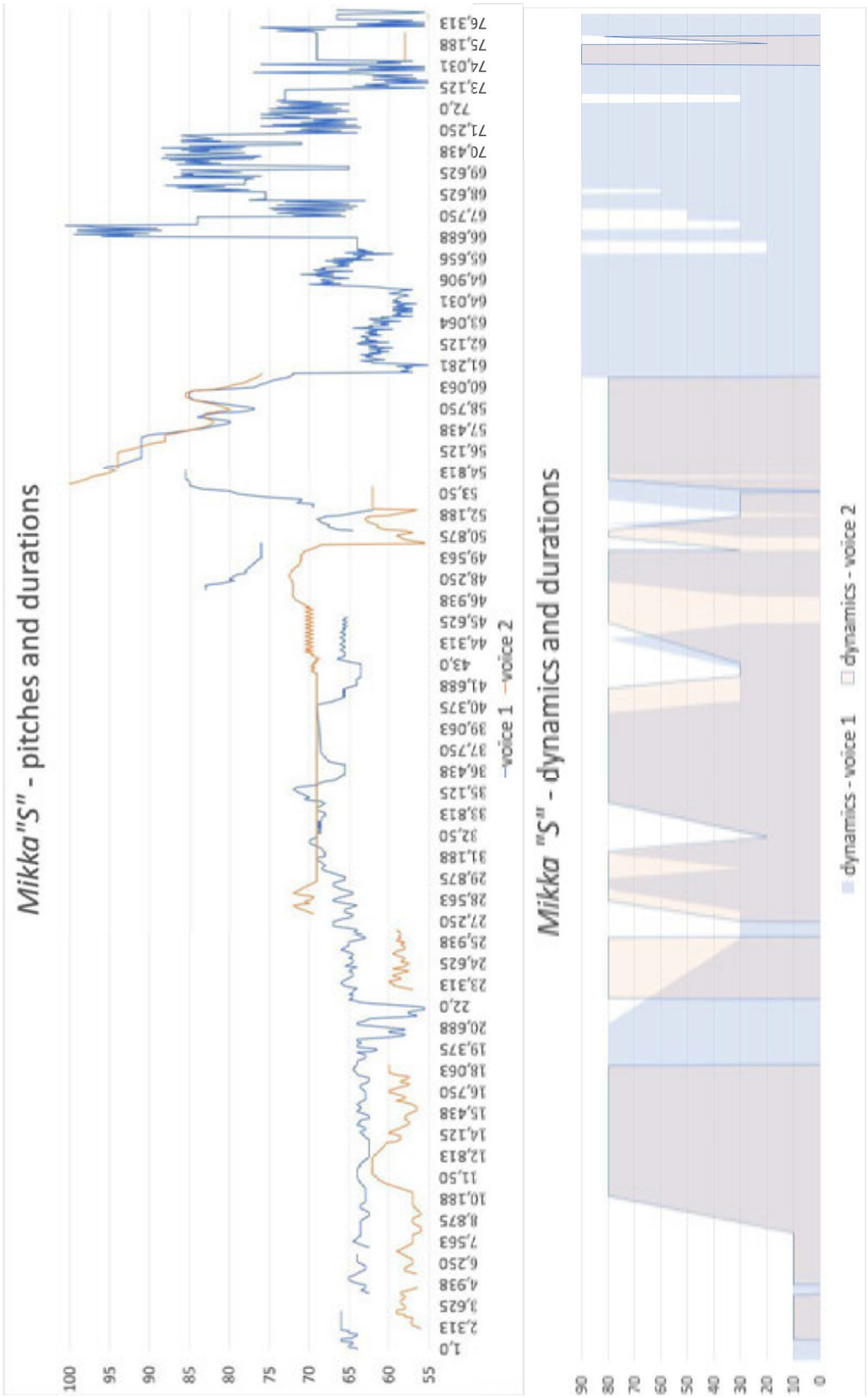

Figure 1: Mikka "S" graphics of pitches, intensities, and durations.

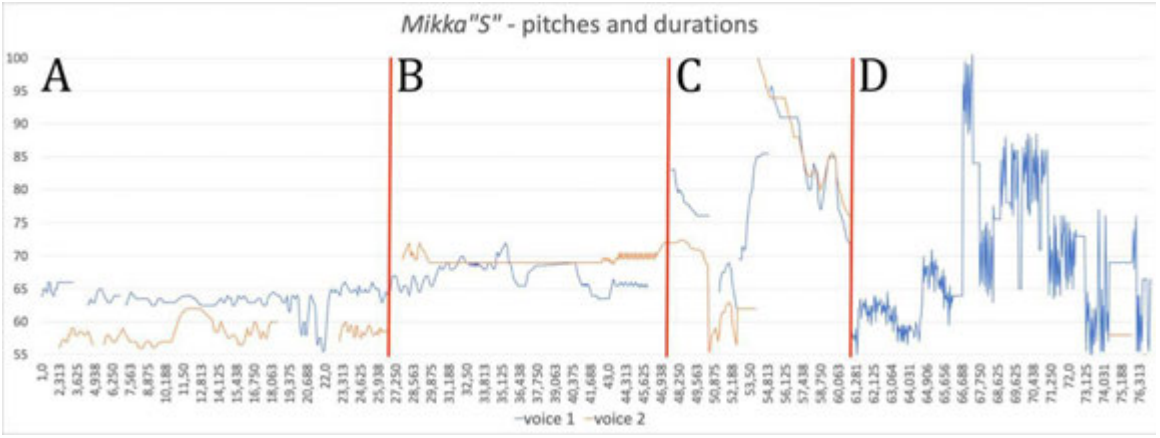

Figure 3: Mikka "S" segmentation in four sections (A, B, C, and D).

3. *Audio-feature analysis*

We choose the recording of the Arditti String Quartet, from the album *Iannis Xenakis: Chamber music 1955 – 1990*, recorded in 2016. Based on the score segmentation, we performed the segmentation from audio, as follow in Table 1:

Segments	A	B	C	D
Bar	0 - 26	26 - 47	47 - 61	61 - 77
Recording Time	0:00.000 - 1:17.067	1:17.067 - 2:23.352	2:23.352 - 2:57.250	2:57.250- 4:20.573

Table 1: Score and audio segments of *Mikka "S"*.

To perform the analysis from audio, we used Python[4] and Jupyter[5] environment and the code is available on a Gitlab repository[6]. To extract the spectral information from audio, we used the reassigned spectrogram module from librosa[7], with a window size of 8192 samples and a hop size of 441 samples. Then we used a librosa peak picking algorithm to select the frequency and amplitude values of each time window and calculate the roughness with the Vassilakis model (Eq 1), as implemented by Antunes; Feulo; Manzolli, 2021. The result of the roughness calculation in *Mikka "S"* for the 4 segments is displayed in Figure 3

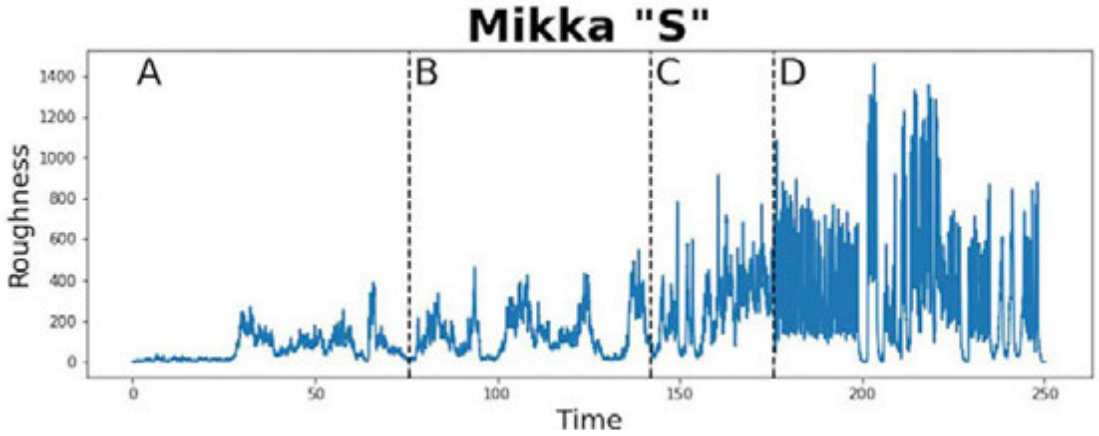

Figure 3: Roughness calculation in *Mikka "S"*.

[4] https://www.python.org/
[5] https://jupyter.org/
[6] https://gitlab.com/micael_antunes/mikka_s_roughness
[7] https://librosa.org/

We notice that the roughness exhibits an accumulation behaviour through time. Both the intensity and the variation rate increase through time. To understand the role of roughness in the composition, we present an analysis with both symbolic and audio data in the next topic.

4. Outcomes and discussion

Due to the role of the roughness in the relationship between voices, we assume as a focus to investigate the roughness characteristics in the polyphonic texture of the piece. So, we selected the first 3 segments of the piece to analyse. In Figure 4 we present the symbolic information of the score considering the pitches and their respective dynamics in the function of the bars, at the top of the figure, and their respective roughness, in the function of the recording time (in bars, above, and seconds, below).

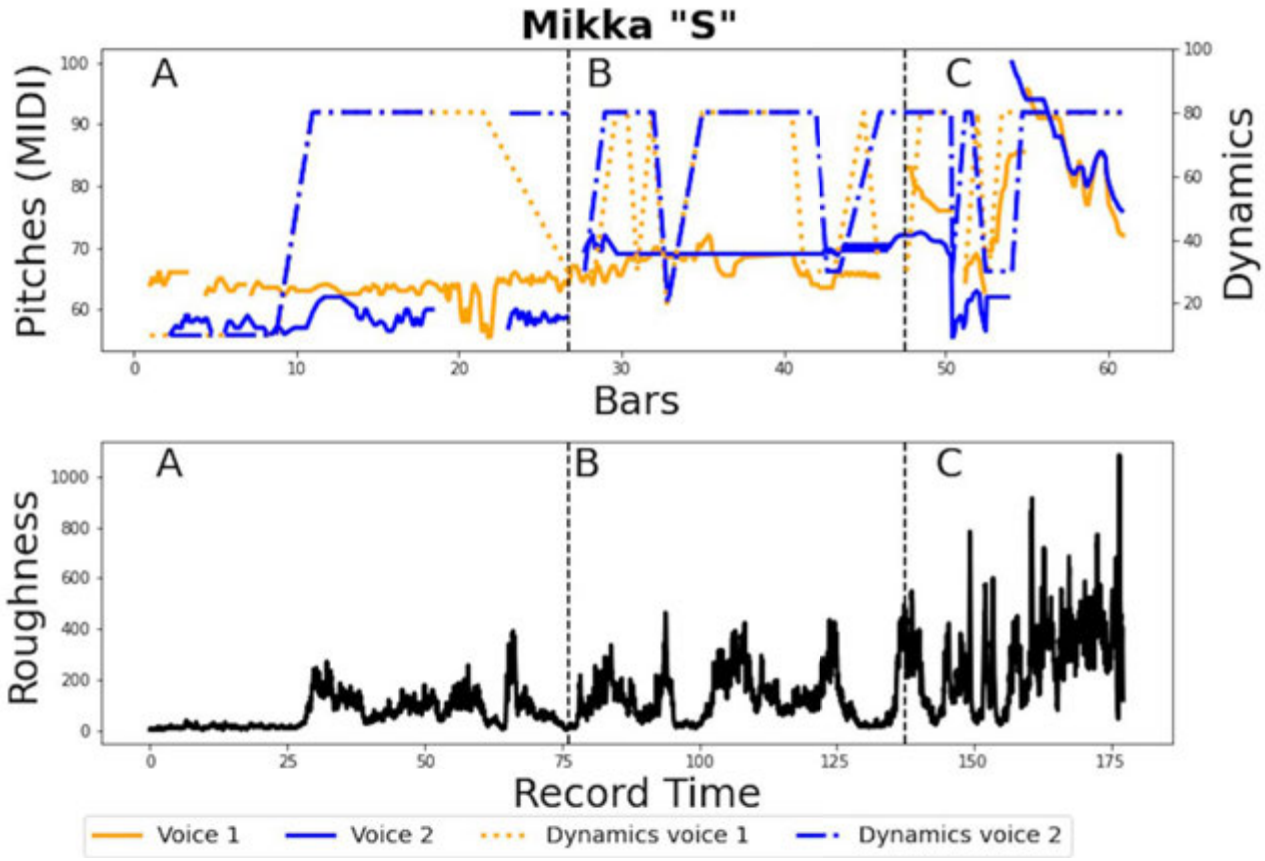

Figure 4: Pitches, dynamics, and roughness in *Mikka "S"*.

By observing Figure 4, we notice an overall tendency of the pitches, starting from lower frequencies in segment A until achieving higher frequencies in segment C. We also observe an increasing profile of the roughness in time, through the 3 segments. A complex pattern of dynamics is observed through time.

To investigate types of textural behaviour in these segments, we selected 3 excerpts from the piece aiming to analyse with more focus, due to the characteristics of the 2 voices' interactions. The first segment is from measure 01 to 18, the second is from measure 30 to 42 and the third is from measure 44 to 60. Those segments and their analysis are presented in Figure 5.

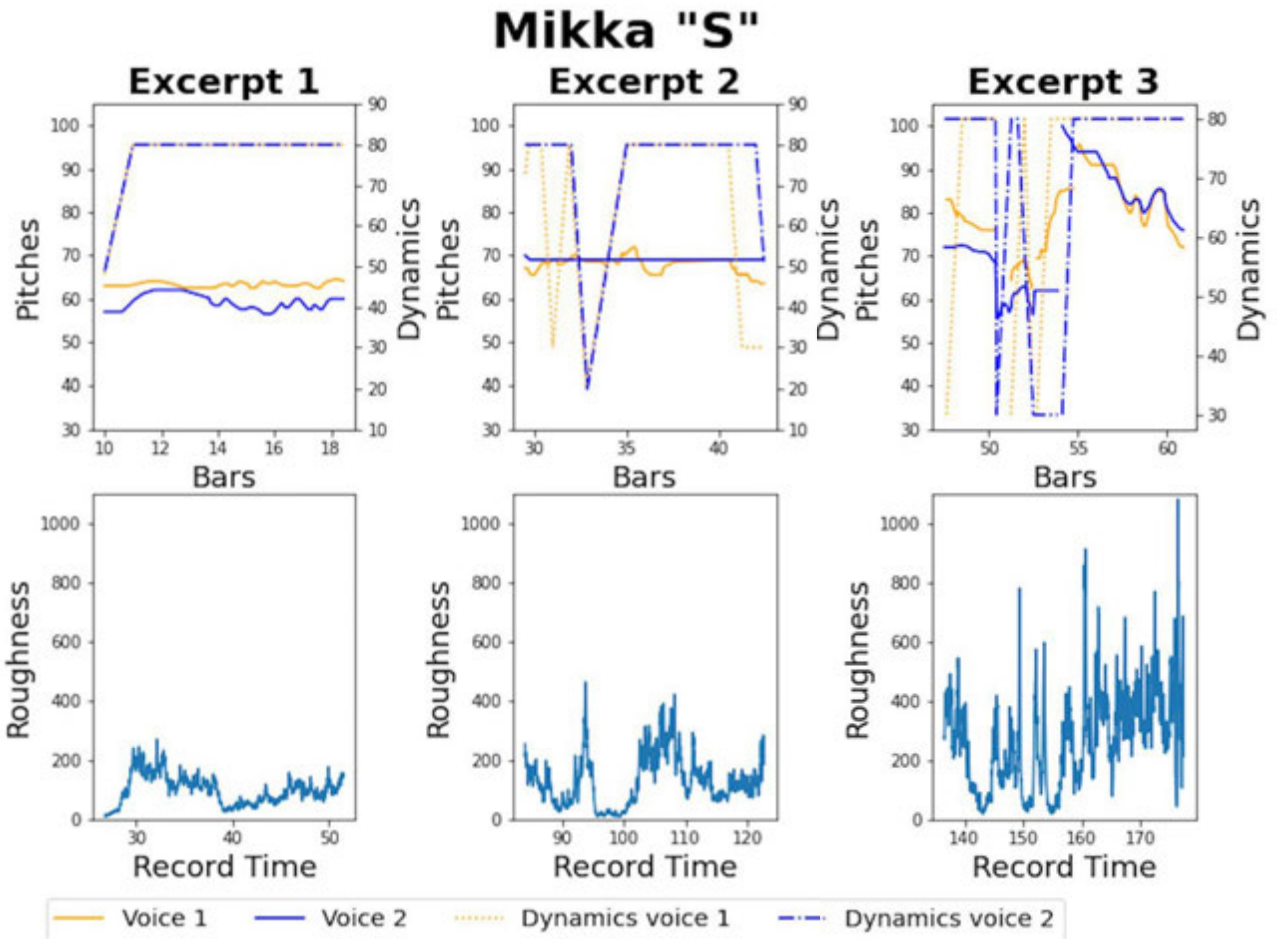

Figure 5: Symbolic and audio data in three excerpts of Mikka "S".

By observing the score from the data collected, we notice that the main focus of the musical texture is the interaction between the 2 voices through the manipulation of the very short intervals between the voices. We notice that excerpt 1 does not exhibit differences in dynamics. Consequently, we see that the roughness levels are a consequence of the very short intervals of the 2 voices.

In excerpt 2, a texture is explored by using a static note surrounded by the pitches of the voice 1. The dynamics display very different values in both voices with some contrasts. In terms of roughness, we observed a very rich exploration of the roughness, with several contrasts, like that observed from 90 to 100 seconds of the recording.

Excerpt 3 exhibits the moment of higher polyphonic complexity of the piece. The 2 voices have their interactions with a huge variety of melodic profiles. From bar 43 to 60, a moment of the high intricate profile of the 2 voices is observed. We also notice that the dynamics dramatically change through the excerpt, with high contrasts, like those of bars from 50 to 54. Due to the complexity of the music excerpt, we notice that the roughness exhibits a very complex profile, with the highest values of the 3 excerpts.

5. Conclusion

By observing the roughness profile of the piece, we notice a general tendency of the musical texture to increase the roughness in time. To achieve this state, we highlight 3 main compositional strategies: the first is to explore the roughness changes by using the difference of distances of notes with no changes in dynamics, like in excerpt one. The second consists in exploring the balance of dynamics in the two voices, like in the initial moment of excerpt 2. And the last one is a consequence of the exploration of polyphonic complexity.

These strategies lead to 2 main perceptual characteristics in roughness exploration. The first with the exploration of slow changes in time, with very subtle changes in time, which is mainly explored in excerpts 1 and 2. And the second, very abruptly changes and very fast variation of roughness in time, like in excerpt 2.

We may affirm that the dynamic extracted from the score and the perceived dynamic from the recording in time is not linear. It means that the execution of the notated dynamic of the score through time changes in the function of its context. Specifically, in *Mikka "S"*, we notice a continuous increase in the dynamic intensity as a performance strategy. So, it is also at the source of the increase in the roughness profile of the piece.

We understand the multidimensionality of the roughness perception opens the possibility of a broad exploration of the musical material. In this sense, we confirm the interest of Xenakis in complex sound phenomena. Although roughness is defined through traditional acoustic and psychoacoustic theories, its dynamical behaviour is dependent on multiple variables and can be controlled and manipulated in time. *Mikka "S"* and other works by Xenakis of this period are the results of his research in new microsound structures by applying synthesis and sonification methods based on complexity, multidimensionality, and inter-relation of parameters. Moreover, the evolution in time of those phenomena is controlled by Xenakis through multiple factors, such as the polyphony behaviour, intensities, instrumental techniques, modes of attack, registers, and the different types of glissandi employed in the work. Finally, the instrumental techniques employed in the compositional process of *Mikka "S"* can be also thought of as a complex system with multiple relations, opening the possibility to the rise of emergent sonorities and psychoacoustic phenomena such as roughness.

Acknowledgments

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The features of the instrumental part in vocal-instrumental compositions by Iannis Xenakis

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Abstract

a) The main characteristic of the work. The phenomenon of Xenakis's vocal music in the aspect of his general composer's creativity consists in the existence of a special complex of artistic and musical means associated exclusively with this sphere of the genre. The insertion of a living human voice in the instrumental timbre palette dictates a completely different sound concept. Actually, its instrumental apparatus cannot be called an orchestra. It is a kind of symphonic ensemble, from a chamber to an extremely expanded one. Unusual choice of instruments, but also their unconventional functionality speaks of Xenakis' complete rejection of academic orchestral writing. b) Analysis of the specifics of the instrumental part in musical tragedies. The stage genre brought its own means to the music of Xenakis. Naming the purposes of music in tragedies, the composer underlines, for example the following ones: sound commentary (the murder of Agamemnon in 'Oresteia'), the play of maids on a wooden and metal simantra during the dialogue between Orestes and Electra (in 'Oresteia'), noise when Medea conjures (in 'Medea'), a choir playing musical instruments, etc. In such scores, the composer approached the question of choosing the right instrumental timbres much more individually, especially in the choice of strings. Thus, only the cello is included in the "Oresteia" of bowed instruments. The same picture is in 'Medea'. In the tragedy "Bacchae" Xenakis completely abandoned the stringed group. For Xenakis, such a selective approach to stringed instruments is unusual, since they have always played an important role in his instrumental opuses. Xenakis divided the vocal and instrumental parts in a historical sense: "archaic" singing was combined with the modern sound of instrumental accompaniment, which gave his music a new dimension. c) Analysis of the instrumental part in the compositions for chorus and instruments. A significant part of Xenakis's vocal opuses are compositions for a choir. Xenakis developed a creative interest in this genre in the early 1960s, with the appearance of one of his most famous choral works, 'Polla ta dhina'. In this area of vocal creativity, the composer actively experiments with choral material, using it as one of the timbres of the instrumental score. Speaking of the instrumental part, one can note the special role of interludes in shaping, the tendency towards symmetry, concentricity and thematic arches. The peculiarities of the orchestration include non-traditional instrumental compounds, the use of instruments in the highest and lowest registers, so that the timbre becomes almost unrecognizable, the divisi technique strongly employed, the preference for non-standard wind instruments. One can notice the non-traditional functions of the orchestral groups in these works, a change in the space performed. The instrumental texture is characterized by glissando, sonoristic sound masses and author's textural techniques: "clouds", clusters, etc. The orchestral part in Xenakis' vocal and instrumental compositions remains a field of innovative experiments and is of particular interest.

1. The General Characteristic Feature of the Work

The phenomenon of Xenakis' vocal music in the aspect of his overall musical legacy consists of the presence of a specific complex of artistic and musical means connected exclusively with this sphere

of genre. Xenakis made use of the entire arsenal of techniques of the vocal language intrinsic to the music of the second half of the 20th century – special types of sound production (shouts, whispers, whistling), the transfer of instrumental techniques onto the vocal domain (glissandi, pizzicato) and many others. At the same time, special interest is also presented by the instrumental part in the vocal-instrumental compositions. The inclusion in the timbre palette of the living human voice dictates a completely different sound conception for the score, presuming the attention towards separate details, an intricate elaboration of the texture, as well as acoustic effects precisely figured out in advance. The figurative world becomes more concrete, and this concreteness comes into the music along with the verbal text. Xenakis' music in the theatrical genre acquired, among other things, the theatrical techniques intrinsic to it, such as figurativeness, which is alien to the general abstract qualities of orchestral works. The orchestra in the vocal-instrumental compositions, obviously, does not presume any kind of particular traditional instrumentation. It is, rather, a certain kind of orchestral ensemble, ranging from chamber-sized to extremely expanded, including about a hundred musicians. Not only the unusual instrumental ensembles, but also its absolutely non-traditional functionality testify of Xenakis' complete rejection of academic orchestral writing.

2. Analysis of the Specific Features of the Instrumental Parts in the musical Tragedies

Xenakis formed his own philosophical-aesthetic conception of reviving Ancient Greek tragedy on the musical stage of the second half of the 20th century. In this case, important roles were relegated to the instrumental parts. In the article "Notice sur l'Orestie" Xenakis brings in concrete examples from his music, such as, for instance, a chorus which dances and plays on musical instruments and the mobility of sound, which occurs when the dancing chorus changes its location on stage, making it possible to expand the spatial effect of the music and the augmentation of the sources of sound. Instruments, such as the shingle in "Medea" whips, metal and metal simantras and bells in "Les Choefores", become elements which enrich the dances, transforming their unique variety of magical, mysterious liturgy.

The genre of music for the stage brought in its own peculiar means to Xenakis' orchestra. When labelling the functions of music for tragedies, the composer highlights the following, among others: the sound-generated commentary (the killing of Agamemnon, "Oresteïa"), symbols of events: fanfares upon the appearance of Agamemnon ("Oresteïa"); noise, when Medea is working magic ("Medea"), stylized noise formatting: the sound specter of Clytemnestra ("Oresteïa"), etc.

Of special interest is the choice of musical instruments. In "La procession" (1953) Xenakis still used the full traditional orchestra, but in "Hïketides" (1964) the composer makes his choice of instrumental timbres in greater detail. Later a limited usage of string instruments is noticeable. In the tragedy "Bakkhaï" Xenakis completely omitted the string group. Such a selective approach towards the strings is generally unusual, since in his orchestral works they have always played an important role. From his very first music tragedy "Hiketides" Xenakis, so to speak, separated in historical time the vocal and instrumental parts – stylized archaic singing combined with the contemporary sound of instrumental accompaniment.

The orchestra in the musical tragedies plays an important role in form generation. By instrumental means the composer highlights large-scale sections, discerns the crucial moments of the drama, and creates thematic arches, conveying a sense of wholeness to the entire composition. By means of inclusion of orchestral ritornellos, Xenakis, for instance, outlined elements of the rondo form in the structure of "Hiketides"– a technique which would be applied in full measure in the composer's subsequent compositions.

2.1. "Oresteïa" (1965-66)

"Oresteïa" is one of the largest and most significant vocal-instrumental compositions by Xenakis. The composition consists of three movements: "Agamemnon," "Les Choefores" and "Les Eumeni-

des," and also, in later versions of the work, two added movements – "Kassandra" and "La Déesse Athéna". The music of "Oresteïa" is built on the juxtaposition of two opposite sound spheres, which are presented very brightly already in the Prologue. The first sphere is instrumental. It demonstrates a tenacious sound mass, with chromatic lines of the instrumental parts entering in an imitative manner, in a facile rhythmic pattern which purposefully avoids repetitions and downbeats. The choice of instruments is in itself interesting: Xenakis incorporates mostly wind and percussion instruments (of the string section only the cello is used). Moreover, the choice of the wind instruments is also not exactly standard, and it discerns an inclination towards extremities of register. Thus, for example, the flute family is presented by the piccolo, the clarinet family – by the E-flat clarinets, while the bassoons – by the contrabassoon. Each of the instrumental lines abounds with dynamic indications: these include micro-dynamic waves and tapering of the sound. No less diverse are the articulation and dynamic marks: *sff, sfff, sffp; stacc., legatiss*. At the same time, in the conditions of imitative texture, articulation-based techniques and dynamic marks in the parts of different instruments never coincide, which is what creates a sonoristic effect of an unsteady, continuously changing sound matter. The second sphere of sound sonority is the vocal texture, which creates an ancient, archaic color in many ways because of its diatonic or pseudo-diatonic nature.

It is noteworthy that Xenakis gives prominence the sections of the formal structure by a certain special textural or melodic technique in the orchestra. Thus, the second section of the Prologue begins with an expressive solo oboe, while the final stanza in the chorus is divided from the coda by a scurry by woodwinds in the *fff* dynamic mark supported by the cello line, after which all the instruments come to a standstill on an immobile chord on a *ppp* dynamic mark. This moment makes it possible to remember the beloved *staccato* sound flurries in the woodwinds in Stravinsky's works. The fanfares encase the episode of Agamemnon's appearance and this time announce the appearance of Cassandra. This entire section turns out to be the central one in the overall concentric structure of the first movement of "Oresteïa".

The instrumental means are used by the composer to convey the crucial dramatic moments of the tragedy and the protagonists' emotional states. The moment of Agamemnon's death is depicted in a noteworthy manner. The final words of the king are placed by Xenakis into the part of the unaccompanied chorus. At the same time, we hear in the orchestra the fatal "blow of the axe" which is conveyed by an ascending glissando passage, the force and rapidity of which are emphasized by a continuous dynamic crescendo sound from *p* to *sfff* and a conclusive fermata (Figure 1). Following Agamemnon's ante mortem sigh, a lonely sound of the piccolo is sounded as the image of a "departed soul".

The sufferings of Clytemnestra, who prays for a swift and easy death, are reflected by the monologue of the piccolo accompanied by strikes of tomtoms.

The third movement of "Oresteïa" – "Les Eumenides", – presents the dramatic denouement of the drama, the trial of Orestes. Xenakis demonstrates his skill of orchestral writing in depiction of a fantastic fresco. What arouses our attention, first of all, is the choice of instruments. The supplements the orchestral ensemble with sirens (who had appeared for the first time only at the very end of the previous movement), connected with the image of the Erinyes. Among the new timbral colors the chime bells stand out. The singers of the chorus play on percussion instruments – metallic simantras. The orchestral part abounds in Xenakis' favored "sound clouds" of various densities.

The strikes of the bass drum remind of a primordial ritual. The wind instruments are amplified by microphones. It is notable that, unlike the previous movements, wherein the light-timbre wind instruments were incorporated, here the composer brings in the bass-clarinet, the contrabassoon and the low-pitched brass instruments – horns, trombones and a tuba.

All of this creates the impression of an underground kingdom where the Erinyes live. Their subdued chanting, alternately fast and slow, is accompanied by a bewitching whistle of sirens and "clouds" of percussion sounds: whips, ratchets and tambourines (playing on some of which is relegated to the

artists of the chorus). The words are barely heard, so, in general, what appears is a purely sonoristic musical picture (Figure 2).

The tension is noticeably heightened. This is connected with the conflict which occurs between the Erinyes and Apollo, who intervenes on behalf of Orestes. The deathly "round-dance" is accompanied by the ostinato of the tomtoms and the bass drum, which sounds against the background of maracas, sirens, *voile métallique* and *drapeaux métalliques*. The conflict is resolved by Athena, the goddess of wisdom. Next after the inserted part comes the episode of the transformation of the avenging goddesses into benevolent goddesses. A clarification of the instrumental texture happens. The high-pitched wind groups appear – namely, the piccolo, oboe, clarinetto piccolo, and, among the brass instruments – the trumpet. The children's chorus, following the composer's indication, performs the role of the Eumenides. The sound of the children's chorus seems to "soar" over the orchestra and the chorus, the latter continuing the dialogue of Athena with the Eumenides.

The music of the final, fifth section is carried out in a new musical style. Separate detached sounds, resembling "lamps" flaring up in various registers, result in the formation of a chord which already sounds in the chorus, at times accruing and subsiding. This kind of textural effect resembles Webern's music (mm. 314-317).

In conclusion, the vocal parts sound out in simple rhythms in a syllabic style, and they are doubled by the light timbres of the winds: the piccolo, oboe and E-flat clarinet. The utterances of the chorus are divided by glissando tutti orchestral passages and "sound clouds" in the parts of the chorus and the simantra.

"Oresteïa" is concluded by a festive coda. The dance rhythm with constantly changing meters is supported by strikes of the tomtoms and the metallic simantra. In the score, the composer in his comment suggests handing out two hundred small metallic sheets, so that everybody could play them along with the chorus.

2.2."Medea Seneca" (1967)

After "Oresteïa", Xenakis composed another composition in the genre of musical tragedy – namely, "Medea". Instead of an orchestra Xenakis makes use of merely a small instrumental ensemble: E-flat clarinet, contrabassoon, trombone, percussion and cello. Among the string instruments, the composer brings in only the cello. In the percussion group, we shall find an already familiar the shingle, the strikes on which are relegated to the artists of the chorus.

The logic behind the structure of "Medea" is directly connected with the division into the instrumental and the vocal spheres. The instrumental interludes carry out the function of the refrain, alternating with vocal episodes. The three large-scale choral parts are framed by the Prologue and the Epilogue. The orchestral interludes are sustained in a single musical stylistic features: the intricate glissando lines of the wings, occasionally punctuated by strong strikes of tomtoms. In addition, the lines within the vocal-instrumental parts are likewise connected by short instrumental insertions, corresponding with orchestral interludes.

The atmosphere called for by the composer is achieved by instrumental means. In the Prologue the effect is created by living breathing and tension. The sound material of the winds, supported by the cello and punctuated by unexpectedly harsh strikes on the tomtoms, simultaneously spans both the lowest (the trombone) and the highest (E-flat clarinet) registers. The clarinetto piccolo and the cello, following the composer's instructions, sustain their tone, freely and irregularly oscillating in its pitch. This oscillation is also emphasized by short dynamic hyper-frequency waves, the duration of which is gradually augmented (Figure 3).

Separate semantic accentuations in the text are singled out by means of the orchestra. Line 305 is divided by a short instrumental insertion (mm. 224-229), the aim of which is to highlight the words *inter uitae mortisque uices nimium gracili limite ducto*, meaning thin boundary between life and

death. The unexpected chamber-like qualities of the sound emphasized by taking out the wind instruments (the soloists are accompanied only by the cello) are most likely designated by expressing the frailness of this boundary, which is spoken about in this tragedy. During the words *stellisque, quibus pingitur aether* (line 310) the cello becomes transfixed on the sound G and pulls it, seeming to depict the activity of ether (Figure 4).

In "Medea" Xenakis makes use of a palette of musical means already familiar to us, however, many of them are intensified, in comparison with "Oresteïa". The composer applies many figurative techniques, however, remaining very attentive to the Latin text of the original literary source, highlighting in detail separate words in the music. We were hardly able to notice such a direct and close connection between the words and the music earlier. "Medea" is one of the most successful manifestations of the Ancient Greek myth in Xenakis' music.

2.3."Bakkhaï" (1993)

In "Bakkhaï" Xenakis avoided almost entirely carrying out any experiments, used the "tested out" artistic techniques. In the orchestral ensemble of "Bakkhaï" the composer completely discarded the string section. The instrumentation includes an ensemble of wind instruments, featuring one of each: the piccolo, the oboe, the contrabassoon, the horn, the trumpet, the trombone and group of percussion instruments (2 bongos, 3 tomtoms, 2 bass drums, 4 boxes, 1 gong, 1 whip).

Xenakis once again made use of the technique of "division in time" of the vocal and instrumental parts devised by him earlier. The orchestral parts present discreet chromatic material, which at first is limited almost entirely to only wind instruments, which are gradually joined by the percussion. However, in the orchestral parts, within this chromatic trace one can trace the modal unfolding of the scale according to the principle of tetrachords.

The instrumental refrains which divide the Stasims carry out two most important functions. One of them plays a form-generating role: corresponding with each other, they cement the entire form in its entirety. The second function is dramaturgical: the music of the refrain is changed, depending on the events described in the text, thereby compensating the uniformity of the basic vocal-instrumental episodes.

Let us examine, as an example, the second instrumental refrain which precedes Stasim II (mm. 131, 132, Figure 5): the oboe on a *fff* dynamic mark, and a trumpet with a mute on a *pp* perform repeated sounds on one pitch each (*G* on the oboe and F-sharp on the trumpet), the piccolo repeats the two-note *A-G-sharp*, delineating the interval of a minor second, with dotted rhythms and on a *fff* dynamic mark, while in the contrabassoon part we observe a peculiar version of the *passus duriusculus*, which is probably connected with the image of Pentheus – "the offspring of a snake." The attention which Xenakis gave to each detail of this fragment confirms once again the importance of the instrumental ritornello sections.

The central episode of "Bakkhaï" is distinguished by its theatricality and efficacy. For the first time the narration occurs from the first person – a solo baritone conveys the speech of Dionysus. An original obligato instrumental line is presented here by the piccolo, imitating the singing of Dionysus. In Stasim IV the frightful outcome of the drama occurs. Xenakis did not include in the text of "Bakkhaï" the most horrifying episode featuring the death of Pentheus. In the choral parts we hear the lines of the text euphemistically describing the frightening chastisement which befell the king. This time, the orchestral refrain sounds extremely dramatically: the repeated passages of the piccolo, contrabassoon and trumpet already familiar to us are accompanied by percussion instruments and tremolos on the maracas in performance by the choral singers at the dynamic level of *fff.* While previously the textures of the chorus and the orchestra were separated from each other on a question of principle, in this episode the choral parts are doubled by winds accompanied by percussion instruments. Everything becomes merged into a single ecstatic sound mass (mm. 309, 310, Figure 6).

It is quite symbolic that after the "Anastenaria" Xenakis' first attempt in the genre of music for the

stage, the composer once again sets to music the story of the cult of Dionysus in what would turn out to be his final musical tragedy.

3. Analysis of the instrumental parts in the compositions for chorus and instruments

A considerable part of Xenakis' vocal compositions is comprised by works for chorus accompanied by orchestra or instrumental ensemble. A creative interest towards this genre was acquired by Xenakis back in the early 1960s – with the appearance of "Polla ta dhina." The composer actively experiments with the choral material, using it as one of the timbres of the instrumental texture. In regard to the instrumental part, we can distinguish the special role of the interludes in the form-generation, the tendency towards symmetric properties, concentricity and thematic arches. Among the peculiarities of orchestration, mention must be made of the untraditional instrumentation, the use of instruments in a maximally high and low registers, so that the timbre becomes almost unrecognizable, the use of maximal levels of divisi, and the preference for the non-standard wind instruments. In these compositions one can note the non-traditional functions of the orchestral groups and playing with the spatial factor. Some of the effects characteristic for the instrumental texture include glissandos, sonoristic sound masses and the composer's original textural techniques: "clouds," clusters, etc.

3.1. "Cendrées" (1973)

"Cendrées" for mixed chorus and orchestra is one of the composer's most massive and most expansive works. Already in its title the composer makes a hint at the expressive character of the music. Ashes as an artistic image arouse associations with death. In addition, the piece is furnished with a peculiar program.

The generality of the artistic image also dictates the corresponding character of musical means. The massive sonorities are interspersed with solo fragments, as if impersonating the world and personal conscience. The fundamental textural-compositional element of "Cendrées" is in the glissandos, which appear in various guises, in both vocal and in instrumental parts.

The ensemble of the orchestra is noteworthy by the fact that in this work the composer passed over the percussion group; however, the strings are presented in full ensemble. Following the contrasting-constitutive principle, in the structure of "Cendrées" it becomes possible to highlight nine sections, the orchestral introduction and the coda.

The integrity is endowed to the entire structure by the solo structures corresponding to each other: section II – by the solo bass and section VIII – by the solo countertenor, which are symmetrically situated in the overall structure. Between them section VI is situated, expressed by the solo flute. If we examine the temporal factor, the solo flute is present in the very center of the structure.

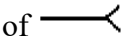
The orchestral introduction in "Cendrées" may be examined by us as a representative example of the composer's instrumental writing. Here, just as in the whole composition in general, there is a broad usage of sonoric techniques: the "thickening" of the line, the broad textural fields, the change of the spatial factor of the sound mass, the change of the thickness of the sound.

The composition opens up with a powerful ascending glissando by strings playing divisi from the note *G*, which is an apparent "reminiscence" of "Metastaseis". The swiftness of the glissando varies in the different parts. The assignment of the amount of parts to every group of string instruments is as follows: 8 parts for the 1st violin, 7 parts for the 2nd violins, 6 parts for the violas and 5 parts for the cellos. The unison of the double-basses performs a pedal point on the pitch *G*, which is sustained during the course of the entire introduction.

The density of the initial glissando is assigned in such a way that the maximal density coincides with the first measure, while in the subsequent three measures it gradually dissolves: 25 parts in measure 1, 19 parts in m. 2, 14 parts in m.3 and 3 parts in m. 4. Thereby the effect of levitation is

calculated, which is lightened up towards the end as a broad brushstroke of an artist. Thus, already in the very first measures of "Cendrées" Xenakis demonstrates his orchestral writing skill (Figure 7).

The sound world of "Cendrées" cardinally changes in the solo sections, the duo of the bass voice and the bass clarinet and the duo of the countertenor and the horn. With the appearance of an individual human voice, the personalized aspect appears, which was not been present before. These duets reminds in part of a baroque arias, wherein the bass clarinet and the horn is perceived as an obligato instruments. Solo flute semantically connected with the vocal solos (m. 298).

In the tutti sections the composer constantly renews the overall timbre of the sound mass, highlighting (among other aspects, in terms of quantity) separate instruments and voices. For example, in m. 201 the soprano vocal group is comprised of three parts, while the alto vocal group has 9 parts. The alto vocal timbre is also supported by the viola group from the orchestra. A powerful chord played by the string instruments *ffff* (the composer's comment being: "harshly, almost a split") marks the beginning of the fifth section. Xenakis introduces a special technique of sound production indicated by the special sign of  , which means the following: "all the conclusive accents are laryngeal, similar to a dry coughing up of the throat, or furious voices (the voices of furies)." Although the present comment undoubtedly refers to vocal parts, this sign also accompanies the parts of the wind instruments. Their performance, obviously, presumes the inflation of one sound with the characteristic ending marked with a grace note.

"Cendrées" expresses the beginning of a new stage in the development of Xenakis' vocal and compositional technique, at the same time providing a synthesis for earlier methods. The score of is permeated with intricate, intriguing details, as well as precise and original compositional solutions.

3.2."Aïs" (1980)

"Aïs" for solo baritone, percussion and orchestra – one of the composer's most dramatic compositions. This composition is much closer to the large-scale choral works than to compositions for solo voices with accompaniment.

The title "Aïs" which is an abbreviation of *aïdos,* means the life hereafter. The text consists of several short fragments. The first presents the text from Homer's "Odyssey", the second involves Sappho's poetry, and the third – a text from Homer's "Iliad".

The constant change of extremely high and extremely low registers in the instrumental part and in the baritone singing is meant to reflect the twofold character of life and death, as Xenakis talks about in the Foreword to the score.

The solo baritone part must be discussed separately. Its range, rhythmic technique, and emotional palette, ranging from an emotionally withdrawn psalmody-like singing to vociferation and weeping, strikes the imagination. The solo part of the baritone is framed by the "obligato" percussion part.

The logic behind the structure of "Aïs" is of a vocal nature – several vocal-poetic stanzas alternate with orchestral interludes. Since the musical material of the "Iliad" turns out to be concordant with the fragment from the "Odyssey" it follows that in the entire structure of composition the principle of concentricity with the fragment from Sappho at the center is traced out.

The orchestra includes four of each of the wind instruments with an enhanced group of percussion and piano. Generally, this is quite a traditional orchestra for the 20th century, which, nonetheless, is not in the least traditional in regard to Xenakis' orchestral style, wherein the composer prefers unusual instrumental combinations.

Among the sonoristic techniques of orchestral writing, we can single out the "breathing" clusters, one of which opens up the composition, the glissando, using instruments in extreme registers, the chromatic and microtonal passages in the strings, formed including on the basis of a sieve.

Our attention is drawn by the sophisticated rhythmic technique, the aim of which is a control of the sound mass, its constant change.

The composer attributes great significance to the parameter of dynamics. Practically each note in the musical score is provided by a dynamic mark. In the final measures of the work the composer writes out a dynamic score separately (m. 181, Figure 8). Its analysis makes it possible to arrive at a conclusion regarding the composer's main idea regarding the dynamics: the orchestra's overall "breathing," ascents and descents possess a single line, however, they never coincide precisely, and the dynamics change with a certain delay. This results in the remarkable effect of the living sound matter.

One of the most enticing moments in the musical score is the first orchestral interlude, more precisely, its second purely instrumental section. The associations aroused by this music and the preceding text allow us to label this fragment as "echo". And, indeed, each sound of the wind divisi enters with a delay, and therefore the effect of an immense space arises, since each sound is reverberated within it several times. The "echo" effect is emphasized by the composer's dynamic indications – *ff* › *p* on each sound (Figure 9).

In "Aïs" Xenakis synthesized the techniques of vocal writing, the correlation between the vocal and instrumental elements, the methods of work with the text which were characteristic both for the compositions pertaining to the "Greek subject matter" and for the concert choral pieces in the vein of the European avant-garde. This synthesis gave a very bright artistic result, the manifestation of which became possible in many ways due to the outstanding performing skills of Spyros Sakkas and Sylvio Gualda.

4. Conclusion

Thereby, we discover qualities which are specific for Xenakis' orchestral writing in his vocal-instrumental spheres of musical composition. The composer does not lack orchestral color, figurativeness, including that which accentuates the meaning of the crucial words of the verbal text, and imitation of folk instruments for the sake of creating the necessary color effect. The orchestra is used in a much more delicate manner than in the composer's instrumental and electroacoustic works. It suffices, for example, to compare the sound guise of "Polla ta dhina" and the electronic composition "Bohor" composed during the same year, the immense power of sound of which created an oppressive impression on the listeners, while Pierre Schaeffer, as is known, compared it to an advancing succession of strikes of the lancet on the ear upon a maximal level of loudness.

At the same time, in many of his vocal-instrumental works the composer continued the quests for spatial expansion of sound begun by him in his electroacoustic music, which was manifested, for example, in non-standard placements of the performers on stage and elements of instrumental theater. The orchestral colorism which we encounter in the works composed in this genre in many ways answer Xenakis' search for new timbral colors in his instrumental and electroacoustic compositions.

The vocal parts in Xenakis' vocal-instrumental compositions demonstrate all the achievements of the avant-garde and impress the listener by their expressivity and diversity of techniques, however the orchestra in the works written in this genre presents not an accompaniment to the vocal parts, but an inseparable part of the sound palette, which is extremely intriguing as an object for analysis and creates an additional touch in Xenakis' compositional style.

5. Figures

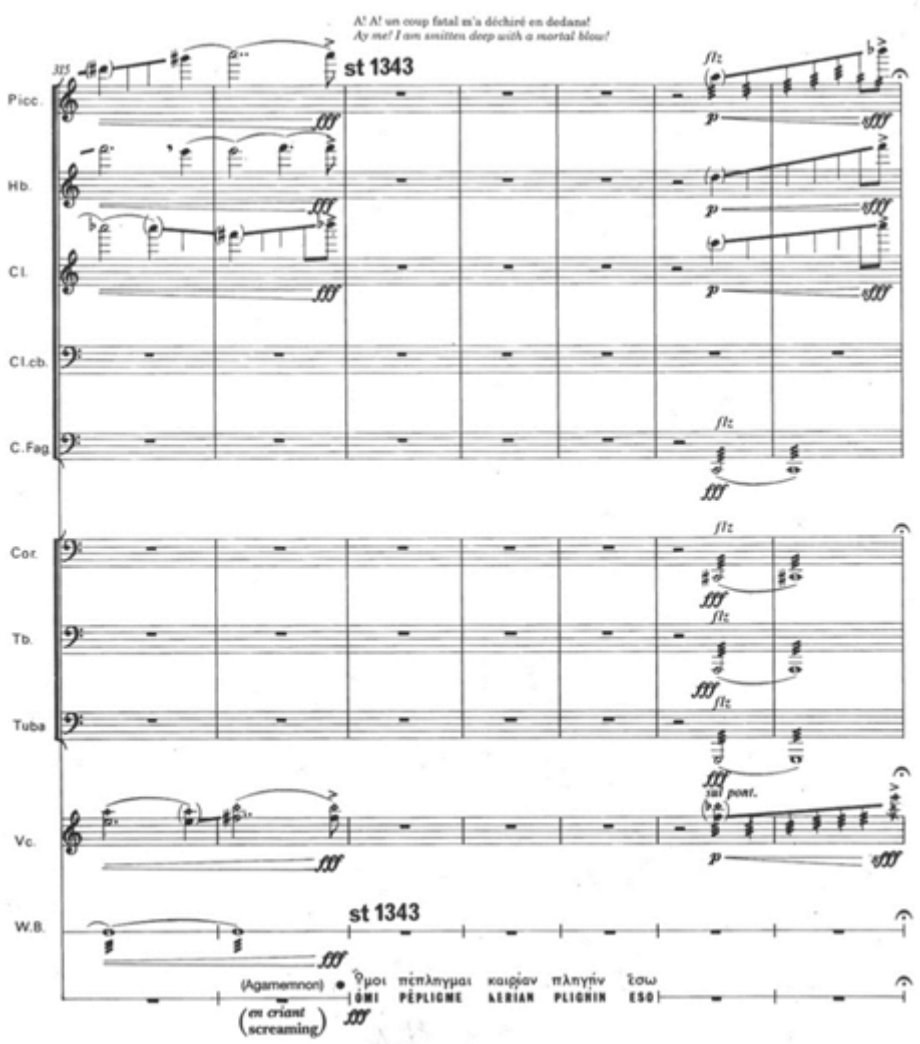


Figure 1: "Oresteïa". The moment of Agamemnon's death.

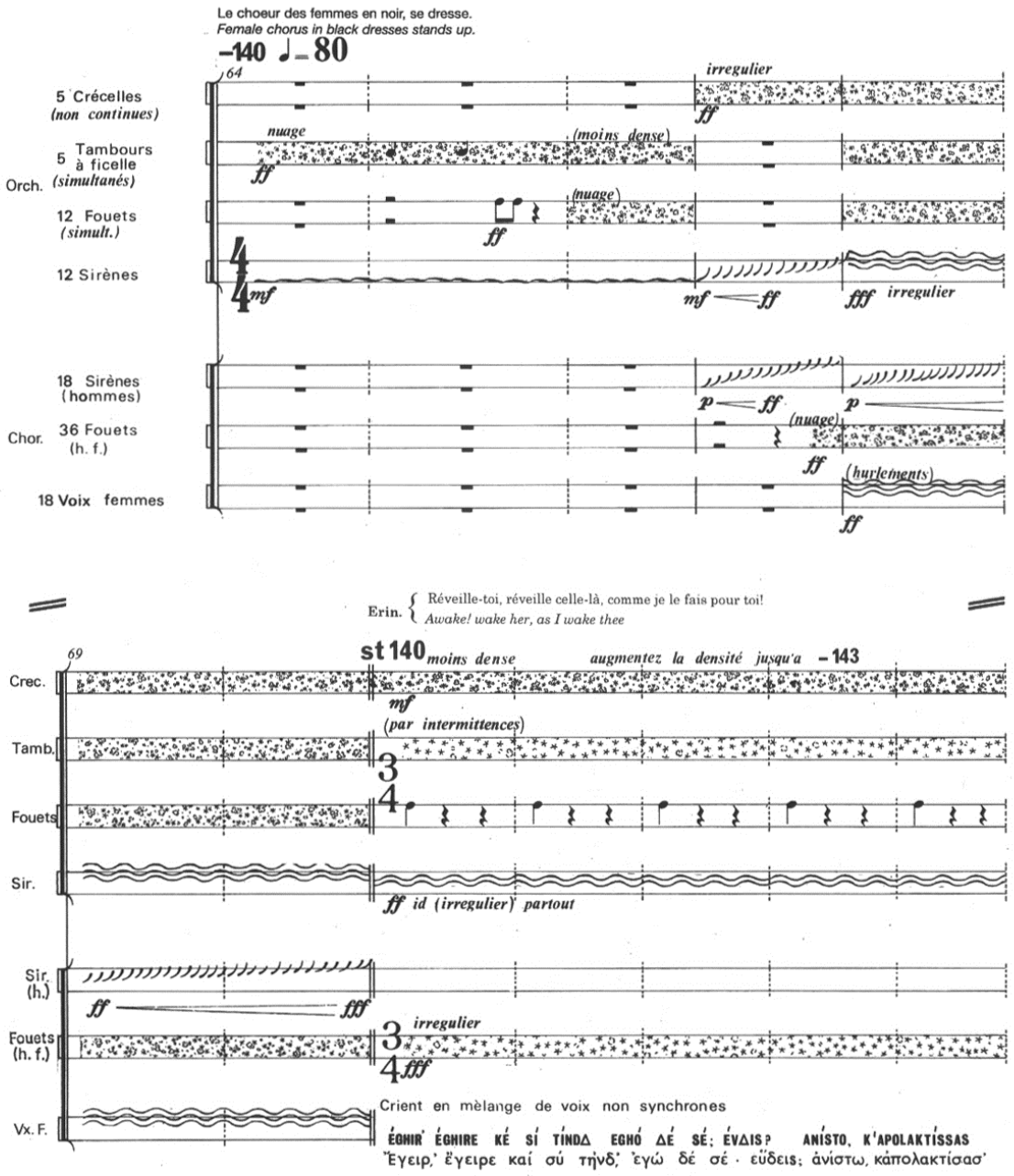


Figure 2: "Oresteïa". "Les Eumenides".

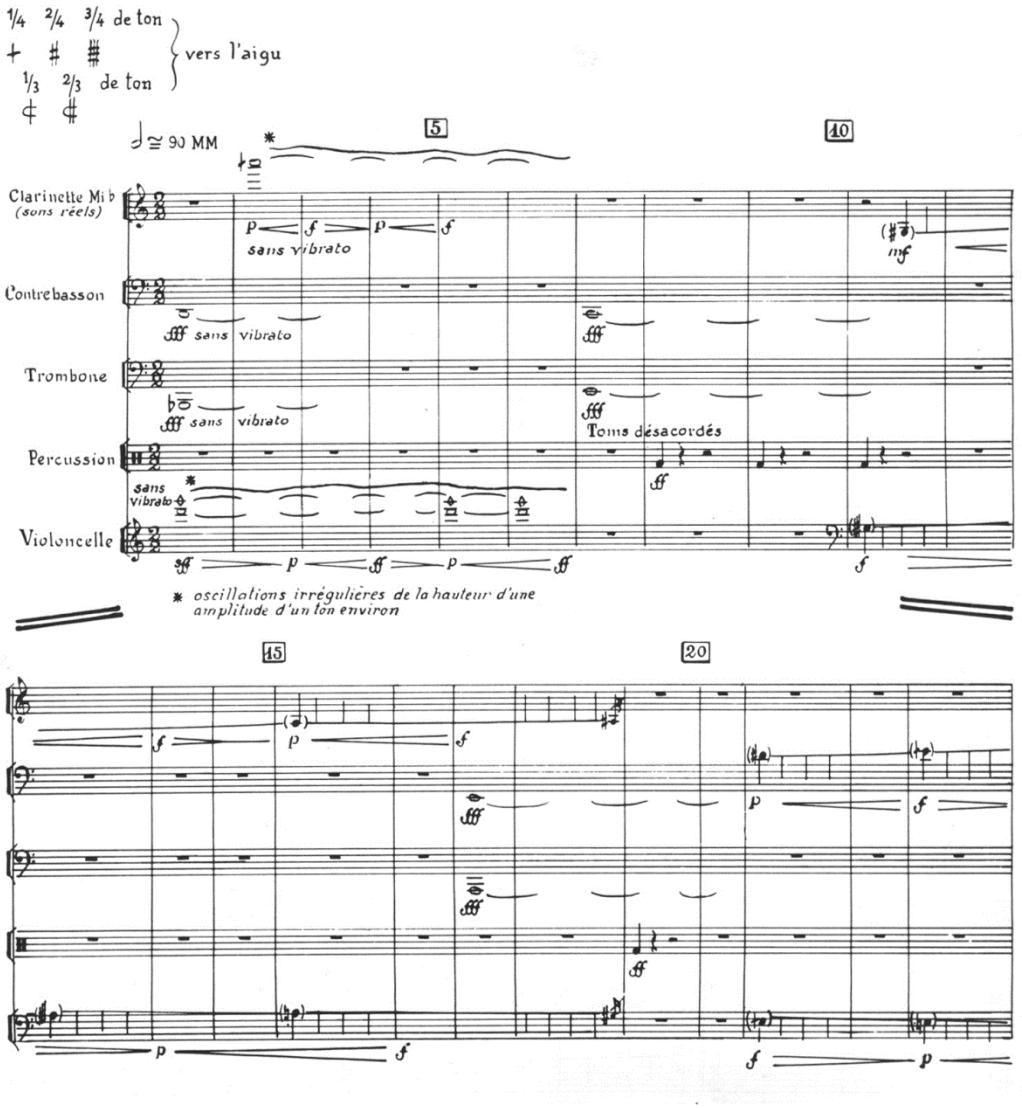


Figure 3: "Medea". The Prologue.

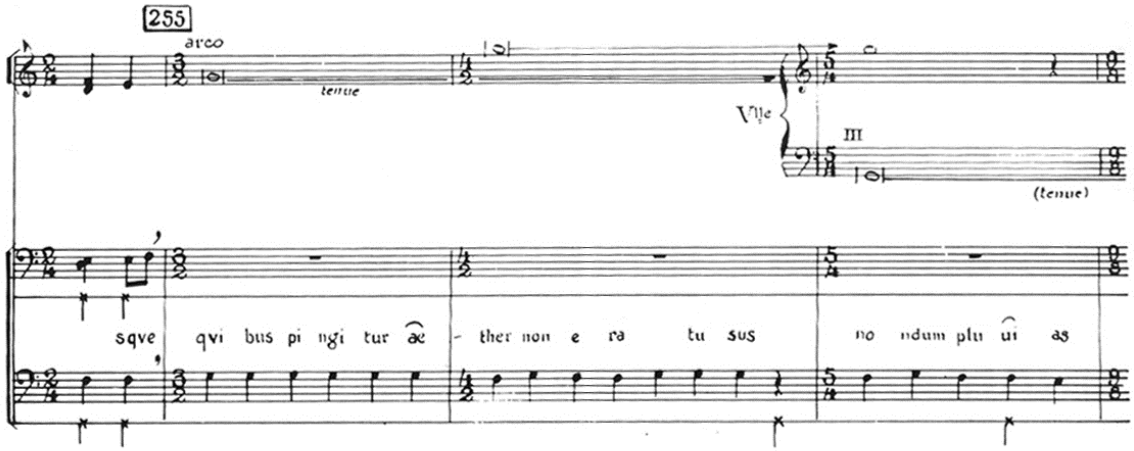


Figure 4: "Medea". Line 310.

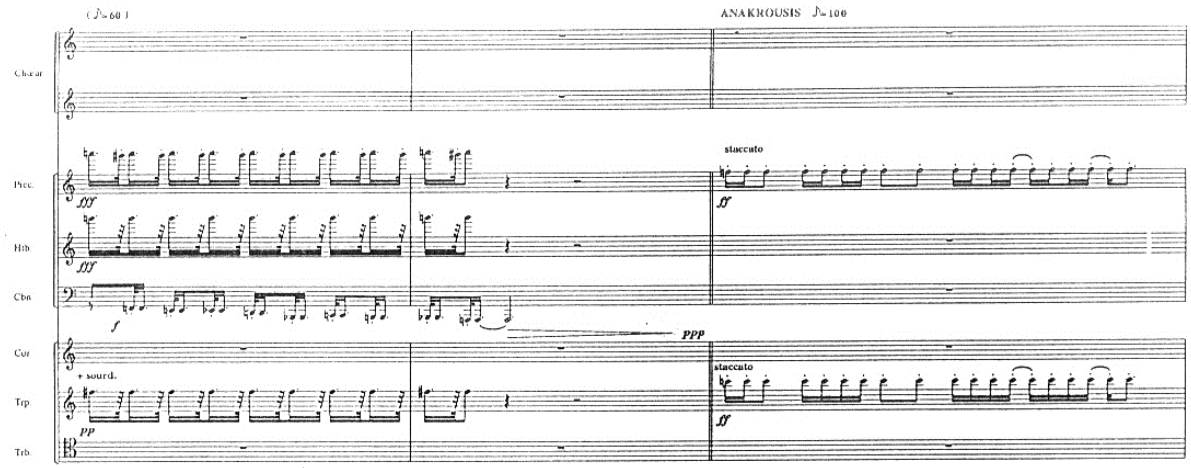


Figure 5: "Bakkhaï", mm. 131, 132.

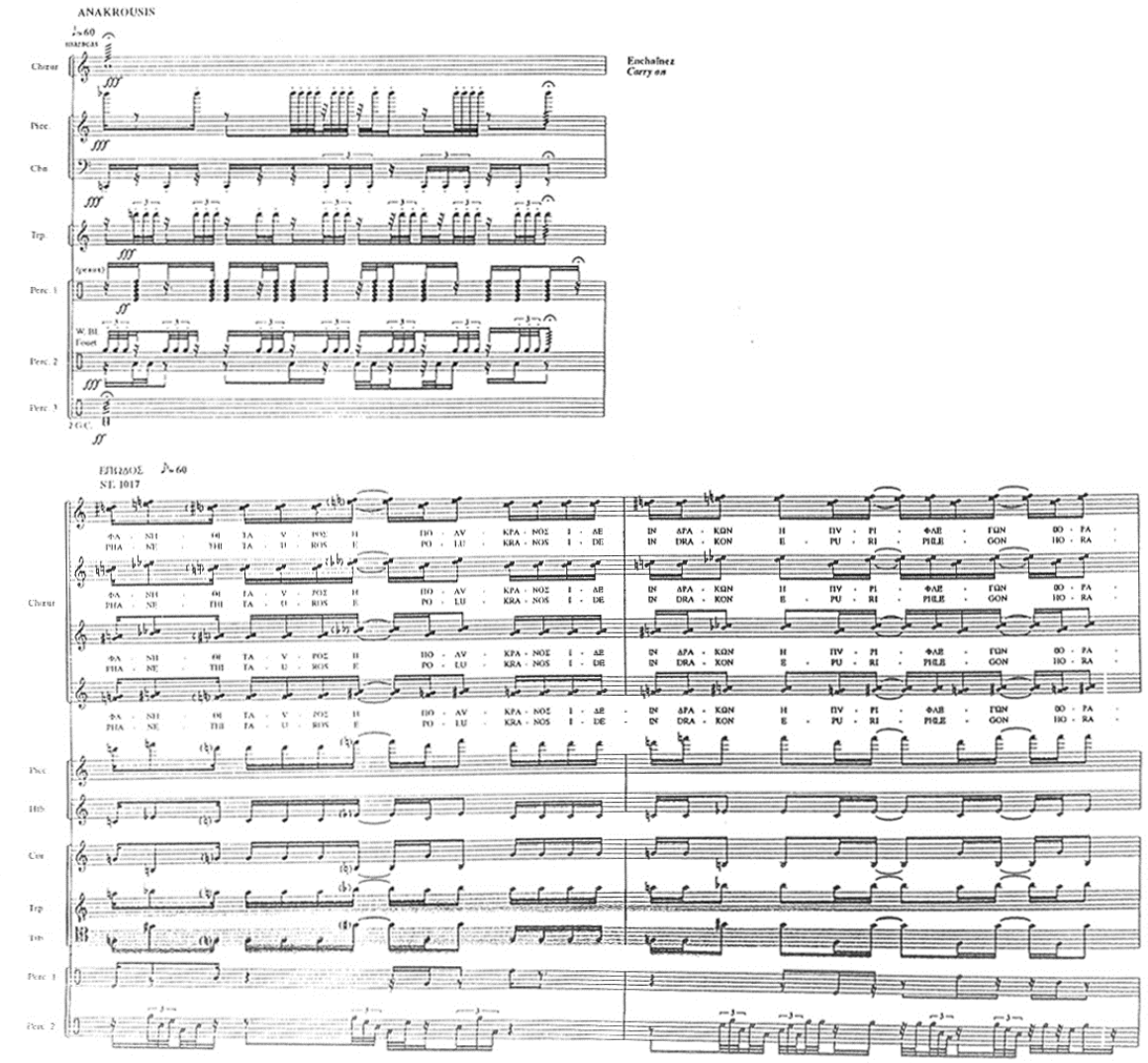


Figure 6: "Bakkhaï", mm. 309, 310.

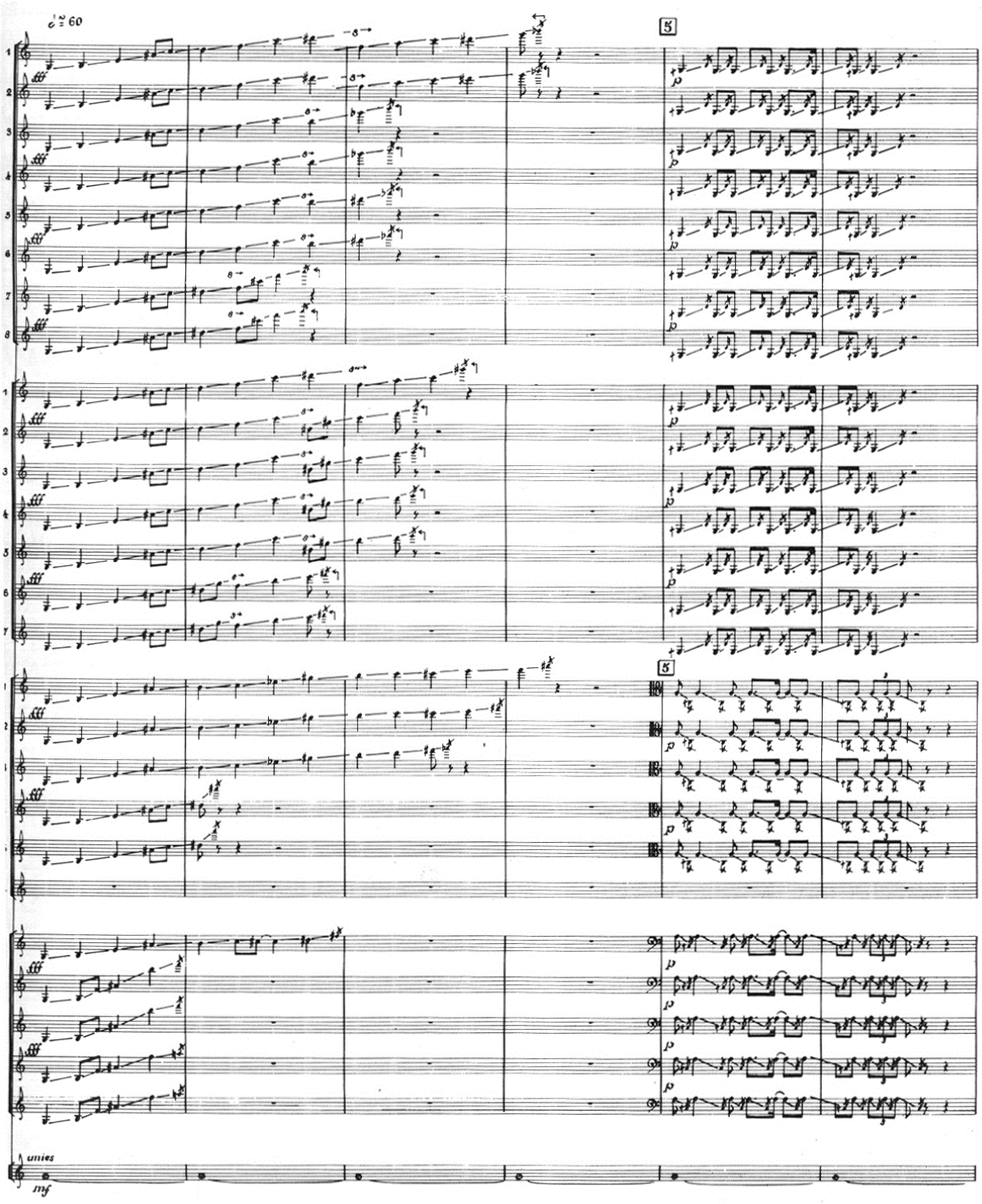


Figure 7: "Cendrées", m. 153.

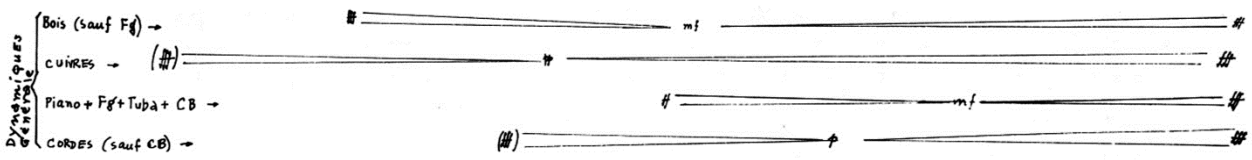


Figure 8: "Aïs", m. 181., a dynamic score separately.

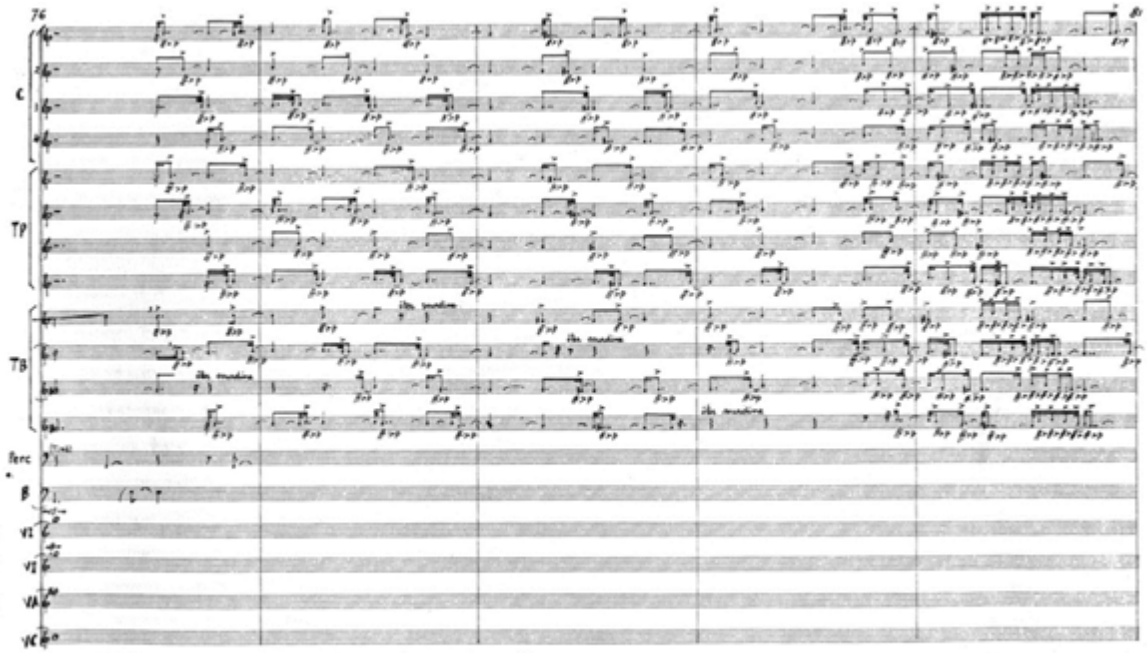


Figure 9: "Aïs", the first orchestral interlude.

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Xenakis' Influence on Electronica

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Abstract

It is well documented that Iannis Xenakis has influenced the world of contemporary classical and computer music. Similarly, musicians outside the classical realm have regarded Xenakis, this heavily avant-garde composer, with great reverence. It is a wonder on what sort of reach he has had compositional-process wise in the nonclassical world. How much of his algorithmic or computational methods did musicians apply to arrive at Xenakis' defining sound world? In this paper, I will summarize Xenakis' influence on nonclassical music, specifically electronica. I will first analyze Xenakis' direct influence on electronic musicians and producers including perception of his music, remixes of his works, and collaboration, and then move to indirect influence from his computer music innovations. Second, I will compare and contrast the sound and compositional process of Xenakis and Alva Noto (Carsten Nicolai) through a study of Nicholai's album *Unitxt*, his project *syn chron*, as well as looking over his works as a whole.

1. Introduction

Xenakis has been mentioned by artists of many different experimental genres, such as Aphex Twin's reference to UPIC or appearing on the Nurse with Wound list, a list of influential musicians and bands written on the cover of their first album. Listening to certain artists who have voiced their appreciation of Xenakis, including electronic musician and artist Alva Noto and noise artist Merzbow, the similarities are apparent. From sound masses to "grains of sound", Xenakis' familiar sonic world is present. Focusing on electronica, there are many producers and musicians with their own unique perception of Xenakis. However, "electronica" is an endless genre with many different schools of thought. We must first define the many factions of electronic music.

The term electronica spread through its usage by the UK experimental techno label New Electronica and came to describe electronic music more oriented towards home listening rather than dance (Bogdanov et al. 2001, 634). Around the same time in the US however, electronica became a catch-all term for all electronic music including dance-based music, until electronic dance music (EDM) became the prominent term in the 2010s. Today, the label has been adapted as an umbrella term for many different types of electronic music, typically excluding dance music and focused on more underground styles. This paper will be focusing on experimental styles of electronica, specifically Intelligent Dance Music (IDM), noise, and glitch. IDM, a term often criticized by its creators and listeners, was inspired by the label Warp's Artificial Intelligence project (Collins, Schedel and Wilson 2013, 138), and its often experimental and less genre restrained music is associated with artists such as Aphex Twin, Autechere and Plaid. Glitch derived out of the electronica movement and characterizes music incorporating different digital distortion and manipulation techniques (Cascone 2000, 15).

Additionally, certain styles of noise music can be included within "electronica", yet "noise" is a complex separate genre with ties to styles outside of electronic music. Noise music and the definition of "noise" varies, with originating styles from rock and industrial to all the way back to Futurist art movements of the 1910s (Collins, Schedel and Wilson 2013, 140). With different ideas for the

meaning of noise music and differing motivations for making noise, such as a representation of something extreme or dissonant to the literal acoustic definition of noise, the variations are endless. Some voices the noise music scene, such as writer Jim Dorling from the Chicago Reader, think that Xenakis' influence on certain noise musician such as Merzbow and Borbetomagus have been limited by his academicism. With styles coming from so many different places of origin and the different music training backgrounds that artists have, it is certainly a question to whether Xenakis could have had influence in this area. Related to the background of musical artists, an interesting thing to note is the recent graying line between "academic musicians" and experimental musicians outside of academia. Conceptually, the line between musique concrète or other academic forms of electronic music and experimental electronica are very blurry. To keep this paper focused on finding Xenakis' influence on the non-classical world, I will mostly be discussing musicians who did not have classical training.

Another point of interest is drawing attention to the depth and complexity of these musicians' works, and showing musicians who, similar to Xenakis, did not have extensive classical training but create fascinating and intricate pieces. It is also a question of what degree of influence Xenakis has had on specific musicians. Which musicians have a basic superficial understanding of his work versus a deep understanding of his style and algorithmic processes. Is the attraction to his music related to his compositional process or just purely his aesthetic? With the complexity of Xenakis' music, it is unlikely that many of his followers will try to emulate the conception behind his pieces. However, the concept of music creation from mathematics or graphical images is a possible inspiration to many. A large attraction to Xenakis could also be the perception of him as an "outsider". A lack of classical background causes these musicians to similarly draw from outside sources to define the aesthetic and structure of their music, leading to Xenakis being a clear role model.

2. Perception and Influence

The perception of Xenakis' music ranges from enthusiastic appreciation to extreme dislike. Many members of the experimental scene enjoy his work, regardless of their understanding of its construction. Drew Daniel from the experimental electronic duo Matmos wrote an article titled "Musique Concrète Smash Hits" in 2003 for Pitchfork, sharing his appreciation for Pierre Henry, Tod Dockstader, Xenakis, Luc Ferrari, György Ligeti and others. His analysis of *La Legende d'Eer* praises Xenakis' piece, describing the very interesting context of listening to the work at a house party on acid. The circumstances might imply a more superficial listening, but the brief analysis describes the subtly transitioning sound, wide pitch range across the work, "unhinged" instruments, and his characteristic glissandi. Daniel is obviously moved by this monumental piece and understands it's timbral focus and complexity. This brief analysis of this work by Xenakis gives an interesting perception and introductory view of Xenakis among the non-classical crowd.

2.1. Sonic Similarities: Experimental Electronica vs Musique Concrète

Daniel is certainty in the world of the experimentally-minded and has a similar interest in exploring timbres and sounds. In their interview with EarthQuaker Devices titled "Show us your junk!", they show off different objects used for their albums, including a breast implant, and a goat spine rubbing a human brain pan. Daniel noted, "I don't have any musical training or talent, I like to cut up sounds…". A point should be made on the perception of a lack of "musical talent" of producers in this scene. Daniel states he feels strange about getting commissions and playing in spaces such as Carnegie Hall because "we're kind of cave people that have figured out ways to make records on our own terms". However, conceptually, there are few differences between Matmos' "sound collage" tracks and the works of composers in the school of musique concrète. Both producers and classical composers share an interest in unique sounds and the progression of timbres. Their works explore a wide range of sounds and complex production techniques. An interesting work is *Ultimate Care II*, with sounds from the album entirely derived from their washing machine. Similar to *Le Legende*

d'Eer, the single track gradually transitions to different tone colors and explores the studio manipulation of sounds over a 40-minute period.

Often people view the experimental music scenes vs. the academic scene as separate musical schools running parallel, and they certainly developed in that way. However, some musicians are peeking across the line of academia have appreciation for their sonically similar colleagues. Daniel shares his opinions in the same Pitchfork article, characterizing *La Legende d'Eer* as "A totally mammoth and inhuman mindfuck which should be approached with caution and respect." Many producers view Xenakis and other pioneers of computer music with a great sense of reverence. However, Daniel also shares the contrary opinion by musicians of this scene, stating "This genre gets a bad rap-- calling to mind a bunch of white guys in suits who use clunky gear to spew out supposedly revolutionary and certainly unlistenable bloops and fnnrts that actually amount to so much dreary audio-lint." That lingering sense of elitism in academia is still present, but with more musicians crossing the academic line, hopefully the sentiment will continue to change.

2.2. Remixes and Collaboration

Some musicians have a more direct connection to his work beyond admiration. The label Asphodel released an album full of remixes of *Persepolis*. Among the list of various composers and experimental musicians is noise artist Merzbow, contributing a 7 minute remix to the record. This track significantly alters its source material, creating much harsher timbres. *Persepolis* has also been remixed by sound artist Ryoji Ikeda within this same album, as well as by the hardcore punk band Orchid. It is a very influential piece in electronic music and noise/industrial scenes. It's often discussed in online forums and articles with a strong appeal to all circles. John Garrat of pop culture magazine *PopMatters* states about *Persepolis* "the reasons that Persepolis appeals to me are the very same things that make avant-garde so unique — unclassifiable, nearly indescribable forms of sounds that have not been heard before and may never be heard again. It doesn't have to be academic if you don't care for it to be". The cultivation of unique sounds and timbres in Xenakis' music is something that draws in and inspires all audiences.

Merzbow has mentioned Xenakis as an influence in an interview with Dominique Leone of Pitchfork. Exactly how much of their work is informed by the classical/avant-garde side of noise music is unknown. Out of the many non-classical musicians inspired by Xenakis, Merzbow has the most obvious sonic similarities. This is a superficial connection to Xenakis however and doesn't show a real influence from his music other than the general aesthetic. Their sounds are obviously similar, with previous research by Ryo Ikeshiro showing the relatable qualities between artists, specifically Xenakis' later GENDYN works. On their compositional processes and views, Ikeshiro notes that they have different perceptions of noise, with Merzbow having the perception of noise as "negative" and "unwanted", contrasting Xenakis' perception of noise in its acoustic literal definition. However, a clear conceptual similarity is they both attempt to make idiomatic computer music and make efforts to ensure that "noise remains noise" within their works, or maintains its formless qualities upon repeated listening (Ikeshiro 2014).

DJ Spooky, or Paul D. Miller, is another figure who has named Xenakis as an influence. He has talked about Xenakis on several occasions and has named him as one of his favorite composers in his writing for the online magazine Perfect Sound Forever. Miller is a unique figure, not only being a DJ but a composer, writer, and multimedia artist. He has bridged the gap between electronica and classical circles, not only with his work but with his direct collaboration with Xenakis. Conductor Charles Bornstein stated that Miller helped plan the ins and outs on the recording of *Kraannerg*, making sure the sound was continuous between the acoustic instruments and electronics, and also managed the tape part of *Analogique A+B* for a CD Release (Bornstein, 2010). Miller is very present in academic circles today. His collaboration and writings about Xenakis have contributed to the linkage between the classical avant-garde and electronica scenes.

2.3. Technological Contributions

The technological contributions made by Xenakis have influenced computer music vastly. But how much of this has made an impact on electronica? Previous research by Anastasia Georgaki has outlined Xenakis' contributions to computer technology. Many of the innovations mentioned relevant to electronica and music producers outside of academia. Georgaki notes Xenakis' contributions to research in most all the computer music domains ("algorithmic composition, sound synthesis, design of interfaces and new ways of performance through technology"). Max/MSP was also "inspired by the stochastic and dynamic algorithmic stochastic methods of Xenakis" (Georgaki 2005, 2). Max/MSP is used by many producers, such as the electronic duo Autechre, and with its connectivity to the DAW Ableton Live, it has brought many producers into the world of algorithmic composition. Another contribution of Xenakis includes being a pioneer in the combination of sound and light in performances. It is rare to go to an electronic music concert or DJ set without an element of lighting or visuals.

An additional clear influence is through UPIC. As mentioned in the introduction, Richard David James, or Aphex Twin, made a strange reference to UPIC in an interview with Andy Jones of *Future Music*. When asked "What software do you use?", James answers "UPIC by Xenakis puts almost everything else to shame. It's under 1MB and it shits on everyone". James has the reputation of being evasive during interviews and sometimes facetious, so it is unlikely that he uses UPIC. The obscure reference is intriguing, however. He has been asked about Xenakis in an interview with *Clash Magazine*, and regardless of how he feels he about his music he is certainly familiar with him, similarly listening to *La Legende D'Eer* and other musique concrète composers during a live radio session on BBC Radio 3. How he feels about Xenakis or exactly how familiar he is with his work is difficult to tell, James is generally a very private and cryptic person.

Strange reference aside, an interesting and UPIC influenced work is his track "ΔMi−1 = −αΣn=1NDi[n][Σj∈C[i]Fji[n − 1] +Fexti[n−1]]", commonly referred to as "equation". A hidden easter egg: upon spectrogram analysis of the song, around 5:30 minutes in an image of James' face appears. The image of his distorted grin matches the very harsh and screech like sound that accompanies the end of a very experimental track. The rest of the track is very characteristic of James' sound, including distorted rhythms, unique timbres, and fast changing drums. Others have discovered patterns in the spectrogram analysis of songs from the *Windowlicker EP*. Because of his cryptic nature, his fans are left to discover these hidden images without help.

James likely used Metasynth for this track (Kahney, 2002). Metasynth is very similar to and inspired by UPIC, with some differences such as instantaneous audio feedback, and being more often used for sound design rather than composition (Thiebaut, Jean-Baptise and Bryan-Kinns 2008, 2-3). Other artists have used programs such as Metasynth to turn images into sound in their music, including Venetian Snares using an image of cats in his track "look", and Plaid using a series of interconnected threes in their track "three recurring" (Pangburn 2017). This is another instance where there are possibly multiple influences and streams of musical genres coning together with a similar sound and concept. Many of the musicians using Metasynth or converting images into music are likely unaware of Xenakis and UPIC. But it is undeniable the influence Xenakis has had on this realm of computer research.

3. Alva Noto (Carsten Nicolai)

Something that makes Xenakis unique within the classical music realm is his difference of background experience from other composers, coming from a life of architecture and mathematics and into music. He is someone without a lengthy formal classical music background who made groundbreaking contributions to the avant-garde world of music and art. I think this is what similarly makes Carsten Nicolai so interesting in the world of electronica. He is not only an electronic musician, but he is also a visual and sound artist. Similar to Xenakis, he studied architecture, along with landscape design. In an interview with Nota Tsekoura of Space Under, he names Xenakis as one of

his heroes, noting their similar history.

Nicolai has a vast discography of different solo and collaboration albums under his pseudonym Alva Noto, ranging from harsh glitch to longform ambient tracks. His overall aesthetic is minimal but within his discography he explores a large range of sounds and ideas. His primary focus is sound and the creation of art, rather than composing music as a traditional musician. Among his many albums, *Unitxt* has elements that stood out as similar to the works of Xenakis, sonically and process wise.

3.1 Unitxt: A Compositional Comparison to Xenakis

The overall sound of this album is glitchy, with sharp digital sounds, shorts burst of static, and very bright beeps of what appears to be telephone and fax machine noises. All the material is sample derived and transformed into noisy rhythmic patterns, with occasional pitch content, usually a low simplistic bass melody, or dynamic longer samples, floating in and out. The rhythm mostly stays in a standard 4/4 meter throughout the album, but the rhythmic patterns are very syncopated and at times sporadic. Each track has its own collection of repeating and gradually developing rhythmic modules that transform through the song. Besides the sporadic interruptions of static noise and glitch, this album is groove based and falls under the genre of experimental and minimal techno. Two tracks include the spoken word of Anne-James Chaton, which consists of counting and occasionally reciting text metrically synchronized but rhythmically contrasting with the music. The music is very granular in nature. There are moments of noisier long sound sonorities, the biggest example of sustained noise being the last track.

“Unitxt Code (data to AIFF)” is a noisy and harsh 7 minute closing track, a mostly static wash of white noise, with moments of harsh glitch. The very differing and dynamic sounds is reminiscent of Xenakis’ *S.709*. Sonically they are very similar. Same length, similar timbres, and overall focus on short scale development rather than large overarching sections. The sounds in both works transform between shorter, harsh, and sporadic high pitched sonorities to long sustained noisy sonorities. And the use of granular harsh sounds is universal throughout, a sonic link to the music of Xenakis. Much of the rest of this album is a very rhythmic and pulse based. The intended setting for the music was the club scene, as mentioned in an interview with Jack Chuter of ATTN:Magazine, so it understandably needed that driving rhythmic nature. There are better examples of sonic matches to Xenakis’ works in Nicolai’s discography that will be further discussed in the next section. A main point of interest in this album specifically was the background processes in creating it.

Nicolai has discussed some of the conceptual and procedural elements of *Unitxt*. Track “U_07” features Chaton, with the spoken text coming from the simple instruction to read notes, credit card information, invoices, business cards, etc. out of Nicolai's wallet, according to the Boomkat record store website. “Unitxt Code (data to AIFF)” is generated from the conversion of PowerPoint, Word files, or other text files onto sound. In an interview with Redbull Music Academy, Nicolai states

“There were a bunch of tracks where I just took the data of programs and whatever and converted it into audio files… Using that kind of data or information – not seeing it as sound, but rather as information – and just playing with it sonically … Yes. In a way it’s kind of an interpretation because the file doesn’t tell you exactly what is left and right channels, so they take the file as if it were a music file and then it just opens up. It’s a great noise that happens. Sometimes it’s surprisingly melodic, sometimes it’s totally noise.”

This use of text data to generate music is a very randomized approach, somewhat similar to Xenakis work. A large point to note is that Unlike *S.709* or much of Xenakis’ works, Nicolai’s process is not a precise randomness guided by probabilities, and can be classified as aleatoric rather than stochastic. Regardless, the use of numerical data and text to guide composition is notable. Something closer to an organized and algorithmic compositional process is in track “U_08-1”, Chaton recites numbers from the golden ratio. Previous research by Greg Beyer shows the use of the golden ratio in the rhythm and metric structure of *Rebonds a and b*. Sonically, there is a clear difference in the execution of this algorithm. “U_08-1” includes a straight recitation of the ratio over the continuing electronic beat,

while Xenakis clearly includes it in the temporal structure of his work. However, the shared interest in this concept is interesting, and use of numerical data converted into sound shows a mathematical structuring of the work. This is more explored in his album *Alphabet*, with the chanting of what sound like number sequences and other text, somewhat reminiscent to the phenome chanting in works by Xenakis such as *Polla ta dina*.

Another rhythmic similarity is the clear grid like and cell-based nature of the album. The tracks were composed in a 120 bpm grid, with overlaying rhythmic modules and structures. The sharp attacks of staccato sounds and clearly delineated repeating rhythmic cells is very similar to *Psappha*. The overlapping of different instruments and textures, use of very sharp articulated textures, brief moments of silence, and transformation of rhythmic cells all recall Xenakis' work. This sequenced style is not too uncommon in this genre, yet the way they are described as "cells" and in his words from the Redbull Music Interview, "rhythmic constellations" is a unique perspective into the construction of the album. Overall, Nicolai's album demonstrates a shared focus in mathematics and algorithms, showing clear parallels between their music. With their backgrounds in architecture, it seems inevitable that their music would develop in this way. Whether or not Nicolai actively drew from Xenakis' music for his tracks is unknown. However, with Nicolai naming Xenakis as a hero, it takes these similarities from coincidences from a shared background to clear parallels hinting at possible influence.

3.2 "syn chron", Sound/Aesthetic, and Architectural Background

The most direct connection to Xenakis is his work *syn chron*. Circling back to his interview with Space Under, Nicolai specifically names the Philips Pavilion project as influential: "I did a project that was very much inspired by it, it is called *syn chron* (2005), an architectural body combining light, space and sound.". There are very visible parallels to *Concrete PH*, but this work will not be analyzed as thoroughly as it delves out of electronica and more into the sound art realm. It is mentioned however because of its very clear stated influence from Xenakis. The spatial nature of the structure and audio, laser beam lighting, gradually evolving timbres, and complex geometric architectural design are clearly inspired by Xenakis.

A couple more examples of a clear sonic connection. His ambient works such as his series of *Xerrox* albums contain a more gradual transformation of timbres and textures. *Univrs*, using the technique of granular synthesis, is a clear sonic connection to the "grains of sound" concept Xenakis incorporated in his works. As Nicolai's career progresses, he has explored many different compositional techniques and overlaps genres. His newest work *HYbr:ID Vol. 1* (2021), a part of the score for the choreographic work *Oval* binds "astrophysics phenomena, fiction, and performance movements" according to his NOTON label website.

Their shared background in architecture brings out the biggest similarity in their compositional processes. Nicolai shares an almost identical approach to mapping out his tracks. In another interview on XLR8R, when asked how he approaches composition, he states "I am also inspired by architectural drawings… When I start an album or a release, I normally begin by sketching (sonically) what I would describe as an atmosphere…". Most of his works have a very apparent shape and aesthetic. The change in timbres and sounds are audible in the music he creates. The timbres have a general progression and direction they are transforming in. Unlike some producers who create a track without a general form or overarching structure, Nicolai architecturally maps out the sonic landscape of his works. Being an artist, most of his performances have a visual element or representation to them. In ATTN Magazine Nicolai states "Even with a touch screen controller, you cannot visualize the complexity of the sounds you're playing, so this complexity is presented in the visuals". There is a strong connection between his music and a visual element or some sort of structural backing.

4. Conclusion

The development of the experimental electronic music scene, including noise music, glitch, and IDM, along with the development of computer music and electroacoustic music, run parallel and can be derived from many different streams of thought and different influences. There have been composers and musicians who have a solid footing in both scenes, but most seem to run along their niche or genre independently. Xenakis, however, is so monumental to the development of computer technologies and avant-garde music that his influence reaches electronic music in both the realms of academia and electronica. Additionally, many musicians outside of academia regard his music with reverence and appreciate his explorative nature, with differing reasons as to why they connect with and appreciate his work.

One reason is Xenakis' outsider nature, something that resonates with many experimental producers. Without a background or formal training of music, many musicians may see him as a non-academic, separate from the stuffiness that is associated with ivory tower music. Like Xenakis, most of the artists mentioned are outsiders with a love of experimenting and pushing boundaries. Additionally, without a strong instrumental or notational background, producers often rely on external influence to form their music rather than traditional music theory and compositional techniques. These producers often find influence in art, technology, or mathematics, which draws them to Xenakis. Musicians like Matmos and Merzbow are concerned with timbre and the overall aesthetic of their music, falling close to musique concrète composers. Nicolai and many other producers often use some sort of mathematical structuring and architectural design when composing. And his transformation of image to music and technological innovations have appeared into the electronica scene. Some of Xenakis' more advanced algorithmic concepts outlined in *Formalized Music* such as his specific stochastic mathematical functions, set theory, etc., did not make an appearance in the works of these electronic producers. Some of the concepts seen can be loosely stochastic, but within the electronica realm, do not reach the same level of complexity.

As mentioned previously, the line between academic musicians and "electronica producers" is graying. Some tracks by producers are sonically indistinguishable between musique concrète artists or the "nosier" variety of the avant-garde. While many of the musicians might not be incorporating stochastic or complex algorithmic processes often associated with Xenakis' work, they do have more structure and formal thinking beyond a randomized collection of irrelevant or repetitive sounds. With musicians like Nicolai, the academic walls are already lowering and the separation between "electronica" or "sound art" or a "formal composition" is breaking down. With genres and styles of composition harder to define, the one thing that is ever present and unifying amongst these composers and musicians is the appreciation of unique sounds and influential composers like Xenakis.

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Xenakis' conception of creativity and the notion of emergence

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Abstract

Since the 1970s, several scientific breakthroughs have brought mathematicians, physicists, life scientists, philosophers and more recently composers to attach new meanings and connotations to the notion of emergence. Xenakis' musical approach announced these developments as early as the 1950s, thus illustrating the composer's belief that music can guide the entire body of arts and sciences.

Xenakis initially simulated emergent processes by fabricating randomness with the help of probabilistic laws. Relying on a granular conception of sound, he made sonic morphologies (masses, arborescences) and even entire musical works "emerge". This approach comes under what physicists call "weak" emergence, which can be rationally explained and, to a certain extent, predicted.

Nevertheless, Xenakis also accepted "pure randomness", irrationality and unpredictability, hence a part of unexplainable, arbitrariness and immastery. He was then brought to *let music emerge*, producing a "strong" emergence that escapes causality. Some particular topics tackled in his writings point to this aspect: the "unfaithful repetition", the "time in itself", the "child's gratuitous play", the "getting out of self".

The notion of emergence is inherent to the Xenakian vision of a humanity which, through its powerful will, relentless struggle and unlimited creativity, is called upon to ensure its survival but also that of the universe. It answers a "compelling need" and a "supreme hope" which, Xenakis argues, is essential to humans: that of "being capable of inventing, creating, not only discovering and unveiling".

Since the 1970s, mathematicians, physicists, biologists, philosophers and more recently also composers have attached new meanings and connotations to the notion of emergence[1]. I would like to suggest that, as early as the 1950s, Iannis Xenakis, through his music and his way of considering artistic creation, foreshadowed these developments. He thus offered a remarkable illustration of his belief that music, with its particular power of revelation[2], can guide the entire body of arts and sciences.

1. The musical work as emergence

The arising of life and then of intelligent life are often mentioned as examples of emergence. This kind of events, which imply an unexplainable transition between two different stages of evolution of

[1] One can mention, among many others, René Thom, Ilya Prigogine, Francisco Varela, Henri Atlan, Edgar Morin.
[2] Xenakis (1979, 12-14) distinguishes three kinds of knowledge: by logical inference, by experience and by revelation. He points that, while the first two are accessible to arts and sciences, the last is reserved to arts.

an organized system[3], is known to be difficult to understand, as it defies causality[4]. In fact, one cannot yet determine the exact cause of the emergence of a new property such as life, or the cause of certain phenomena studied by quantum physics.

Music is also concerned by emergence. Indeed, does not composing amount to making something new emerge?[5] Is the musical work not an emergent phenomenon, in the sense that, according to an established formula, it represents "more than the sum of its parts" (in this case, more than the sum of the sounds that compose it)? [6] Moreover, do we not have the impression that it "emerges" in an unaccountable, even mysterious way, at the whim of inspiration? [7]

Xenakis does not address the notion of emergence in an explicit way. He deals with it indirectly, in the context of the reflection he leads on notions such as creation, novelty and originality; he also evokes in this respect dualities like determinism-indeterminism, order-disorder, causality-non-causality or rationality-irrationality. Beyond this theoretical reflection, his musical approach and compositional techniques refer in many ways to the notion of emergence.

2. Weak emergence: simulations of randomness

Borrowing two terms employed by physicists, I would start by suggesting that Xenakis' music illustrates two kinds of emergences: "weak" and "strong" (adjectives which in this case do not imply a value judgment)[8]. Weak emergence concerns phenomena whose causes are only partially or provisionally unexplainable. It can therefore be understood rationally, at least to a certain extent.

In contrast, strong emergence is supposed to be entirely unexplainable. It manifests itself in the form of a pure, absolutely unpredictable randomness, as seen in quantum phenomena. There is something irrational about it, a kind of "magic" which makes scientists uncomfortable, as it seems to support the idea that something can arise from nothing.

2.1. The mass-granular approach

Modern physics has shown that the complexity of the interactions occurring in a turbulent cloud of particles is a source of randomness, of unpredictable events and thus of emergence. The behaviour of the sound masses in *Pithoprakta* evokes the evolution of such a chaotic cloud. It implies a great deal of complexity in musical structures, due to the large number of operations involved[9]. It is this complexity that made it necessary to adopt a stochastic approach.

Xenakis also imagines every single sound as a complex cloud of tiny "grains" that he calls *phonons* or "sound quantums". In theory, this kind of granular approach should allow, as Horacio Vaggione remarks (2019, 61-62), to compose sonic emergence through a logic of "coupling" between different scales of temporal organization[10]. Scientists nevertheless warn that conceptual emergence, which is a matter of logic, should not be confused with physical emergence, which actually happens.

Xenakis' granular approach, using probabilistic laws, is certainly supported by a powerful concept: that of stochastics. Yet this abstract concept engenders a real sonic dynamic and with it a striking

[3] Xavier Hautbois (2019, 34) argues that the transition between different levels of reality, each governed by specific laws, "is not accessible to knowledge". The theories of emergence, he adds, are precisely built on the assumption of the "irreducibility of reality".
[4] Geoffroy Drouin (2017, 84) evokes in this respect a "causal break", due to "the impossibility of a causal articulation" between two different structural levels.
[5] Horacio Vaggione (2019, 57) notes that a composer is above all concerned with the question of how to make things emerge, which implies the existence of an acting subject.
[6] As Vaggione put it (2019, 66), "the musical work is an emergent phenomenon for it is not reducible either to its parts or to its constituent elements, or to the operations carried out during the processes of composition".
[7] Xavier Hautbois (2019, 144) notes that, since it "resists traditional logic", emergence risks making us "fall into a metaphysical explanation".
[8] On various aspects of weak and strong emergence, see : Bedau (1997), Bersini (2007), Lestienne (2012) and Virole (2015).
[9] As Geoffroy Drouin remarks, (2019, 112, 429), in music the "over-accumulation of writing operations" is a framework for emergence.
[10] Emergent processes, Vaggione points out (2019, 59), can be "composed" starting from a "diversity of overlapping strata".

impression of emergence. Stochastics still have their limits: Xenakis (1994, 62) thus acknowledges that randomness can be fabricated only up to a certain point. For, he argues (1976, 76), humans have not so far managed to provide a satisfactory explanation of "pure randomness".

Then, if, as Michel Philippot put it (1963, 13), for Xenakis, composing means making a suitable level of order "emerge from disorder", this emergence is a "weak" one, since, as the composer acknowledged, it is not the product of a "pure randomness". The striking aural impact of *Pithoprakta*'s masses comes in fact from their capacity to set up a pseudo-randomness allowing to simulate the emergence of sonic morphologies against a background[11].

Analogiques A and *B* show another case, that of an endeavour to make "second-order sonorities" emerge through the fusion of o lot of individual sounds (Xenakis 1963, 122). This process, which can be seen as sound synthesis on a higher scale (Solomos 2001, 137), is also an example of "weak" emergence. The "failure" of *Analogiques*, as it has been evoked (Di Scipio 1997), then rather reflects the impossibility, in the given circumstances, to produce a "strong" emergence[12].

With the *GENDYN* programme, Xenakis made a last visionary attempt to induce emergence through controlled transitions between three different levels of sound organization. In the experimental works he composed with the help of this algorithm, the musical structures "emerge" by means of a generative mechanism which determines the temporal evolution of sound "grains", but also that of medium-sized sonic morphologies and of macroform[13].

2.2. Organic growth

Organic growth processes are an inspiring model of emergence, especially in the Xenakian works featuring arborescences[14]. These tree-like structures are remarkably complex. Their branches can also "run" in the opposite direction to that of organic growth, thus involving a reversible time. However, like traditional polyphony or heterophony, they globally unfold an irreversible time which is in fact that of bourgeoning (*Thallein*) and of branch growing (*Evryali*)[15].

Arborescences also show a kind of fractal invariance, in that their branches are replicated at higher hierarchical levels[16]. This duplication is, here again, "unfaithful". It implies irregularities similar to those of real vegetal forms[17], justifying the status of "presumptuous rival" of nature conferred to Xenakis by François-Bernard Mâche (1972, 52). Moreover, the arborescences announce the computerized models of organic growth which today allow to imagine "a music evolving like a living organism"[18].

Yet they do not interact with their environment and do not self-organize "by taking care of themselves", as living organisms do[19]. Consequently, they do not display the kind of unpredictability that Xenakis nevertheless associates with life (Delalande 1997, 66). While the composer apparently

[11] Xenakis' sound masses, seen as forms (*Gestalt*) arising against a background, can be discussed in the light of a theory of information according to which music is "the emergence of a form from noise" (Moles 1972, 134). Michel Serres (1972, 181-194) points out the originality of Xenakis in his report to the "background noise of the universe". René Thom's catastrophe theory, with its concepts of *pregnance* et *saillance*, also sheds a light on Xenakis' morphodynamic approach (Iliescu 2000).
[12] For a discussion of emergent processes in Xenakis and Agostino Di Scipio, see Makis Solomos (2010).
[13] The difficulty of this project is not unlike that faced by physicists searching for a "theory of everything" which could explain all the interactions observable in universe, from the infinitely small to the infinitely large.
[14] Makis Solomos (1993, 120) identified the Goethean principle of the "original plant" (*Urpflanze*) as early as in *Pithoprakta*, a work which he thinks is a simulation of the structure of a living organism. Pierre Albert Castanet (1987, 26) argues for its part that Xenakian arborescences are the perfect example of a "topographical/biological transfer".
[15] Mihu Iliescu (2000) suggested that the arborescences also illustrate the morphogenetic model of bifurcation described by René Thom in his theory of catastrophes.
[16] Xenakis (1992, 22) remarks that fractal geometry finds "a mathematical expression to natural patterns apparently due to pure randomness".
[17] Natural forms, Peter Stevens observes (1978, 126-127), are "neither so regular as to be boring" nor "so irregular as to be shapeless".
[18] According to Mikhail Malt, quoted by Geoffroy Drouin (2019, 109).
[19] For Peter Stevens (1978, 125), a tree gives the impression of "taking care of itself".

strives to make the "style" of natural shapes his own (Restagno 1988, 49), his arborescences (unlike the *rhizomes*[20]) thus can only feign the specific emergence of life.

Organic growth and self-organization are also at stake in *Horos*. In this orchestral work Xenakis uses a cellular automaton[21], a mathematical formalism allowing to simulate the proliferation of organic cells, thanks to which he tries to approach what he calls the "mystery of sound" (1992, XII). He thus undertakes to make "new and rich timbral fusions" emerge out of certain harmonic progressions[22], a process that can be attached to the notion of *algorithmic emergence*[23].

3. Strong emergence: irruptions of irrationality

Over the years, Xenakis abandoned the mathematical formulas he used in the 1950s and 1960s and controlled the sound flow rather empirically. Having achieved "a superior form of nonchalance" (Restagno 1988, 50), he relied more on his intuition. He then also accepted a part of immastery[24], opening the door to a "strong", irrational emergence[25].

One may wonder, however, about the real significance of this evolution. Is this not just another form of simulation, certainly more subtle than that discussed so far? To answer this question I will briefly discuss four notions tackled by Xenakis, which show the irrational, non-formalizable part of his "formalized music". The first one is that of repetition, more exactly the non-identical or "unfaithful" repetition.

3.1. "Unfaithful repetitions"

Repetition is synonymous with life, Xenakis argues. "We need repetition", he declares. Moreover, he adds, "there is no rule without repetition" (1994, 91-92). He then sets up repetition itself as a rule - the most fundamental of all - that must be respected in musical composition. He thereby confers to it an aesthetic value, also considering it as a primary source of creation[26].

However, Xenakis specifies, repetition has to be "unfaithful", that is, non-identical. This requirement can be understood in the light of Gilles Deleuze's dialectic of difference and repetition, but it also refers to a number of dualities that reveal the mechanisms producing emergence: permanence-variation[27], identity-plurality[28], redundancy-variety[29], invariance-drift[30], archetype-realization[31].

Xenakis postulates that reality never reproduces a given entity, for there is always "unfaithfulness" in reproduction. In other words, to use Deleuze's terms, there is always difference in repetition. It is precisely this difference that engenders various kinds of irregularities leading to what modern physics calls singularities, and then to emergence.

[20] As thematized by Gilles Deleuze and Félix Guattari (1980, 31), the rhizome differs from the arborescence precisely by its capacity to burst forth, that is to emerge anytime and anywhere, in an absolutely unpredictable way.
[21] On Xenakis' use of cellular automata, see Peter Hoffmann (2002) and Makis Solomos (2005).
[22] As emergent properties, these new timbral fusions are indicative of what Nicolas Darbon (2006, 81) calls "chaocity". This term precisely concerns the chaotic nature of processes such as those involved in organic growth which also inspired Ligeti, another composer who referred to cellular automata.
[23] Geoffroy Drouin (2019, 429) designates by "algorithmic emergence" the "switching to a higher level" which occurs in musical works drawing on the model of complexity through noise.
[24] The notion of "immastery" (*immaîtrise*), as discussed by Jean-Paul Dupuy (2005), could be understood in the light of the concept of "unavailability" forged by German philosopher Hartmut Rosa (2020).
[25] The concepts of "gap" (*écart*), "*dé-coïncidence*", "*inoui*" (unheard-of) and "incommensurable", forged by French philosopher François Jullien, also provide an exciting perspective for understanding the notion of emergence.
[26] On the various ways of repeating through self-borrowing in Xenakis' works, see Benoît Gibson (2011).
[27] Geoffroy Drouin (2019, 113) qualifies this duality as a "privileged moment of emergence".
[28] Duality identified by Makis Solomos (2013a, 404) in Horacio Vaggione's music.
[29] Henri Atlan (1979) points out the role of this duality in the functioning of living organisms.
[30] Michel Serres (see Xenakis 1979, 109) considers that the duality invariance-drift is characteristic of music.
[31] On Xenakis' musical approach seen as a repetition of archetypal cosmogonies, see Mihu Iliescu (2015, 225-240).

By mentioning the Epicurean concept of *ekklisis* as a philosophical foundation of unfaithful repetition, Xenakis highlights the latter's irrationality. The *ekklisis* - an infinitesimal deviation exceptionally affecting the trajectory of certain atoms - has indeed no rational explanation. It introduces, Xenakis notes, "a senseless principle within the marvelous deterministic atomistic system" (1976, 77-78).

This senseless principle legitimizes the many "errors" that the composer commits in regard to the rules he sets himself. In fact, like those observed in the evolution of living organisms (Atlan 1976), these are not really errors. They rather mark the salutary abandon of a certain mechanical rigour[32] in favour of the irrationality of creation, that is, of emergence.

3.2. "Time in itself"

A number of physicists and biologists assume that emergence is fundamentally bound to time (Lestienne, 2012, 146). Some of them put forward the hypothesis that time itself is an emergent property, resulting from random processes occurring at a microscopic level (Prigogine 1996, 69)[33]. With the GENDYN programme, Xenakis illustrates this hypothesis: he makes the macroscopic time of the musical work emerge through stochastic procedures applied to the microstructure of sound.

Beyond the singular experience occasioned by GENDYN, any *in-time* expression of what Xenakis calls *outside-time* structures is likely to produce emergence, for it involves an irrational aspect. From Saint Augustin to Ilya Prigogine and Isabelle Stengers (1988, 145), time is indeed deemed to be "obscure", difficult to grasp, thus escaping rationality. The last Xenakis (1994, 98, 106) also describes it as "fuzzy", "impalpable flow", lending to "mysterious judgments"[34].

After having founded his "formalized music" of the 1950's on the radical hypothesis of "the exclusion of the time factor" (1963, 186-187) - since music, estimated then Xenakis, "does not really happen in time" (1972a, 28) - and after having asserted the necessity "to tear itself off from time", "to hold on against the river of time" (1994, 101), in his late writings he thus finally takes into consideration what he calls "time in itself", that is time acknowledged to be irreversible.

The idea of a "union of Parmenides and Heraclitus", formulated by Xenakis in the 1970s, clearly indicates this turn. The composer's ontology, initially centered on the Parmenidean Being, now accommodates the Heraclitean Becoming, implying irreversibility. Such a change has significant consequences: as Horacio Vaggione remarks (2019, 63), once the irreversibility of time is recognized, sound pitch is no longer an absolute parameter but, at least partially, an emergent phenomenon.

It results, concerning Xenakis, a singular mix of reversible and irreversible. Michel Serres describes it metaphorically as "an irreversible gorged with reversible", referring to a music which "flows while restraining itself from flowing" (1977, 187). These paradoxical formulations imply the possibility to produce emergence through a partially rational control of the temporal flow, in spite of its intrinsic irrationality. They thus reconcile a global mastery of creative processes with a punctual immastery.

3.3. "A child's gratuitous play"

In Xenakis' words, music is a "child's gratuitous play" (1976, 40). To understand this sentence which the composer never developed, I will first interpret it in the light of a passage from Nietzsche's *Zarathustra*:

> The child is innocence and forgetting, a new beginning, a game, a self-propelled wheel, a first movement, a sacred "Yes". For the game of creation, my brothers, a sacred "Yes" is needed.

[32] Edgar Morin (1980, 368) highlights the significance of the "lack of rigour" as a source of profitable errors. We can "live with error", he argues, and even "make of an error a virtue".

[33] More recently, Carlo Rovelli and Alain Connes put forward the hypothesis that time emerges progressively in a universe composed of tiny grains of space and/or time that are still indistinguishable from each other (Lestienne 2012, 212).

[34] Yet Xenakis continues to express doubts about the "reality" of time. Is it not, he asks, "merely a notion-epiphenomenon of a deeper reality [...] and therefore a delusion that we unconsciously accept?" (1994, 94).

While the child's play, associated with the idea of a new beginning, carries a cosmogonic connotation, the self-propelled wheel symbolizes a mechanism running endlessly with no external intervention. It reminds an automatic process like that of *Achorripsis* which can be ideally launched, as Xenakis assumes, by a simple "initial push" (1991, 518): an inaugural gesture considered by mythical cosmogonies as a privilege of gods and demiurges[35].

Heraclitus' Fragment 52, which inspired Nietzsche's philosophy[36], further clarifies the meaning of Xenakis' sentence:

> Time [αἰὼν] is a child playing draughts, the kingly power is a child's.

In ancient times, the Greek word *aïon*, today usually translated as "time" or "eternity", also designated the lifespan of human existence and the energy needed to achieve it[37]. Fragment 52 then teaches us that living one's life is in a way similar to a child's gaming (Therme 2017, 646-647). Yet this game should be taken seriously, like the one referred to by Heraclitus. It is actually a combat game, common in ancient Greece, which requires concentration and strategy.

Some of Xenakis' works, recalling the jousts of antiquity, evoke this kind of game which "combines rules and unpredictability" (Therme 2017, 645-646). In *Duel* and *Stratégie*, two conductors confront each other through their orchestras, using "tactics" elaborated with the help of mathematical game theory. But the decisions they make in the midst of their "battle" are partially irrational. The game is anyway biased as its staging leaves little room to unexpected events and thus to a genuine emergence.

Another intriguing case is that of an emergence that was found to be disappointing. During the creation of *Tauriphanie*, in the Nîmes bullring, the bulls' and horses' choreography planned by the composer could not be properly controlled (Couprie 2020, 434-457): unlike humans, animals did not "play the game". Although their presence was important to him[38], Xenakis eventually dispensed with them, perhaps acknowledging the unpredictability of life.

3.4. "Getting out of self"

The last irrational source of emergence I will discuss is the surpassing of self. Xenakis actually prefers the expression "getting out of self", a translation of the Greek word *ekstasis*. He assumes that the loss of control induced by the *ekstasis* is beneficial to artistic creation; for, he argues, "if you dominate everything, you don't create anything" (Xenakis 1997, 60). The *ekstasis*, he adds, reveals the true human nature; it allows the "soul" to escape its destiny and to affirm its creative vocation (1994, 67).

In this ancient sense, the *ekstasis* appears to be similar to the Dionysian state of trance. Xenakis finds indeed that music shares, with alcohol and love, the "power of Dionysus", which he admits he would like to acquire (1987, 18)[39]. Dionysus actually embodies for him the irrational nature of a creation arising from chaos, as expressed by Nietzsche in his famous sentence from *Zarathoustra*: "You need chaos in your soul to give birth to a dancing star".

It also seems possible to "get out of self" through an extremely challenging effort, like that required from musicians performing the reputedly unplayable Xenakian works. The inevitable compromises and approximations inherent to their execution actually lead to unpredictable emergences. However, the *ekstasis* finds its supreme expression in the collective effort that, according to Xenakis, human species should undertake in order to surpass its own "mental categories".

[35] "Aren't gods a kind of automaton, much more powerful?", Xenakis asks (1988a, 5).
[36] On Nietzsche's self-identification with Heraclitus and on his tendency to use riddles involving children at play, see Anne-Laure Therme (2017, 653-657).
[37] On the interpretation of Heraclitus' Fragment 52 and especially on the polysemy of the word *aïon*, see Marcel Conche's commentaries (Héraclite 1998, 446-449).
[38] In Xenakis' view (1988b, 105), through the presence of animals his music was supposed to "become Nature".
[39] Xenakis (1994, 134) also mentions the "divine spark" of Dionysus, an expression directly referring to ancient gnostic doctrines.

A “very high effort”, he observes (Xenakis 1994, 107), is in fact necessary to simply survive, be it for a person, for humanity in general or for the universe. This kind of effort illustrates what he calls the “dialectical struggle” of life “against extinction, against nothingness”[40]: a universal, cosmic process which, by its cyclicity, also reminds Nietzsche’s eternal return[41].

Xenakis’ music thus emerges from a fierce struggle: a fight going back to the composer’s commitment to the Greek Resistance during World War II. It requires a strong determination which is that of transgressive heroes such as Prometheus and Sisyphus, and of the “essential man” described in the Hermetic gnosis and evoked by Xenakis in *La Légende d’Eer*[42].

4. Making emerge and letting emerge

Finally, Xenakis’ conception of creativity is quite ambivalent, as it implies the possibility of *making emerge* but also of *letting emerge*. In the first case, the recourse to mathematical formalisms pushing the limits of rationality has effects which could be assimilated to “weak” emergence. In the second case, irrational, arbitrary or unmastered decisions allow a “strong” emergence.

This ambivalence bears a contradiction which is inherent to emergence itself, insofar as this notion can be defined as “a mix of freedom and determinism” (Besnier 2010, 30). Indeed, on the one hand, Xenakis assures he wants “the things [he] asks for [...] to be randomness”; he requires “more freedom”, which implies a part of irrationality and unpredictability. But, on the other hand, he imagines “a constraint, an abstract mechanism, which would do exactly what [he] asks”[43].

He generally solves this kind of contradiction in the manner of a presocratic philosopher, by reducing it to one and unique principle. He thus claims a “tautological” approach that reduces oppositions to identities[44]. For example, he argues, determinism and indeterminism are two aspects of one and the same thing, so they “can ultimately be confused” (1994, 114-115) [45].

Music, however, escapes this tautological approach. It preserves an irreducible part of irrationality, where its power actually lies. “I attain the inaccessible through my music”, Xenakis declares (1972b, 58). Maybe what he means by this is having access to the privilege, once reserved to the gods, of creating *ex nihilo*, that is of producing a “strong” emergence, although he calls it otherwise: “engendering the unengendered”, or birth “out of the nothingness” (1994, 105; 115).

Emergence is in fact inherent to the Xenakian vision according to which humanity, by its powerful will, relentless struggle and unlimited creativity, should ensure its survival as well as that of the universe. It answers the “imperious necessity” of a “supreme hope”: that of being capable of “inventing, creating, not only discovering or unveiling”. “There must be creation in the universe”, the composer claims (1994, 136-137). He acts accordingly, considering himself as a parcel of the universe.

The Xenakian understanding of the notion of creativity ultimately refers to a perpetual emergence that cannot be dissociated from the return to nothingness. “It is necessary”, Xenakis points, “to stand by [the] conclusion of a universe open to the new, which would relentlessly arise or disappear in a truly creative whirlwind, from nothing and disappearing into nothing”. This open cosmic vision also applies to “the foundation of art” and to “the destiny of humanity” (1994, 111).

[40] Xenakis imagines in this respect a universe “desperately struggling to cling to existence, to the being, by its own endless renewal, at every instant at every death” (1994, 105). His metaphor of the “hecatomb of pure sounds [...] necessary to create a complex sound” also expresses this connection between life (renewal) and death (1963, 61).
[41] Xenakis evokes a scenario in which the Being, “in order to continue to exist, had to die, and then once dead, to begin its cycle again” (1994, 111).
[42] On the Hermetic and other gnostic elements in Xenakis, see Mihu Iliescu (2015).
[43] Quoted by Solomos (2013b).
[44] In this regard, Xenakis quotes Parmenides: “the same is at once thinking and being”; then he paraphrases him, pushing the tautology to its ultimate consequence: “the same is at once being and not being” (1992, 24).
[45] Xenakis argues that “Einstein’s god should possess the power to encompass and overcome the apparent opposition between determinism and incertitude.” This god, he adds, “means us, the cosmos” (Delalande 1991, 70).

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Rendering embodied experience into multimodal data: concepts, tools and applications for Xenakis' piano performance

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Abstract

Iannis Xenakis' performance practice has increasingly been the object of investigation by both interpreters and musicologists. After a first generation of pioneering performers, who attempted to register and communicate what at the time was a singular challenging experience, subsequent generations have systematically kept developing practice-based research methods for learning and playing Xenakis (Kanach 2010). Similarly, musicology has been shifting its attention from Xenakis' structuralist approach (Xenakis 2002) to post-structuralist (Exarchos 2015) and ecological approaches (Solomos 1996), to Xenakis' composition as practice (Gibson 2011) and quintessentially towards performance analysis, in the wider context of a performative turn (Lalitte 2015) and a more recent embodied cognitive turn (Leman 2008), (Besada et al. 2021). The results of this double movement by performers and musicologists have exemplarily been codified in the series of conferences "Interpréter/Performer Xenakis"[1].

The reasons for the constancy of this research interest might be located in a specific trait: Xenakian performance presents us with a unique manifestation of the 'mind-body problem'. In accordance with contemporary empirical and psychological studies in performance analysis and education (Clare and Cook 2004), (Parncutt and McPherson 2002), we assert that ancient distinctions between abstract understanding, performing technique and artistic interpretation can hardly address the emergence in sound of mathematical algorithms and geometrical structures, which are communicated through dense symbolic music notation and are realized with extreme physical investment. This

1 https://musidanse.univ-paris8.fr/spip.php?article1519

tension between Xenakis' conception, notation and performance is usually framed in terms of impossibility, meta-/anti-virtuosity, athleticism, energetic striving and effort (Varga 1996) or of utter disembodiment and deconstruction of bodily reflexes (Thomopoulos 2010).

In this paper, we attempt a paradigm-shifting approach to performance analysis for the fourth generation of Xenakis' performers, considering the relation between notation and embodiment as expressed in multimodal performance data: the mind-body problem is to be addressed as a decoupling in the relation between the musical score, on the one hand, and the multimodal performance data on the other.

We will present a library of data collected over many years, as well as a wide range of applications for learning and performing Xenakis' piano works. We will provide an overview of technological means for capturing, analysing, assisting, augmenting and communicating Xenakis' performance practice, with reference to his three major works for solo piano: *Herma* (1961), *Evryali* (1973) and *Mists* (1980). In particular, we will look at how multimodal data are indispensable in addressing Xenakis' tensions codified above, but also how Xenakis' transcendental performance challenges the very notion of body rendition in itself.

We will address the following axes:

1. Capturing the Xenakian body: Affordances, constraints and invasiveness in system development

2. Analysing the corporeal subtext of Xenakis' notation: Recent work towards evaluating relationships between musical structure and multimodal data, including effort-related EMG

3. Beyond unnecessary challenge: Creating interactive systems for enabling learning through multimodal data

4. Augmenting Xenakis performance: Integration of the data in an augmented reality spectacle communicating latent layers of performance information to the public

Along these axes, a certain biopolitical trait, the notion of body rendition through data (Zuboff 2019), is counterbalanced by irreducible physical elements that "escape computation"[2]. Thus, the ancient friction between mind and body will be reframed in terms of the friction between what can and what cannot be computationally captured and manipulated in Xenakis' piano performance, in order to define new potentialities.

1. Introduction

Sixty years after the Japanese pianist Yuji Takahashi commissioned Xenakis with his first significant solo piano work, *Herma* (1961), this paper aims at updating the artistic and scientific study of Xenakian piano performance practice. On the one hand, Xenakis' music has by now become part of the contemporary music canon: It is widely performed by students and professional artists around the globe, to a degree that exhausts the tropes concerning impossibility, surpassing, athleticism, meta-/anti-virtuosity and piano heroes, still found in a wide range of scholarship and journalism, in stark contrast to Takahashi's elegantly laconic remarks (Takahashi 2008). On the other hand, both conceptual and technological advancements in the study of performance make this update urgent: First, the performative turn in musicology since the 1980s (Cook 2013) has revealed the specificity of performers' approaches to musical works as complex phenomena that live in multiple domains, the symbolic notation and the notion of the 'work' being only one of those.

2 https://www.slomoco.surf/projects/provocations/resource-collection/provocations-events

Second, the embodied cognitive turn in musicology since the 2000s (Leman 2008) has stressed the importance of embodiment in shaping the understanding of the symbolic notation itself, in learning as well as in performance. Finally, the development of technologies for the documentation of musical performance has resulted in a multiplicity of methodologies for studying not only the sonic outcome, but every aspect of the multimodal phenomenon of performance, including image, gesture, movement and touch, especially since the democratization of sensor technologies and interactive music in the 21st century.

What makes Xenakis' music particularly fit as a case-study for the artistic and scientific research of performance is what we defined in our abstract as its 'mind-body problem': On the one hand, Xenakis is effectively transcribing algorithmic and geometric structures in conventional music notation, often codified in his original complex calculations and compositional sketches. This fact generates a first decoupling between the conception of the musical work and its embodiment in notation as the main communication interface between the composer and the performer. On the other hand, the very structures themselves are consciously driven by Xenakis' own predilection for athleticism, extremes of energy expenditure and effort. This aspect invites the form of performative approach that has been defined as 'energetic striving' (Cox 2002), and even more so when the notated structures are occasionally not taking into consideration the biomechanics of human performance and the construction of the instrument. Thus, a second form of decoupling emerges, between the embodiment of the performer and the embodiment of concepts in notation. This decoupling needs to be consciously addressed by the performer, without loss of the expressive quality of transcendence.

In what follows, we propose to transpose the question of these decouplings onto the decoupling between notated symbols and captured multimodal data in performance. The reason for this is that both forms of recording, in notation and in data, are fixed in their respective media, which allows for their qualitative and quantitative analysis and for their effective communication to third parties other than the performer and the composer. Thus, the usual first-person, subjective descriptions offered by the performer can be transformed into third-person, objective ones.

However epistemologically sound such an approach might be, it reveals several aporias: First, on the developer end, the media for capturing performance are often constrained by numerous factors, which will be explored in detail. Second, on the user end, such media always require performance trade-offs depending on their body invasiveness during the act. Third, this aspect becomes even more pronounced in Xenakis' performance, with its very particular set of biomechanical problems, which take us to the domain of 'extreme users in extreme situations'[3]. Fourth, the combination of these media and the potential range of applications present their own challenges, which are to be addressed not only at a properly technical level, but also at a conceptual and methodological level, necessitating very careful rethinking of performance/interpretation in general and in Xenakis. Finally, the attempt to capture embodiment in data bears a certain biopolitical trait, what the American sociologist Shoshana Zuboff has termed 'body rendition' (Zuboff 2019), and which in an age of acute data surveillance and 'cognitive capitalism' (Moulier Boutang 2007) cannot remain unexamined: To what extent are the elements that "escape computation"[4] still desirable and what are the limits and ethical considerations of intimate body data being studied and shared?

Our paper is articulated as follows: First, we present a brief chronology of systems' development for studying Xenakis' piano performance. Then, we address the theme of affordances, constraints and issues of invasiveness in system development (section 3). Subsequently, we offer an overview of methodologies for the study of three Xenakis piano works, *Herma* (1961), *Evryali* (1973) and *Mists* (1980), from a computational musicology point of view (section 4). In the fifth section, we provide an overview of the *GesTCom* system (acronym standing for *Gesture Cutting Through Textual*

3 https://www.inria.fr/en/ex-situ

4 https://www.slomoco.surf/projects/provocations/resource-collection/provocations-events

Complexity), as a concept and tool for technology-enhanced learning and performance in Xenakis. Finally, we present an augmented performance of *Evryali,* employing motion capture, augmented reality and interactive staging.

2. Chronology

This work has followed four distinct chronological stages, corresponding to material/technological and conceptual/methodological advances:

A first phase of development of a prototype system called *GesTCom* (acronym for *Gesture Cutting through Textual Complexity*) took place at IRCAM (2014). The goal of the prototype was to enable recording of movement data of a piano player, simultaneously with audio. It was developed with the constraints of being easy to set up, transportable and affordable to be duplicated by performers. A first prototype was then built using a *Kinect* camera (colour and depth images) and two wireless custom-made 3D accelerometers and 3D gyroscopes, based on the Modular Music Objects (Rasamimanana et al. 2010), attached to the wrists. The software was built using Max/MSP[5] and particularly the package MuBu[6], enabling advanced recording and data processing. This setup was evaluated and used for recording several pieces, and in particular Xenakis' *Herma* and *Mists*. Some of the preliminary results are presented in (Antoniadis et al. 2014).

A second phase of system development and recording was achieved at the University of Strasbourg (2014-2018), in collaboration with IRCAM. The use of capacitive sensing via *TouchKeys*[7] (Augmented Instruments Laboratory) was added in order to capture the position of the hand and fingers on the keyboard. The software was also updated to visualize MIDI information. Next to these hardware and software developments, a methodology for the mappings between notation and movement and for notational processing on the basis of movement was developed in (Antoniadis and Bevilacqua 2016).

A third phase of development including full-body motion capture, augmented reality systems and interactive scenography for the enhancement of the spectator's experience has been taking place since 2020, at EUR-ArTeC, Université Paris 8, in collaboration with the labs MUSIDANSE and INREV-AIAC (Antoniadis et al. 2022).

Finally, in the context of independent collaboration with Stella Paschalidou, we combined some of the *GesTCom* capabilities with full-body motion capture and EMG recordings, in an experiment of registering and tracking multiple datasets, with the intention of studying mappings between notation and effort.

3. Capturing the Xenakian body: affordances, constraints and invasiveness in system development

In this section, we present an overview of themes that will be detailed in the following ones along three axes: affordances, constraints and invasiveness of the systems in question, both on the developer's and on the user's ends.

Affordances and *constraints* are terms used in ecological psychology (Gibson 1979) to describe the sort of action and perception that a given environment allows to (or affords for) a given organism with given abilities.

In developing systems for the capture, analysis and augmentation of Xenakis' piano performance, we needed to make choices concerning a series of issues and themes:

First, the sort of modalities and data that are to be captured. Given the democratization of sensor

5 https://cycling74.com/

6 http://forumnet.ircam.fr/product/mubu-en/

7 https://touchkeys.co.uk/

technologies and multimodal data methodologies since the 2000s, there is an abundance of systems that can be distinguished according to the modality captured (image, sound, inertial data, location on a surface, movement around a space, etc).

In the following case-studies, combinations of heterogeneous capture systems are used that afford a variety of modalities and performance data. Variety ensures the possibility of capturing multiple aspects of the performance phenomenon, but is constrained by both specific limitations of the capture systems, as well as the limitations of their combinations. The most notable one is the need for aligning the heterogeneous data-streams spatially and temporally and segmenting continuous data into discrete events and actions, or inversely, deducing higher-order structures from discrete data (MacRitchie and McPherson 2015).

Other important issues concern the question of the relationship (technically called *mapping*) between the captured data used as input in a system to output parameters, such as digital audio or, in this case, visual feedback and notation processing, the temporal or spatial structure of the mappings, etc. (Bevilacqua et al. 2011). Such issues are explicitly addressed by the development of the *MuBu* (acronym standing for *Multiple Buffer*) library.

Additional issues regarding measurement concern the inherent complexity of the performance act, notably in terms of biomechanical complexity, which is often analysed in terms of movement coarticulation (Godøy 2011), proximal or distal control of movement fluency (Gonzalez-Sanchez et al. 2019), the action-perception cycle (Leman 2008) etc., and how can this complexity be mapped upon the data-streams, that can be organized in low-level raw data or higher-level descriptors.

Talking about motion capture usually means capturing the whole body movements (generating a virtual skeleton), which can include fingers, but this requires high-end systems. Recent motion capture systems are also able to capture facial expressions in the case of performance capture mostly used in cinema or video-game industries. Motion recording quality is now quite precise but the challenge remains in creating algorithms to extract data regarding expressivity or emotions.

The complexity of the motion capture setup or suits and its invasiveness could influence the performance recording and somehow transform or even bias data. Regarding the general problems of motion capture, it is important to take care of several elements:

- the set-up requires a specific marker-set and calibration according to body measurements. It has to be done accurately in order to avoid offsets;

- if the motion capture is used offline, data synchronization with other data (such as music or video) is crucial to avoid offsets in space and/or time;

- if the motion capture is used online in real-time, the processing requires more computing and also need to be synchronized with other data-flows for the same concern about offsets.

In any case, the question of spatial and temporal alignment of multiple datasets has to be addressed.

All these aspects are accentuated by the extremity of Xenakis' performance practice in terms of energy expenditure, speed and intensity, what has been termed the *athleticism* of Xenakis' piano performance (Kanach 2010), so that the usual constraints of the systems on the users' end need to be rethought as double constraints and be treated accordingly.

4. Analysing the corporeal subtext of Xenakis' notation: mappings between notated structures and data

In this section, we present an overview of previous and ongoing work towards the evaluation of relationships and technologically-enabled mappings between musical structure and multimodal data from a computational musicology point of view. Multimodal data refers to a variety of captured inputs, including the *GesTCom* datasets (Antoniadis 2018), as well as effort-related EMG

(Paschalidou et al. 2016). Methodologically, we explore ways of discovering and comparing patterns between multimodal and symbolic notation data, visualizing their couplings and decouplings. In that sense, we seek to systematically explore what the German musicologist Martin Zenck has described as the 'corporeal subtext' of music notation (Zenck 2006).

4.1. Mists

In (Antoniadis 2018) we have proposed a methodological framework for the analysis of texture and form through multimodal performance data. We pursued the analysis drawing on Xenakis' distinction between *outside time* and *inside time* structures as exposed in (Xenakis 2002).

As far as the outside time structures are concerned, three types of algorithmic processes are defined by Xenakis: linear random walks, non-linear random walks / stochastic distributions and arborescences undergoing geometric rotations in time-space. We recognized these structures and we mapped them onto distinct types of texture and physical movement, captured and analysed through the system and methodology described in (Antoniadis and Bevilacqua 2016).

Inside time structures were consequently defined on the basis of the multimodal data analysis, revealing middle-ground structures in relation to movement and offering a performer-specific interpretation of the global musical form.

Finally, we identified a third temporal category, *inside learning time*, and we proposed types of musical score navigation, drawing on a typology initially developed in (Stefanou and Antoniadis 2009). Four dimensions of learning (*scanning*, *stratification*, *resistance to the flow* and *line of flight*) are identified and studied through multimodal data.

In the following video[8], the first two steps of our methodology are demonstrated: the recording and analysis of multimodal data through the *GesTCom* system. The video presents the playback of multimodal data, recorded during a performance of Iannis Xenakis' *Mists*, page 1. Figure 1 presents an annotated snapshot of the Max/MSP patch used for the reproduction and annotation of the data.

From top to bottom in the blue panel on the right side of the figure, there is a visual representation of the following datasets:

• Stereophonic audio;

• Twelve gestural signals from inertial sensors on the player's wrists. 3D acceleration data are shown with black, green and blue signals, for both the left hand ('LH ACCEL') and the right hand ('RH ACCEL'); 3-axis gyroscope data are shown with red, yellow and orange signals for the left hand ('LH GYRO') and the right hand ('RH GYRO');

• MIDI information from the keys and the two piano pedals. Colour coding indicates velocity;

• Capacitive data from *TouchKeys* sensors on the keys of the piano. Colour coding indicates the position of the finger on the key, clusters are traces of hand-grasps.

The black markers superimposed over these datasets indicate a segmentation, which is defined by both quantitative and qualitative data according to the methodology in (Antoniadis and Bevilacqua 2016).

The quantitative data used here are the orange gyroscope signals for both hands and the TouchKeys clusters. The orange gyroscopic signal peaks (shown with red circles in Figure 1) indicate two of many hand position changes, or hand displacements, which are visible in the video at the moment the red cursor crosses over the thick marker (00:29-00:30 in the video). This marker is thick because both hands are displaced towards the bottom of the keyboard, as opposed to thin markers, whereby only one hand is displaced.

8 https://www.youtube.com/watch?v=io9iGpVUAkI

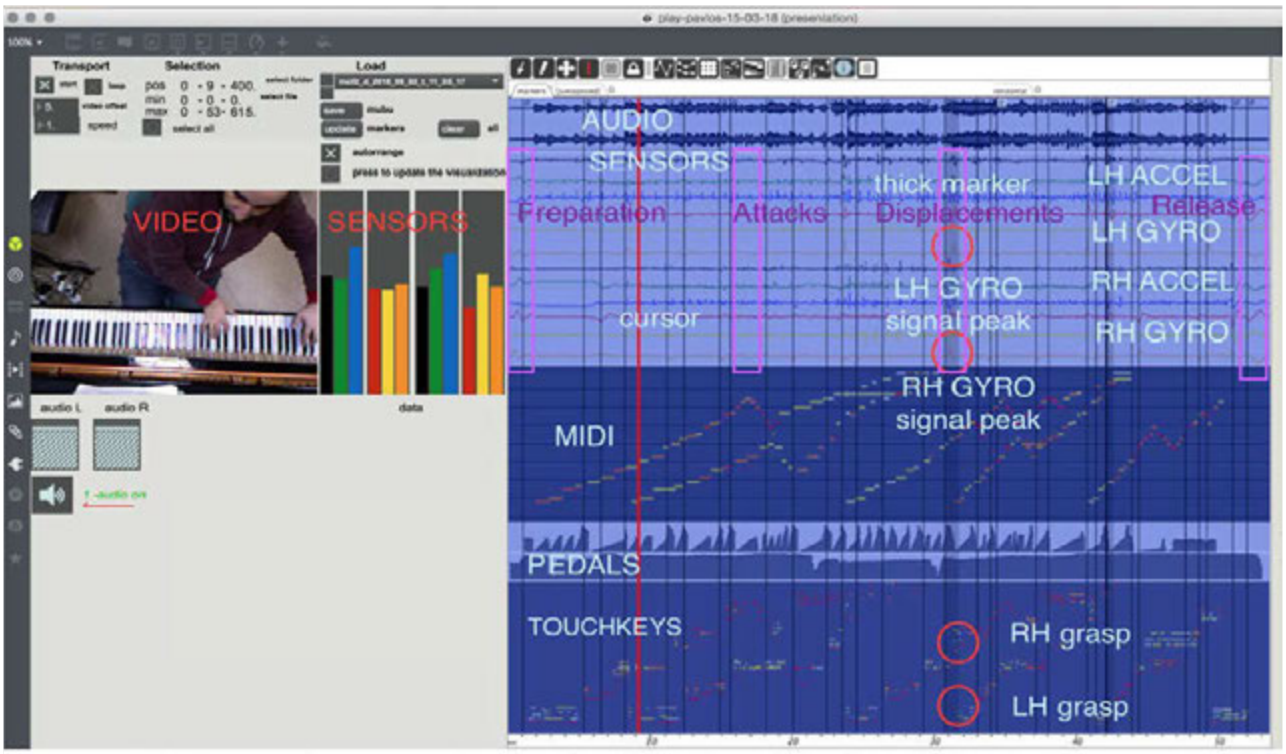

Figure 1: Max/MSP patch for the reproduction and analysis of recorded multimodal data (audio, movement, video, MIDI, TouchKeys)

The qualitative data used are performer's annotations. There is also a qualitative comparison of the gestural data to the *Kinect* video (left side in Figure 1), for visually confirming the displacement of the hands.

This pattern-matching between gyroscopic signals, TouchKeys data and annotated hand-grasps is indicative of the fact that subjective annotations can have an objective expression in multimodal data. In (Antoniadis and Bevilacqua 2016) we have described a syntax of piano movement derived from multimodal data. This syntax takes the form of 'movement envelopes' consisting of movement Preparation, Attack, Displacement and Release phases. We called them 'PADR envelopes'. In Figure 1, purple boxes indicate instances of these types of movement. Practically, attacks are accelerometer activations between the gyroscope activations that indicate displacements. So, in this particular example, attacks take place in-between the markers of displacements and the preparation and release gestures are visible before and after the sound (Figure 1).

4.2. Herma

The previous methodological framework is expanded through a current multimodal analysis of *Herma*, based on Xenakis' analysis of the piece as exposed in *Formalized Music* and adapting the theoretical framework of symbolic music to the study of physical movement.

At a first stage, we proceed with a computation of movement density, expressed in terms of displacements (the 'D' of the PADR envelope in Figure 1) per metrical unit of time in relation to the calculated pitch densities by the composer.

At a second stage, we have proposed a visualization and alignment of Xenakis' deep algorithmic structural elements, summarized by the composer as a *function flow chart* and *temporal flow chart*

(Xenakis 2002, 176), with recorded multimodal data as in this video[9].

At a third level of abstraction, we propose symbolic logical operations for movement as an equivalent to Xenakis' treatment of pitch and we explore relations and mappings.

Next to studying the relation of movement and symbolic notation, we aim at defining measures of notational and movement complexity, to be employed in a series of experiments on human technology-enhanced learning.

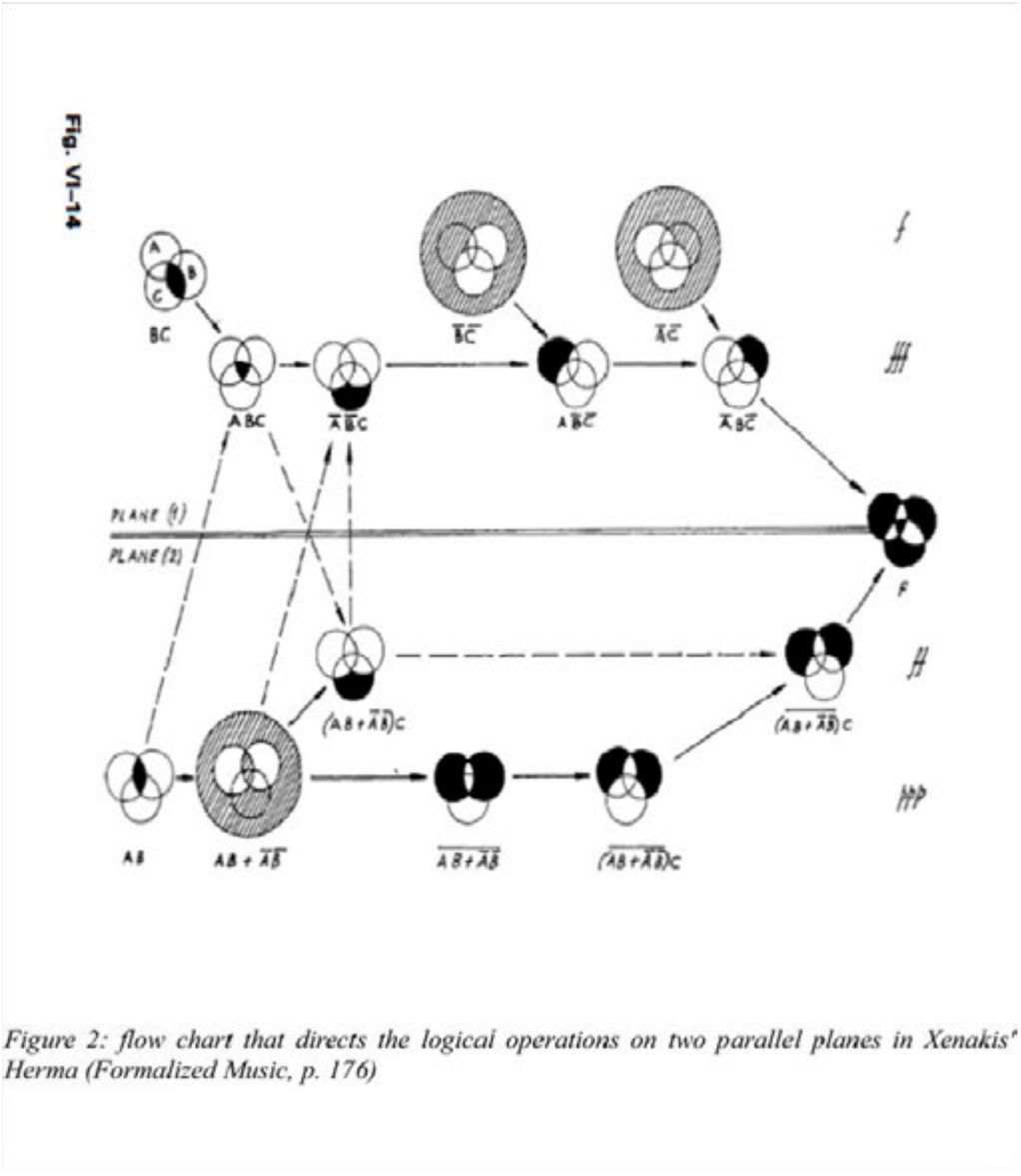

Figure 2: flow chart that directs the logical operations on two parallel planes in Xenakis' Herma (Formalized Music, p. 176)

4.3. Evryali

In more recent work, we have attempted to address issues of virtuosity and performability with respect to physical effort and energy expenditure in the context of *Evryali*. Associations of bodily and mental effort to movement features, but mostly to pitch-related information of melodic glides

9 https://youtu.be/L8pAjnAiQ9E

that invite higher levels of physical power by the performer have been found in Hindustani vocal music by (Paschalidou et al. 2016). Virtuosity in Xenakian terms has been attributed by (Solomos 1996) to measures of 'pure consumption of physical energy' rather than number of 'wrong' notes, ‘sheer physical pressure and transcendence of the performers’ limits’ by (Varga 1996). Therefore, we raised concerns about whether the notorious difficulty and even near-impossibility in performing specific passages of *Evryali* (Antoniadis et al. 2022), due to sensorimotor constraints that the textures of the dense and complex graphical notation request the performer to surpass, might be associated with equivalent levels of action power or not. For this reason, we ran a pilot study for recording and analysing surface electromyography data, that is electrical potentials produced during synergistic muscle contractions, which are supposed to reflect levels of muscle-activation or force-related information exerted by body joints.

Recordings were conducted in an ecologically valid setting at the music department of the Aristotle University in Thessaloniki, Greece and they included the acquisition of the following separate data streams for capturing motion, audio, video and EMG data on three different computer systems:

- Full-body IMU (inertial) motion tracking of a total of 32 sensors at ~60Hz (Perception Neuron v2 by Noitom), including hands/fingers, data transferred over wifi through dedicated router;

- 3 synchronized RGB video recordings of the performance scene at 60Hz each, 2 from the side and one from the top (PS3 Eye cameras by Sony, USB);

- 2 EMG & IMU recordings, EMG data running at 200Hz and IMU at 50Hz, one for each hand / wrist (Myo Armbands by Thalmic Labs, data transferred over bluetooth);

- 1 depth-video recording of the performance scene / top-view at 22.8.Hz (Kinect for Xbox 360 by Microsoft/PrimeSense, USB);

- 2 individual IMU sensors at 100 Hz, one for each hand (RIot Bitalino by PLUX wireless biosignals S.A., data transferred over wifi through dedicated router);

- 2 separate stereo audio recordings at 44.1 kHz - 16bits each, one for close miking and one for ambient recording (1. A pair of condenser microphones DPA ST 2011C / audio interface RME Fireface UFX - firewire / synchronized audio-bitalino-kinect recording in MaxMsp7/patch based on the Mubu object, 2. Sony PCM-D50 with onboard mics), comprising a limited version of the GesTCom set-up presented before.

Multiple IMU data were recorded by different devices as a means to visually align them and thus cross-verify the clap-based data synchronization. For instance, IMU data of the PN system can be aligned to the IMU data of the Myo Armbands, thus also EMG data to IMU.

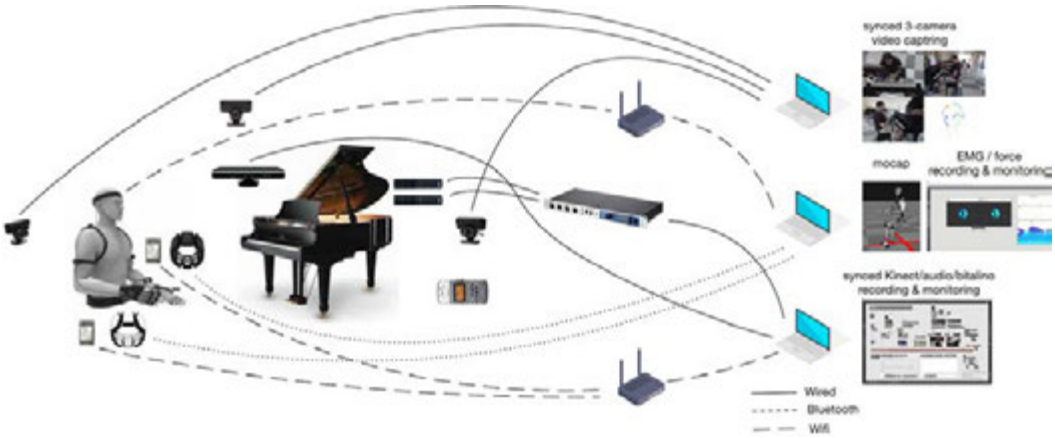

Figure 3: Hardware setup of pilot study

Several technical challenges were raised during these recordings, with a potential effect on the temporal and spatial resolution, data reliability and the reproducibility of the study.

Foremost, we were concerned with issues of synchronizing independent data streams of varying sampling rates for the time-critical analysis of combined multimodal information. As hardware solutions for synchronization (for either common time-stamping or forcing hardware devices to stay locked to a central clock or reference signal) are rarely at hand in music research, this mostly refers to two things:

- Successfully triggering common start- and end-marking points manually (by hand claps) to manually synchronize different data streams in post-processing. This means in practice producing clear signalling points that will allow to accurately trim individual data streams;

- Keeping the different data streams aligned over time. This means avoiding different data streams to progressively drift apart from each other over the duration of each recording, which is a problem that may arise by either unstable sampling rates or individual frames being dropped, and which commonly results in a mis-match of time lengths between recordings of different types of data.

Such issues arose during the recording process and led to the necessity of manual post-production work. These were mostly due to the unstable wireless PerceptionNeuron-pc communication as well as occasional frame drops of the three HD-video streams being recorded on a single computer. This led to tedious manual post-production work.

Despite advantages of ecological validity in using a IMU motion capture system which requires a less controlled environment than a passive optical marker-based motion capture system, magnetic interferences from the metal construction of the building and the piano led to occasional spatial drifts of joints and thus partially unreliable position data.

Another challenge we faced was related to the PN system's affordances and the constraints it imposed on the performer's finger movements, which were considered unacceptable for performing the work of *Evryali*. This led to coming up with original, less obtrusive (or at least destructive) solutions in using flexible gloves for attaching the sensors on the fingers (Figure 4).

As much as posing technical challenges, the use of an IMU system for recording motion data was opted against the alternative of an optical mocap system due to its flexibility, ease of setup, portability and lack of optical occlusion.

Figure 4: Flexible textile gloves for finger sensor placement

Finally, there were decisions to be made with respect to the calibration and normalization of EMG data based on minimum and maximum force values, which were addressed by an initial recording phase, whereby the musician was asked to perform a maximum tension (full muscle contraction) gesture versus a release (full relaxation) pose.

Videos and graphs displaying spatio-temporal relationships of multimodal data streams were plotted and were used in an explorative approach in the analysis, which is still in progress. Local spatio-temporal peaks and troughs of force-related data can be visually identified, as those in (Figure 5) for the hands in the first page of *Evryali*, and are cross-evaluated against the composer's complex graphical notation, in which effort-related information of action affordances are embedded in varying densities of arborescence branch sketches.

5. Beyond unnecessary challenge: motion following as basis for interactive notation learning in Xenakis' *Mists*

Beyond the documentation and visualization of the performative act in Xenakis' piano music, and beyond computational analysis, a central application has been technology-enhanced learning and performance optimization. This application resonates with the objectives outlined in the introduction: demystification of Xenakian performance practice and assistance of the learning process in the physical and mental domains. The system *GesTCom*[10] in its current state is conceived as a sensor-based environment for the visualization, analysis and following of pianist's gestures in relation to notation. It comprises four modules, implemented in the form of Max/MSP patches featuring the *MuBu*[11] toolbox and connected to *INScore* scripts[12]:

a) a module for the synchronized recording of multimodal data of a performance (refer to 4.1 of the current);

b) a module for the reproduction and analysis of the data (refer to 4.1 of the current);

10 https://medias.ircam.fr/x2253e1

11 https://forum.ircam.fr/projects/detail/mubu/

12 http://inscore.sourceforge.net/

c) a module for the processing of the notation on the basis of the data;

d) a module for real-time gestural interaction with the notation.

In the last module, we distinguish between a *recording phase* and a *following phase*: in the latter, the system follows variations of a gesture recorded in the former. This module is based on the notion of motion following (Bevilacqua et al. 2011, Bevilacqua et al. 2010), a probabilistic, one-shot Hidden Markov Model architecture that dynamically compares the two gestures, originally implemented in the Gesture Follower[13] (GF). This project's contribution to the original GF is that, through the notion of coarticulation / PADR envelopes, as described in section 4, an expansion of the range of gesture variability is attempted: not the performing gesture itself, but rather a reduced form of it (the PADR envelope) is recorded. The PADR envelope is also mapped on the processed notational representations of the third module, so that the system can follow extreme variations of the performance, both in terms of movement and in terms of notational representation. This notion of performance variability is connected to several hypotheses regarding top-down learning, multimodal feedback and prioritization processes in complex music.

13 http://ismm.ircam.fr/gesture-follower/

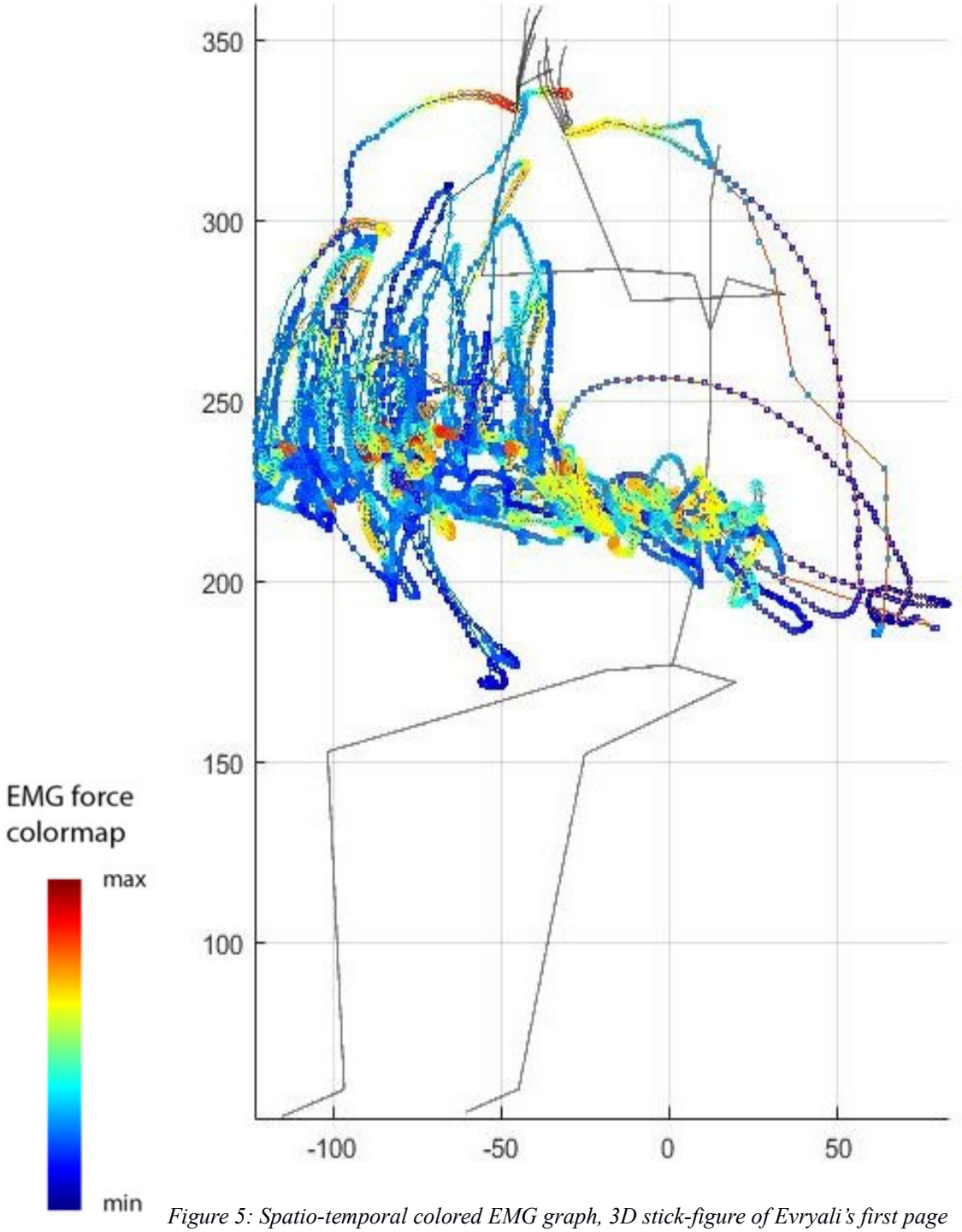

Figure 5: Spatio-temporal colored EMG graph, 3D stick-figure of Evryali's first page

In terms of the end user, the *GesTCom* features the following workflow: In the first step, the performer generates multimodal data through a recording of a performance of the original notation (module 1). In the second step, the quantitative and qualitative analysis of the data, in comparison to the qualitative analysis of the notation, results in a shared segmentation that we described as PADR envelope (module 2). On the basis of this segmentation, the original notation is processed and reshaped into a multilayered 'tablature' (module 3). Eventually, again by virtue of this common segmentation and machine learning techniques, the multilayered tablature can be trained to follow the performer in variations of the initial performance. The performer, that is, interactively controls the tablature through gesture and expressively navigates networks of notational parameters in real-time. Please note that the new output notation can be fed back into this loop, generating new performances, recordings and tablatures. Thus, the following interaction schema emerges:

Figure 6: the GesTCom interaction schema

The further development of the *GesTCom* system seeks to integrate developments from co-adaptive systems employing active learning and reinforcement learning. Co-adaptation[14] indicates that the system and the user adapt to each other during learning. In that sense, the *GesTCom* would adapt to user-specific learning pathways and would provide feedback, which would in itself facilitate both the acquisition of motor skills and the deciphering of notation. Interactive reinforcement learning indicates techniques of user feedback to the machine, which improve the process of the co-adaptation. Active learning equally involves the users by querying them to label specific examples picked by the system. The end goal is a system of mutual reinforcement learning between humans and machines. Such a system would optimize the piano performer's learning experience through longitudinal multimodal performance documentation, real-time activity monitoring with augmented multimodal feedback and guidance, and real-time adaptation of the complexity of the music notation, according to the user's developing skills.

14 For more on the notion of co-adaptation for extreme users in extreme situations, please refer to the work conducted at the Inria (National Institute for Research in Digital Science and Technology) research lab https://ex-situ.lri.fr/ directed by Wendy Mackay.

Let's now take a closer look at this module in use for Xenakis' *Mists*, as demonstrated in the following video[15]:

It consists of one INScore representation, connected interactively to the motionfollower Max/MSP patch through another Max/MSP patch (indicated in purple as 'INScore', 'motionfollower', 'connector', Figure 7).

An INScore script generates this augmented interactive score, which consists of the following graphic objects: the reduced proportional score representation of the first page of *Mists,* a cursor and a signal, as shown in the Figure above. The reduced proportional notation has been generated automatically by the MIDI data, using command-line tools based on the GUIDO Engine[16] and developed by Dominique Fober. The cursor in red and the signal in blue are controlled through the inertial sensors in the wrists of the pianist. The signal in blue comes from the motionfollower.

The score's interactive possibilities are based on the motionfollower, an object in Max / MSP and a customized patch shown in the next Figure 8.

15 https://youtu.be/Rql732JUm5M

16 http://guidolib.sourceforge.net/doc/guidolib/

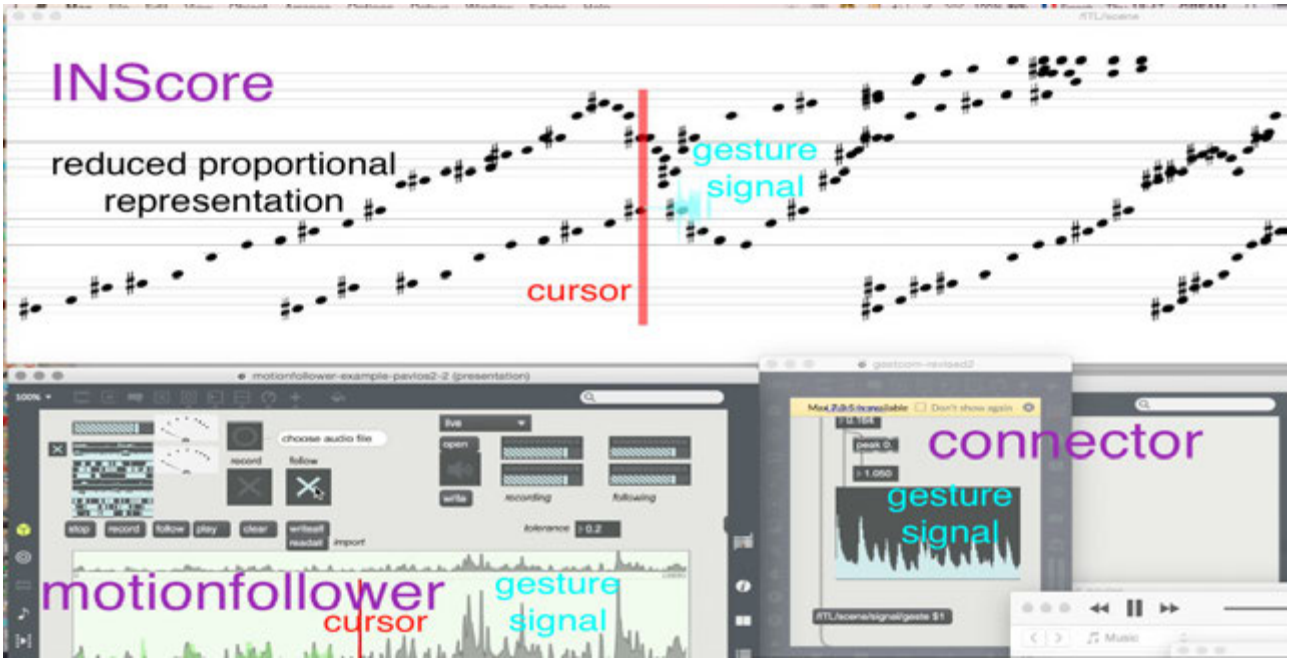

Figure 7: Augmented interactive score controlled through sensors and connected to the motionfollower through a connector Max/MSP patch for Iannis Xenakis' Mists

In the first phase, a gesture is recorded (as in the video, 00:00 – 00:25). This gesture is represented by the grey signal in Figure 8. This signal is the sum of the twelve signals we saw before in the recording patch (Figure 1), plus audio energy. In a second phase (00:25 – 01:24), this gesture is compared probabilistically to a new, incoming gesture, represented by the green signal in Figure 8, which is superimposed over the grey signal. The system essentially predicts the probability of the new gesture being similar enough to the recorded gesture. If this is the case, the system "follows" the player, and this "following" is indicated by the smooth movement of the cursor. If not, the cursor is moving with a certain viscosity, gets stuck, jumps abruptly forward or is waiting for the performer and so on. On top of the visual feedback, the motionfollower may offer sonic feedback, as the initial recording is of both movement and sound.

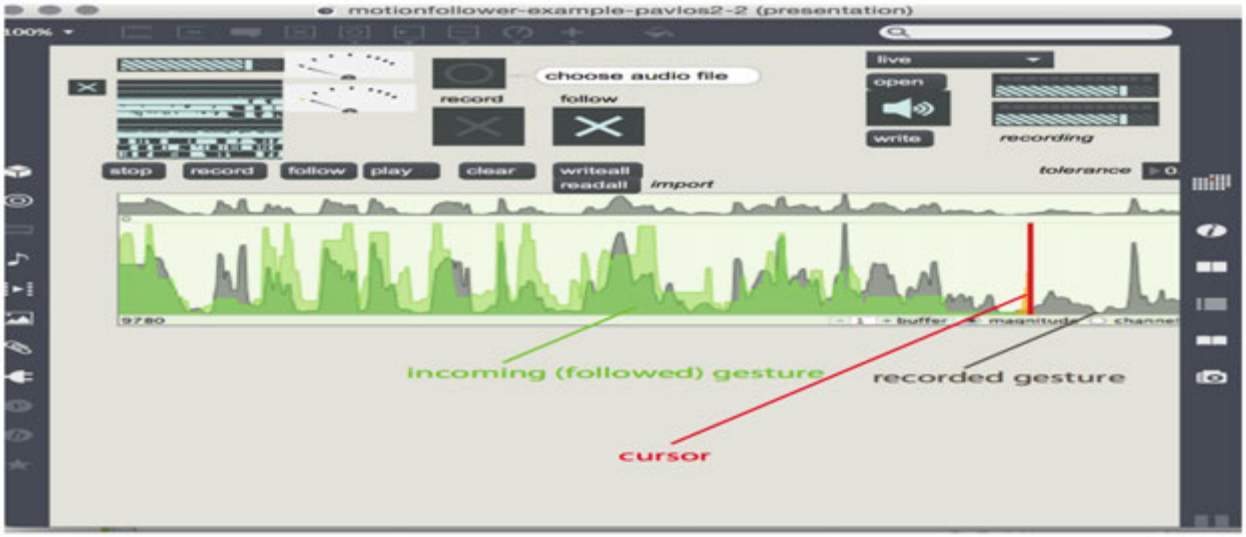

Figure 8: Max/MSP patch for motion following

The third component is a Max/MSP patch, which functions as a connector, sending the incoming new signal of the motionfollower, to the INScore tablature in the form of Open Sound Control[17] messages.

The crucial element, which allows for the motion-following to be reflected in the notation and thus become score-following, is that both the gesture and the notation are sharing the same basic segmentation.

In the recording phase (00:00 - 00:25), the user follows any mobile element of the INScore, in our case the red cursor, which is set to move at a desired speed, like a classic metronome would do. The musical score has already been graphically segmented and assigned a duration according to a specific INScore space-time formalism (explicit mapping). In this recording phase, the motionfollower learns, so to speak, the mapping from the performer (implicit mapping), who follows the mapping of the INScore (explicit mapping). In the 'following' phase, the performer can pursue highly varied performances: a faster performance (00:25 – 00:45 in video), a faster performance with softer dynamics (00:45 – 01:02), a performance with different (staccato) articulation and even mistaken notes (01:03 – 01:24). This time, it is not the performer that follows the system, but rather the system that follows the performer, given that the segmentation is correct and common in all these varied performances. Thus, the performer may control the mobile elements of the INScore tablature. The feedback of the follower has been extended to score compound representations. The gesture-following has been turned into score-following.

17 http://opensoundcontrol.org/introduction-osc

6. Augmenting Xenakis' performance

We entered in 2020 to a fourth phase of exploration crossing multimodal recordings and interactivity. To do so, we choose to work on *Evryali* (1973) by Xenakis for solo piano. The score composed of tree structures sketched on graph paper is considered as "extreme" since it contains multiple arborescences which are a tangle of lines in pitch-time space like a bush or a tree, undergoing rotations, expansions, deformations, etc. The piece raises several challenges for the performer and the audience to handle its complexity:

- The score made of complex and detailed graphics creates an innovative polyphony which evokes the elusive infinity of the sea or the uncontrollable energy of the waves. We proposed to decompose it as a palimpsest presenting different layers of information on a screen: from the original scores, to manual and graphic annotations, to the display of augmented information about the performer's movement and body engagement in a 3D interactive virtual environment;

- To visualize the energy and body engagement of the pianist required to perform *Evryali*, we opt for embodied data visualization in real-time of the pianist movement, focusing on the kinematics of the two hands and the head such as speed/acceleration/jerk visualized in 3D;

- The challenge of visualizing the body from different perspectives was explored by developing an avatar which allows switching interactively and continuously between first-person and third-person point of views. This control is done by a visual artist present on stage;

- In order to engage the audience[18], we proposed to integrate the data in an augmented reality spectacle with the goal to immerse spectators. On top of this, we offered the possibility to one spectator to come on stage and co-perform with the visual artist.

Regarding technical aspects, Xenakis' sketches were reworked and separated according to the different parts of the piece and are displayed in the main projection on stage.

In order to capture the pianist's performance, we used the Perception Neuron[19] motion capture system made of 32 inertial sensors. The gestures are recorded and reproduced in real-time in the form of digital data that can be viewed on an abstract digital twin (avatar) of the performer. Data was streamed from the Axis Neuron software to Unity 3D, a real-time and cross-platform 3D engine where we developed the gesture analysis and visualization tools described in (Jégo et al. 2019).

The scenography, inspired by the polytopes of Xenakis which are immersive events, is composed of 4 video projections on the stage, the ceiling and the public were designed to create a volume of sensory habitation, reflecting the concept of 'dwelling' as in (Ingold 2000). A large projection at the back of the stage displays the avatar of the pianist in real-time, which allows switching from egocentric to allocentric points of view and viewing the acceleration and velocity vectors of the two hands.

We developed modular interfaces to control the various visual effects, and some of them are participative, allowing a spectator to come on stage and manipulate the controls on 2 touch screens.

The visual effects of the pianist movements intend to dilate the micro-movements of the body,

18 Antoniadis, Pavlos, Duval Aurelien, Jégo, Jean-François, Solomos Makis. "Augmented reality for Iannis Xenakis Evryali for piano solo". Online video of a performance and a debate. https://www.youtube.com/watch?v=iOrbrHbkqZc

19 https://neuronmocap.com/?gclid=Cj0KCQjwz7uRBhDRARIsAFqjull6Cext3xeCfXBhiByYwBk0nCf6gq6UvSCTFNa61NLpXXr2atWMCu0aAnxOEALw_wcB

usually invisible to the naked eye, in particular of the hands. In this way, the spectators attend a version of the performance augmented by kinesthetic elements which contribute to making the experience of the concert multisensory or, in a prospective way, transmodal.

Since our artistic goal is to immerse spectators and to reveal elements that are usually invisible, we choose to explicitly show the technological artifice as part of the interpretation: the equipping phase of the motion capture suit, usually hidden, is orchestrated like a ritual. The technological devices and setup are not set back either, but on the side of the stage, highlighting the different actors of the performance, whether the visual artist or the spectator invited to interact.

This augmented performance invites the audience to inhabit a hybrid environment blurring the boundaries between the stage and the public, the performer and his digital avatar, the visual artist and the performer, and the physical and symbolic spaces. This immersive space, echoing the volume of the wide sea, tends here to offer a new form of access to the learned elements of Xenakis, which are multiple, complex and sensitive at the same time.

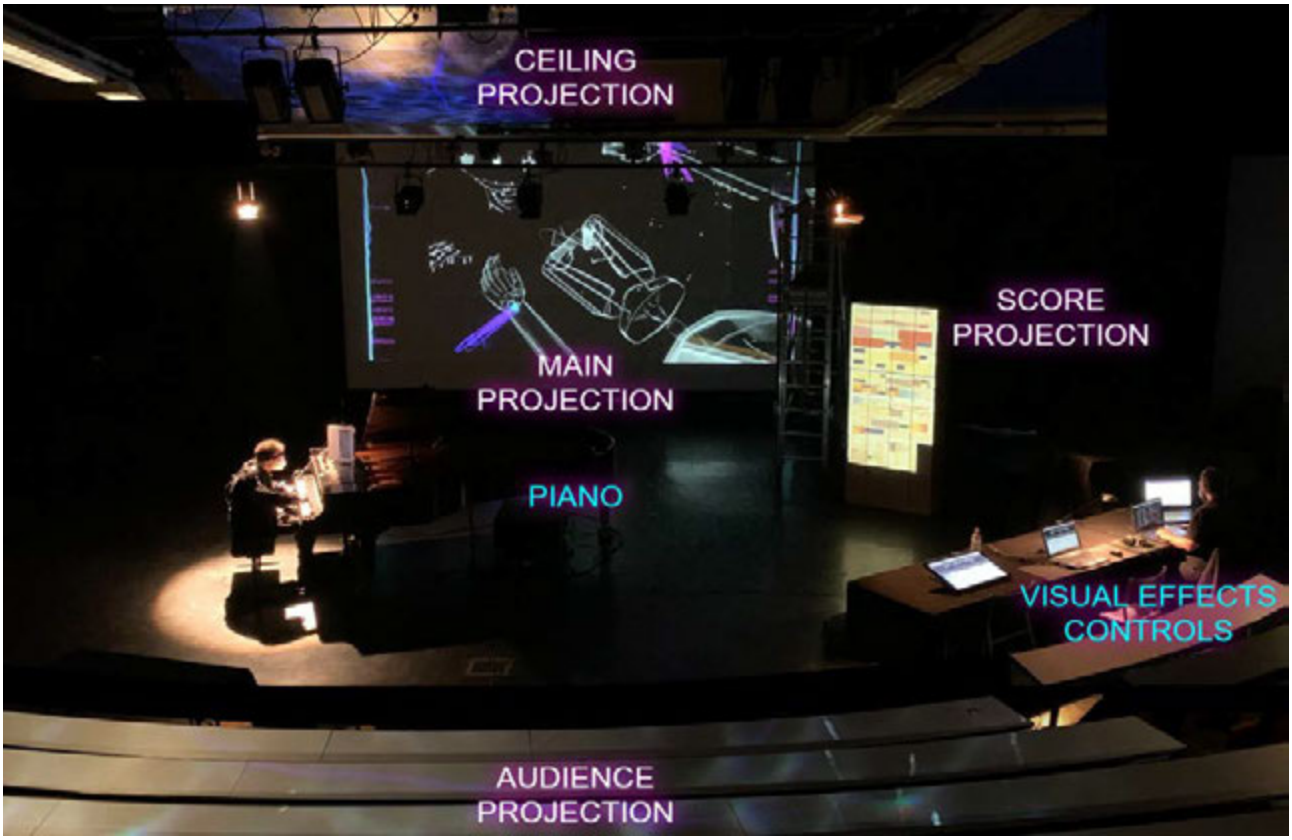

Figure 9: Scenography of the Evryali performance presenting the pianist wearing a motion capture suit, the controls and the video projections

7. Conclusion and Discussion

We have tried to approach what we identified as the ‘mind-body problem’ in Xenakis’ piano performance as a problem of rendering human experience into multimodal data through concepts and tools that have been developed over a period of eight years in the context of different projects. The various technological breakthroughs presented above and stemming in the domain of Human-Computer Interaction are coupled with conceptual breakthroughs in the domains of performance practice, systematic and computational musicology and embodied cognition. These advances aim at demystifying Xenakian performance practice, while simultaneously enhancing, facilitating and

communicating the learning process without compromising the transcendental expressive qualities in concert.

The notion of body rendition into data for research purposes opens up a domain of urgent ethical questions. 'Your body is reimagined as a behaving object to be tracked and calculated for indexing and search' (Zuboff 2019, p. 231), even if the end purposes described above might as of yet be far from the usual utilitarianism of manufacturing and sales through behaviour prediction and modification of consumers:

"Rendition describes the concrete operational practices through which dispossession is accomplished, as human experience is claimed as raw material for datafication and all that follows, from manufacturing to sales." (ibid., p.223)

Is it that far, though? Could we imagine a form of economy, where practicing Xenakis through 'smart' equipment could be the key to producing crypto-currencies or where the biometric data of musicians would be traded in online markets (such as NFT collectibles) producing profits for third parties? Even though such speculation might seem premature, it might be key to designing ethical practices for harvesting musicians' data in the very near future.

The second issue addressed in the introduction was of a different epistemological order: Is it possible that the elements that escape computation are the vital ones in addressing human performance, and in particular the performance of Xenakis' music? What are the limits of digital materialism and is there a danger of missing the particular Xenakian transcendental expression by trying to contain the challenges? A provisional response is that by containing unnecessary effort and challenge, one can channel the performing and expressive energy more efficiently, pushing the envelope of transcendental expression even further. In any case, the only way to address these issues is by taking this line of research to its potential end.

Acknowledgments

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From stereophonic to spatial audio processing: Voyage absolu des Unari vers Andromède by Iannis Xenakis.

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Reproducing the creation circumstances of a musical piece is impossible even for electroacoustic works. The acoustic of the concert hall, loudspeaker setup, technology of diffusion and historical circumstances have changed from the concert's creation. When you need to transpose an electroacoustic work from a loudspeaker setup to another you have to answer a lot of questions and every choice you make assumes attentive sound experimentations. In a context of a collaboration between the Cité des Sciences et de l'Industrie and the CICM team of the Musidanse Laboratory (Paris 8 University), the UPIC works of Iannis Xenakis *Voyage absolu des Unari vers Andromède* will be performed at the Planetarium in march 2022. Composed in 1989 for an international exhibition of kites in Osaka, Temple Kamejama Hontokuji, *Voyage absolu des Unari vers Andromède* is a stereophonic piece. How can we take the opportunity of the diffusion setup of the Planetarium to spatialize this piece ? In the case of UPIC works it could be interesting to make spectrum adaptation too because of the sound result (commonly qualified of « tough ») due to the UPIC generators. Those questions will be handled with experimentations and analysis to propose a spatialization which will go beyond the stereophonic version while respecting the original work. This exploration will give rise to a durable algorithm for the diffusion which could be suitable for several technical specifications and diffusion setups with a particular ergonomic care. In this workshop we will travel from the beginning of the exploration process that we made to give rise to the spatialization proposition. We will start from the raw material - stereophonic files - to go to the spatialization experiments and spectrum always by associating manipulation and listening. After an introduction to the issue we will open the doors of our laboratory to show the process and comment our choices in hands-on. Neither knowledge in computer music nor in digital audio are required to participate to the workshop. The target audience are sound engineers, computer music designers, musicologists and music lovers who want to have an initiation to current issues linked to electroacoustic works and music technology. The duration of the workshop is approximately thirty minutes.

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Towards a Morphogenesis: Light in Xenakis's Work

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Abstract

This research examines light in Xenakis's *oeuvre*. The article presents a survey and analysis of Xenakis's use of both natural and artificial light. It allows us to grasp Xenakis's broad range of design strategies. Morphogenesis models were used as the analytical tool to offer a new perspective on light transformation and composition. A form-time scale framework was introduced to develop a deep understanding of Xenakis's composition of space via light form transformations.

1. Introduction

Light, in Xenakis's *oeuvre*, is a material that creates space, generates patterns, changes colours, evolves forms, and composes movement. Light connects his two vocations: architecture and music. For him, *real* architecture is a combination of space and light proportions (Xenakis, 1992), and "everything in light is close to music" (Xenakis, 2008).

From the shape of the Algerian olive oil container for the "light cannons" at *La Tourette* (1954-59) to the "anemone" laser configuration in *Diatope* (1978), Xenakis implemented morphological approaches in light compositions. Unlike static shapes, the light grows, transforms, and evolves. In biology, an organism's shape transformation, development, and growth process are called *morphogenesis*. This paper utilises morphogenesis models as the analytical tool to offer novel perspectives on the light transformation and growth in Xenakis's compositions.

In this research, I examine Xenakis's light from two categories: *natural light* and *artificial light.* Direct and indirect light from the natural environment are forms of natural light. The interior light of the *Convent of La Tourette* ("light cannons", "machine guns", and "undulating glass panes"), and the "path of light" of *Villa Mâche* (1966-77) belong to this first category. The artificial light category includes artificially generated light sources, such as lasers, electronic flashes, bonfires, torches, and searchlights. I focused on the "streetlight" at the *Unité d'Habitation Marseille*, as well as Xenakis's *Polytopes*, specifically the *Polytope de Montréal* (1967), the *Polytope de Cluny* (1972-74), the *Diatope* (1978), and the *Polytope de Mycènes* (1978).

In this paper, I used two digital morphogenesis models to analyse the light forms: *tip growth* and *stochastic form growth*. As an emerging computational design method, digital morphogenesis has great potential to investigate these light-based projects thanks to their close relationship with morphology theories, mathematical models, and digital techniques.

Furthermore, I introduce a form-time scale framework to develop an understanding of Xenakis's light compositions. Xenakis's light works have significantly influenced the media arts field. This article surveys a broad range of light design strategies employed by Xenakis spanning more than two decades of his career. Based on the form growth analysis of Xenakis's light works, computational morphogenesis suggests a new system to investigate the design process and to develop future

multimedia arts.

2. Xenakis's natural light projects

Sunlight, the source of energy for life on earth, travels 8 minutes and 20 seconds from 150 million kilometres away to the earth (Cian, 2013). Xenakis developed a series of approaches to design daylight in architectural space that uses direct light, indirect light, and a combination of both. In the natural light category, we analyse projects at two different geolocations. The first one is Xenakis and Le Corbusier's collaborative project, *Convent of La Tourette*, near Lyon, France. At this location, the day length is 15.75 hours in summer and 8.6 hours in winter. The second project is *Villa Mâche* located on the island of Amorgos, Greece, with a day length of 14.65 hours in summer and 9.5 hours in winter.

I focus on five specific light designs: the "light cannons", the "machine guns", the "undulating glass panes", the "path of light" at *La Tourette*, and the "path of light" at the *Villa Mâche*. Xenakis' design approaches can be grouped into three strategies: *protrusion*, *perforation*, and *screen*. In these light projects, he made significant contributions to daylight design using both direct and indirect sources.

2.1. Protrusions from an architecture's skin

La Tourette's church features two essential light components, "light cannons" (Figure 1) and "machine guns" (Figure 2). These elements protrude from the ceiling to the exterior architecture's skin, just like living organisms. One morphogenesis model that describes these forms is *tip growth*. In other words, living cells evolve into an elongated cylindrical cell morphology with rounded tips. In biology, *tip growth* refers to cells deformed using their membrane and its wall by adding new proteins and their extension (Pelce, 2000). The morphology of coral is an excellent example of *tip growth*. The three "light cannons" grow inconsistently in different dimensions, heights, and directions, whereas the "machine guns" grow steadily in relatively the same size, height, and direction.

The "light cannons", located at the north lower chapel of the church, use indirect light to create a space of contemplation. The north chapel is a grand-piano-shaped crypt apse. Its floor surface is approximately 180 sq metres, and an average ceiling height of 4 metres. This cave-like space is surrounded by an undulating concrete wall that inclines inwards. A partition wall (approx. 2 metres high) visually divides the spaces between the lower chapel and the church nave. Light and sound connect the two spaces.

Xenakis borrowed the shape of Algerian olive oil tins for the "light cannons" form (Xenakis, 2008). The internal surfaces of the "light cannons" are irregularly curved concrete walls painted in white, red, and black, respectively (Figure 3). The light contours from the ceiling are three organic circle shapes varying in sizes, with white as the largest circle, red at the middle, and black as the smallest one. Starting from the interior ceiling, the "light cannons" tip grows towards the sky, like fungi, in different directions. The white "light cannon" on the east protrudes from the ceiling and grows towards the northeast. The red "light cannon" in the middle extrudes to the north. And the black one on the west points its tip to the northwest.

Natural light washes the internal surface of the "light cannons" to provide indirect skylight to the crypt and lateral lights of the church (Figure 4). The 14-metre-high church adjacent to the lower chapel's south blocks direct sunlight to the "light cannons". The only direct light that comes into the lower chapel is the morning light from the east during midsummer (Walker, 2016). With the variety of colour, proportion, protrusion direction, and skylight-facing orientation, the white "light cannon" has the brightest luminosity, and the black "light cannon" has the lowest fluorescence.

Unlike the inconsistent *tip growth* of "light cannons", Xenakis designed seven unified polygons and protruded them from the sacristy's ceiling towards the south (Figure 2 and 5). The seven quadrilateral shapes of "machine guns" extrude in two rows. There are four "machine guns" in the

front and three in the back. It is worth noting that this arrangement also suggests a natural morphology–the alternate leaf pattern. In addition, similar to the pointed quartz crystal, the "machine guns" have sharp angles, which point to the courtyard of the Monastery. Xenakis oriented these irregular concrete prisms and carefully tilted the top glazing panel. With careful calculation and sun path study, the "machine guns" invite direct sunlight into the church nave during the two yearly equinoxes (Xenakis, 2008).

Xenakis used a protrusion approach on an architecture skin to design daylighting in his collaboration with Le Corbusier. This approach is an excellent example of a poetic relationship between morphology (curved surface, geometry, proportion, arrangement, etc.) and natural light. The "light cannons" and "machine guns" suggest a morphogenesis model of *tip growth* as an approach to develop irregular-shaped lighting devices to create a poetic daylight effect for a space of ritual.

Figure 1: A view from north-east of the three "light cannons" protruding from the roof of the piano-shaped lower chapel at La Tourette. The wall of the chapel is an undulating concrete surface that inclines inwards toward the interior space. The church blocks most direct light from the south. (Photo by author in May 2016).

Figure 2: A view from south-east of the seven"machine guns" protruding from the roof of the sacristy. Four in the front row, and three behind. (Photo by author in May 2016).

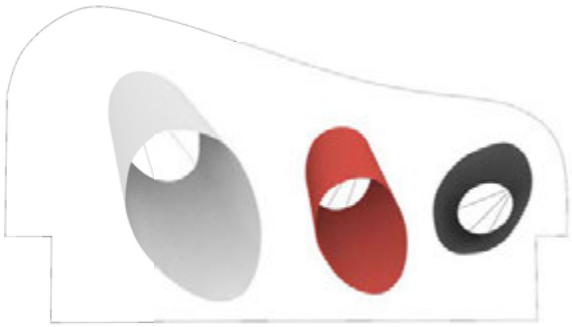


Figure 3: A view from the bottom of the "light cannons" with the ceiling contour. The white "light cannon" on the east grows towards the northeast. The red "light cannon" in the middle extrudes to the north. And the black one on the west points its tip to the northwest. (Digital reconstruction by author in March 2022).

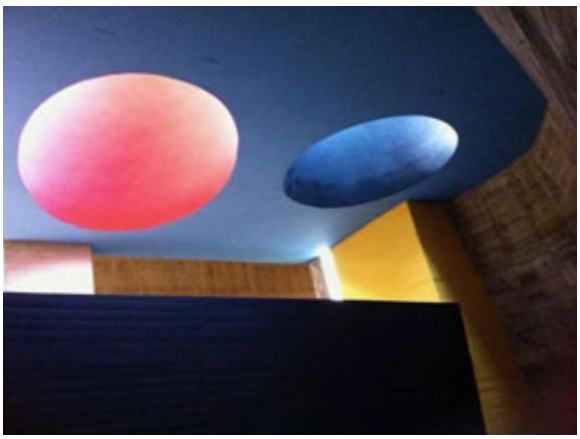


Figure 4: A View from the bottom of the red and black "light cannons" with the partition wall underneath (photo credit:51 la tourette CFX © Famille I Xenakis DR).

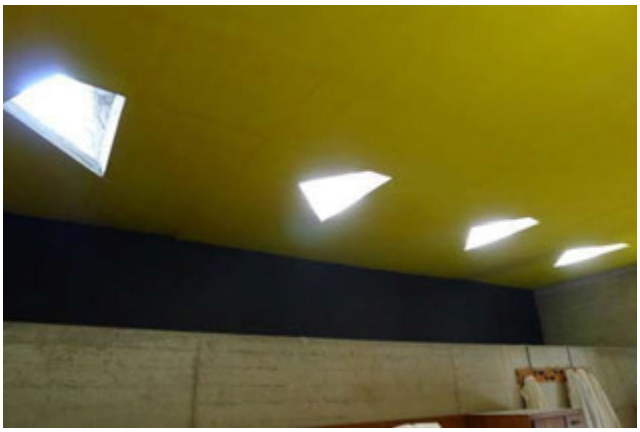


Figure 5: A View from the bottom of four polygon shapes from the "machine guns" (photo credit: 30 la tourette CFX © Famille I Xenakis DR).

22.Perforations on an architecture's skin

Musical "neumes" and their light paths, a recurrent leitmotif, has become one of Xenakis's signatures in his architectural projects (Kanach, 2008). Every light path that Xenakis designed is specifically created for a unique site. The light path *perforates* the architecture's skin by replacing a solid wall with glazed panes. For example, we can find such implementations on the rooftop stairwell bulkhead (Figure 6) at *La Tourette* and on the façade of *Villa Mâche*. The light pattern grows stochastically from a relative centre point to a neighbouring position. One model describing such a type of stochastic growth is a *random walk*. In mathematics, a *random walk* is a stochastic process that starts from a centre point of a lattice and grows on paths based on probability. In nature, crystallisation is an

example of such a stochastic growth form.

Although it seems to grow randomly, the realisation of the light path processes functional, meaningful, and aesthetic goals. The light path at *La Tourette* is the first project where Xenakis applied the perforation approach to a lighting design. If we place the floor plan of the complex next to the "path of light" of the rooftop stairwell bulkhead, one can easily see the visual connection between the circulation plan (Figure 6) with the geometry perforated on the wall. The highlighted area represents the walking paths of corridors, the lower church, the sacristy, and the atrium. To be more specific, these are the locations of Xenakis's lighting design: "light cannons", "machine guns", and "undulating glass panes". In other words, Xenakis abstracts his "path of light" to develop a *random walk* that starts from the atrium. It is a symbolic manner for the convent. The walking path of everyday life at the convent is closer to the sky than ever.

Facing the southwest, daylight at *La Tourette* ends at the "path of light" on the rooftop every day. A perfect location to bid farewell to the daily natural light cycle at the convent. Direct and indirect light comes through the narrowed cuts of the wall into the staircase. Unlike other lights that create space, the slim light beam divides this space. The chiaroscuros and proportion between light and space is an essential design element in Xenakis's architecture projects.

The light paths at the *Villa Mâche* are a combination of random growth paths and stochastic distribution of windows (Figure 7). The distribution of such "neume" windows first appeared in the *Unité d'Habitation de Nantes-Rezé* (1950-54), a project also realised in Le Corbusier's studio. Xenakis designed the façade of the roof kindergarten using stochastics. At the *Villa Mâche*, we can find the continuous light paths and the detached windows intertwined together, based on probability theory.

Wall openings are a bridge to nature. Xenakis used the openings to frame the natural landscape from the interior view; meanwhile, the natural light also arranges the interior space by generating visual contrast. The perforations on the façade of the *Villa Mâche* are mainly facing north. In addition, a perforation was also applied to the ceiling in the living room. The narrow cut on the ceiling creates a laser-like light beam that splits the space into two. Although indirect light is the main source, the white surface on the wall and the bright skylight create a strong illuminated spatial composition for the interior space.

The realisation of the *Villa Mâche's* façade not only frames the landscape views, but also presents a meaningful abstraction: the composer François-Bernard Mâche's initial. We can identify various abstractions of the letter "F" on the façade. For example, the square window and the light path in the living room compose the letter "F" (Figure 8). Xenakis stochastically grew the light form to achieve a new aesthetic of lighting.

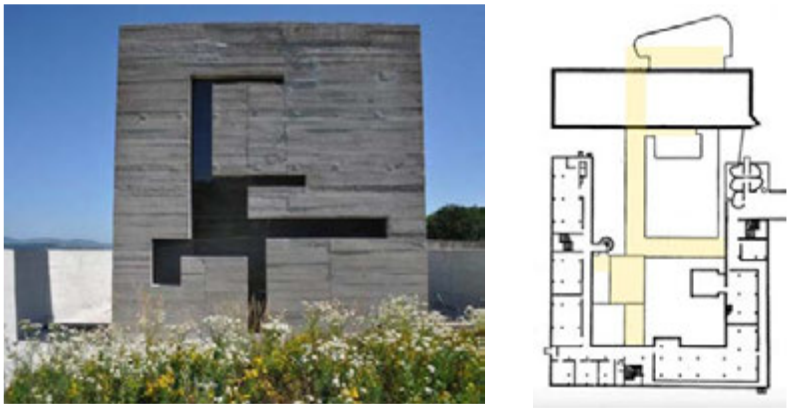


Figure 6: Left image: The "path of light" on the rooftop stairwell bulkhead on the terrace (Escalier toit-terrasse, vue générale © Famille I Xenakis DR). Right image: Light path abstract diagram on the floor plan of La Tourette (Plan from wikiarquitectura, diagram by author).

Figure 7: Interior view of Villa Mâche (10 Diapo Maison Mâche © Famille I Xenakis DR)

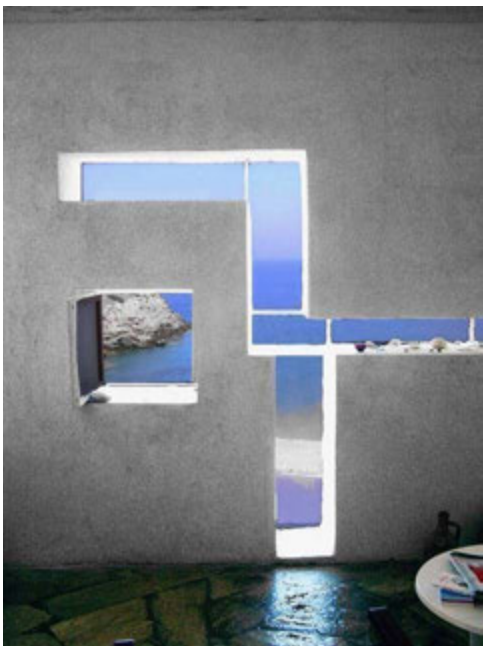


Figure 8: Interior view of Villa Mâche (7 Diapo Maison Mâche © Famille I Xenakis DR)

2.3. Screen: light acting as an architecture's skin

The last approach that Xenakis used in natural light projects is the *screen*, known as "undulating glass panes". The natural light of "undulating glass panes" is not merely a light source. Light becomes part of the architectural body; for him, light is architecture. The first light that comes into interior space is the tip of the growth form. Based on the *tip growth* model, the relationship between the density of the light and the density of the concrete frame is inversely proportional. In other words, when the light's protrusion is high, the density of the concrete frames will be low.

Furthermore, the density and continuity in the "undulating glass panes" became Xenakis's musical expression in architecture. "Undulating glass panes", first applied on the façade of the Secretariat in Chandigarh, is a modern architectural innovation by Iannis Xenakis and Le Corbusier. It appears in many of Le Corbusier's projects, as well as Xenakis's independent architectural works (Kanach 2008). Perhaps, the most famous one is located on the west façade at the *Convent of La Tourette* due to its scale, proportion, and musical movement. The top two levels on the façade (Figure 9) are *Modulor* living cells, and the lower levels are musical glass panes. This façade embodies two architectural ideas: Le Corbusier's *Machines for Living In*, and Xenakis's music in architecture.

Facing the northwest, the natural light illuminates the interior space. Selective direct and indirect light grows into the interior space through the glazing. At about 3.66 metres floor-to-ceiling height, light and shade perform a musical gesture inside. While walking at a constant speed, one can perceive dramatic light movements thanks to the continuous change of the concrete frames' density. The rhythmic experience is a continuity of light transformation. A new lighting aesthetic has emerged through Xenakis's music composition, intellectual contemplation, and mathematical abstraction.

Figure 9: A view of the west façade. Two levels of modulor house unite on the (Photo by author in May 2016).

2.4. Analysis of natural light forms and time

Time and duration are important criteria for light composition. On the other hand, growth rate is an important parameter in morphogenesis analysis and design. If we have the duration and the form, we can extrapolate an estimated growing model. Table 1 shows a summary of five natural light projects. The time scale is based on hours. For example, the daylight event of the "light cannons" happens once every day; the direct light event of the "machine gun" happens once every six months. For the lights' surfaces, three design strategies have different calculation methods. In the protrusion group, the light surface is the area that reflects and diffuses natural light. For example, the light surface area for the "light cannons" is the sum area of the three cones. For the perforation group, the light surface is the wall opening area. Lastly, for the screen type, the light surface area is the whole screen size. In section 3.3, we will discuss the analysis of forms and time scales.

Natural Light Project	Location	Morphogenesis Model	Light Type	Light Surface Area (≈ sq metre)	Light Event Time and duration

 Light Cannons (1954-1959)	Couvent de La Tourette (Lower Chapel)	Tip growth	Indirect light	12	Every 24 hours. Daylight = 15.75 hours in summer, and 8.6 hours in winter.
 Machine guns (1954-1959)	Couvent de La Tourette (Sacristy)	Tip growth	Direct and indirect light	3.5	Every 24 hours. Daylight = 15.75 hours in summer, and 8.6 hours in winter. Direct light every 6 months.
 Path of light (1954-1959)	Couvent de La Tourette (roof stairwell bulkhead)	Stochastic growth	Direct and indirect light	1.5	Every 24 hours. Daylight = 15.75 hours in summer, and 8.6 hours in winter.
 Path of light (1966 – 1977)	Villa Mâche	Stochastic growth	Direct and indirect light	2	Every 24 hours. Daylight = 14.65 hours in summer and 9.5 hours in winter.
 Undulating glass panes (1954-1959)	Couvent de La Tourette (hallways, meeting rooms, refectory, library, etc.)	Tip growth	Direct and indirect light	140	Every 24 hours. Daylight = 15.75 hours in summer, and 8.6 hours in winter.

Table 1: Light form and time scales in Xenakis' natural light projects

3. Xenakis's artificial light projects

After working with natural light, Xenakis came to see the light – in general – as an architectural gesture. He began to envisio light as a material in his compositions in additio to time ad duration. As he noticed, "man has access to events made of real light thanks to–for the time being–lasers, electronic flashes, light projectors ad c omputers" (Xenakis, 9 .

Under the artificially light category, I will focus on five projects: the snail-shaped light fixture in the *Unité d'Habitation Marseille* (1951-52), the *Polytope de Montréal*, the *Polytope de Cluny*, the *Diatope*, and the *Polytope de Mycènes*. These projects can be classified as *static* and *dynamic* types.

The static type is a light form that does not change over time. In contrast, the dynamic type is a light form that evolves and changes over time. The *Polotypes* belong to the dynamic type. Through artificial light, Xenakis achieved a landmark in light art and paved the road for a new type of art: multimedia.

3. The static light form of snail lamp

In his first[1] artificial light project, Xenakis used fluorescent tubes as a basic light source. The snail-shaped lamp (Figure 10) is an organic form lighting fixture for the corridors of the *Unité d'Habitation Marseille*. Designed by Le Corbusier and Xenakis in 1951-52, the lamp can be rotated in several directions. The hidden fluorescent tubes wash the curved sheet-metal surface to achieve an indirect lighting effect. The bent reflecting surface is approximately 0.35 sq metre (0.7m in length and 0.5m in width). The shape is closer to a golden spiral; as the name suggests, it resembles a seashell of a snail. The light glows from the inside to the outside, following a Fibonacci sequence. Once the lamp is turned on during the night, it provides a curvature shape of light. As Sharon Kanach observed, "This organic shaped independent structure creates an interesting contrast with the pronouncedly angular aspect of the main building" (Kanach, 2016).

Figure 10: Large snail-shaped lighting fixture (1951-52) along the corridors of the Unité d'Habitation Marseille (photo by author in May 2016)

3.2. The growing forms of the Polytopes' light

After the success of "musical glass panes", Xenakis had new thoughts on approaching light: speed and form. In his *Polytopes*, Xenakis used a variety of artificial lights, such as electronic flashes in Montréal, lasers in Cluny, and bonfire and searchlights in Mycenae, among others. Although the sites and scales were varied, there was a unified strategy in his *Polytopes*: using lights to compose movement and evolve forms. In Sharon Kanach's words, a "musicalization of space".

Both in indoor and outdoor settings, his *Polytopes* inhabit a relatively dark environment, which gives Xenakis an "empty" universe in which to create light. Like the chapel at *La Tourette*, without light, there is nothing. To enact his ideas of light form, Xenakis used lattice structures, such as steel

[1] This paper considers the snail lamp as the first project in the artificial light category. As a side note, Xenakis once directed a tragedy based on lighting, and lighting changes in his 20s.

cables or grid systems, on to which the artificial light sources were attached. For example, he designed five curved surfaces that intersected using 200 steel cables at the central void of the France Pavilion in Montréal (Figure 11). These cables create hyperbolic geometries for the dynamic and colourful light surfaces during the performance. In Cluny, since it is forbidden to touch the venue's historical walls, Xenakis used a metallic grid to construct a scaffolding structure next to the vaults and walls (Figure 12). Lasers, mirrors, and speakers are positioned at the desired spots; meanwhile, the participants still have a spatial sensation of the original ancient Roman bath. In his *Diatope*, the interior surface of the vinyl PVC fabric was coated in grey to create a dark space for the light performance (Kanach, 2008, Kiourtsoglou, 2018). The most spectacular *Polytope*'s site was Mycenae which took the audience back some 6000 years. After sunset, the ancient land of civilization became the composer's canvas. If the other Polytopes lights were grown upon a metallic network, the light of the *Polytope de Mycènes* was grown based on the history of human society. We thus become witness of the evolution of civilization through light.

Figure 11: Photo of the Polytope de Montréal (Collection of Françoise Xenakis). Music and Architecture, Iannis Xenakis and Sharon Kanach, Hillsdale N.Y: Pendragon Press, 2008. Page 206.

Figure 12: Light flashes on metallic grids for Polytope de Cluny in situ (Collection of Françoise Xenakis). Music and Architecture, Iannis Xenakis and Sharon Kanach, Hillsdale N.Y: Pendragon Press, 2008. Page 227.

Figure 13: An interior view of the Diatope. Rastoin, Bruno (1954-2020). Photographer, "[Diatope 1978-79, Paris, photo couleur : vue de l'intérieur à hauteur du spectateur, lasers 5]," Centre Iannis Xenakis, accessed March 22, 2022, http://www.centre-iannis-xenakis.org/items/show/4006.

Figure 14: Polytope de Mycènes (Collection of Françoise Xenakis). Music and Architecture, Iannis Xenakis and Sharon Kanach, Hillsdale N.Y: Pendragon Press, 2008. Page 234.

3.3. Analysis of artificial light forms and time

With digital technologies, such as lasers, flashes, and computers, light becomes a material that creates space, generates patterns, changes colours, evolves forms, and composes movement. More importantly, light can change its speed and design on a smaller scale. For example, the frequency of the fluorescent tube in the snail lamp is 100-120 Hz. Our human eye can barely perceive this frequency range. Once the light is on, the static shape is formed The illumination of the sensitive range for human vision is 10-30 Hz. In the *Polytopes*, the flashlights' frequency falls in this range. Table 2 summarised four *Polytope* projects' artificial light sources and light event durations. In these four projects, Xenakis's light composition ranges from 6 minutes to 1.5 hours. It is worth underlining again that light became a musical expression for Xenakis and allowed him to explore new forms. That is general morphology.

To develop an understanding of the form-time relationship in Xenakis's *oeuvre,* I identified ten discussed projects in an axis of the form-time scales system (Figure 15). Green star is labelled as a natural light project, and white star as an artificial light project. The X-axis is the time scale from second to year. The Y-axis is the form scale from centimetre to kilometre. As shown in the image, the time duration of the natural light projects is relatively the same. It suggests that the form scale would be more important for a variation and design purpose. On the other hand, Xenakis's artificial light projects varied in both time and form scales based on the site and goals.

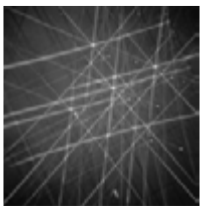
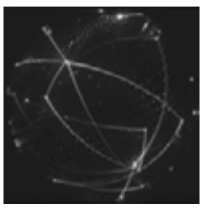
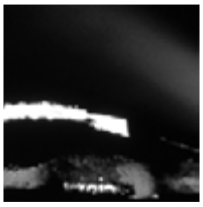
Light Project	Location	Light Source	Light Abstract Form and Surface Area (≈)	Light Event Time and duration
 Snail-shaped lighting fixture (1951-52)	Corridors at the Unité d'Habitation Marseille France	Fluorescent tube	Snail (The curved surface is approx. 0.34 sq.m	100 - 120 times / second (not perceivable by the human eye)
 Polytope de Montréal (1967)	French Pavilion (currently the Casino de Montréal) Canada	1200 Electronic flashes (800 white, 400 colours in yellow, red, green, and blue.)	Rivers, arms, leaps, wisps of fire, etc Surface area estimated 1,300 sq metres	25 times per second. 9000 times during the six minutes of the performance. The show ran once every hour.
 Polytope de Cluny (1972-74)	Thermes de Cluny, Paris, France	Three lasers (green, yellow-green, and blue) Mirrors, and 600 white xenon tubes	Geometrical: circles, parallel, crossing lines, spirals, arcs, etc Natural: rivers, lotus, anemone, etc. 300 sq metre	25 times per second. The performance lasted 24 minutes. Several performance per day.
 Le Diatope (1978)	Place Georges Pompidou, Paris, France	1680 electronic xenon flashes (on cable network, wall of the shell, and under the glass-tile floor) 4 lasers (3 green, 1 red) 400 fixed or pivotal mirrors	Spirals, etc. 400 sq metres	25 times per second. The performance lasts 45’48"
 Polytope de Mycènes (1978)	The acropolis of Mycenae, Greece	Lasers, electronic flashes, bonfires, torches (torch-bearing children), and 12 searchlights, a bonfire, light between goats' horns, and fireworks	30,000 sq. metres	The performance lasted 1.5 hours

Table 2: Light form and time scales in Xenakis’s artificial light projects

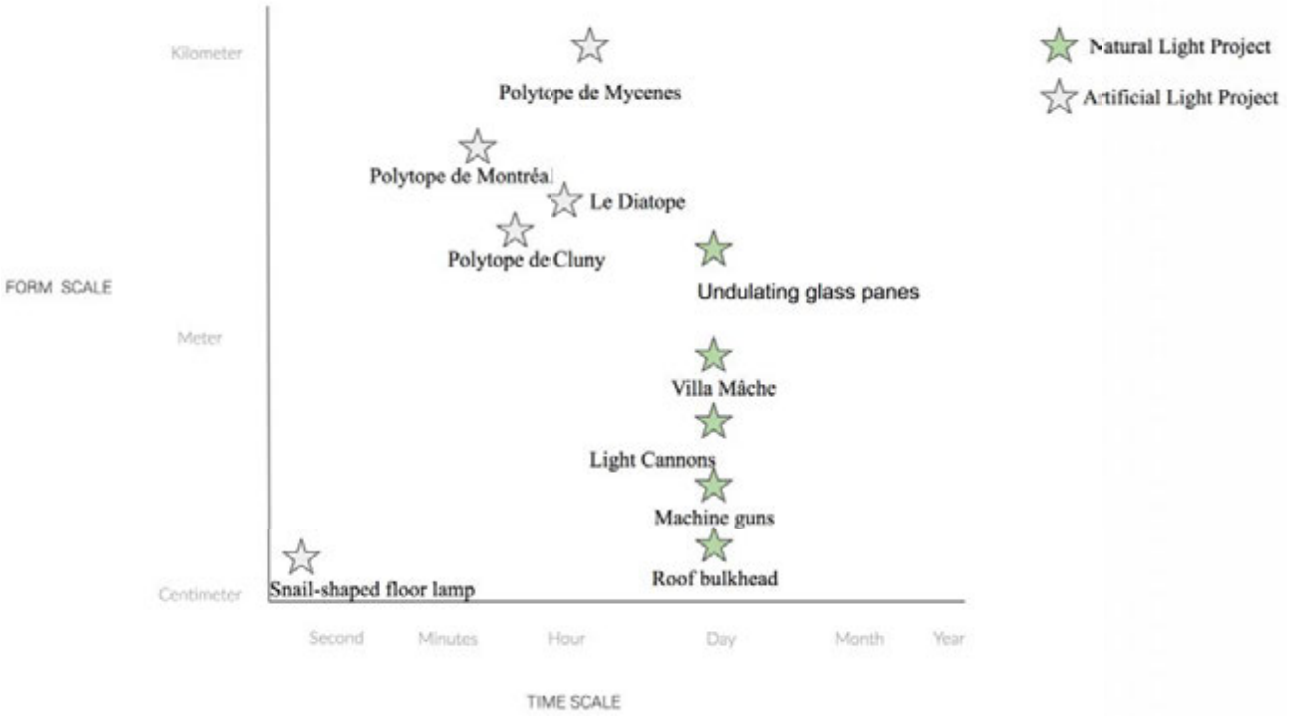


Figure 15: A form-time scales framework to analyse Xenakis's light works

4. Conclusions

Light in Xenakis's works has three phrases: light as architecture, light as music, and light as morphology. In Xenakis's early light work we can find a series of form findings and explorations. From borrowing the shape of an olive oil container to the sharp polygon light guns, Xenakis used both geometric architectural elements and light form to express his ideas. That was light as architecture. A turning point happened during the completion of the undulating glass panes. Xenakis started to compose light with consideration of time and speed. During the period of *Polytopes*, the light slowly evolved and developed forms and patterns, which led to morphogenesis in multimedia composition. His light is poetic, dramatic, emotional, and powerful. Xenakis not only created a new aesthetic of light art, but also projected a future direction for the role of light.

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Music to architect time: the Iannis Xenakis' undulating glass panes

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Abstract

In the twentieth century, favourable circumstances gave rise to a variety of junctions between arts and sciences. Einstein's theory of relativity introduced the temporal dimension of space, which had previously been considered uniform and static, and opened up new possibilities for arts to express themselves. Iannis Xenakis broke through the established boundaries and linked Music and Architecture in his work. What interpretation can we make of the experimentation of this collision between these two seemingly distant disciplines? How can the element of the undulating glass panes be interpreted in relation to these movements?

Our reflection began in 2019 with a survey of Iannis Xenakis' undulatory panes carried out at the Couvent de la Tourette as part of Prof. Franz Graf's project workshop at the EPFL. One thing leading to another, we experienced a fascinating relationship between music and architecture in the form of dilation, compression or acceleration of the space felt thanks to the frequency of the concrete posts, throughout our wandering. As we walked through this device, we became the cursors reading the music frozen in the undulating panes at each passage and we were then transformed into both actors and instruments of this music. The end result of this first work was concretely to set the crystallised notes of the undulating sections to music in a piano score and to play it in public. A clear link with the musical composition work of Iannis Xenakis can be felt, particularly through the notions of glissandi and sound continuity.

Could it be that the link between Music and Architecture is deeper than a simple tribute? The concept of the undulating glass panes can be found in one of the greatest monuments of Ancient Greece: the Acropolis of Athens. The optical effect sought, called the parallax effect, makes the interstitial space behind the architectural elements exalt. The colonnade used in the Parthenon appears to vibrate as the visitor moves around it. Its peristyle acts as a filter between two different temporalities: one natural and the other eternal. The grooves take on a mystical quality, vibrating as the walker go through them, with the same force as the undulating glass panes.

The undulating glass pane then also becomes a threshold between the profane and the sacred, unfolding around the sacred space of the church of La Tourette. Its presence gives rhythm to the temporality of its inhabitants and ritualises their different tasks throughout their day and their life. The architectural element accompanies the individual, collective and spiritual life of the convent. Bringing the proud ancient caryatids into the modern age, the undulating glass pane then architects the human figure through the *Modulor*, making it resonate in the light of a new age. Let us take the measure of this architectural element by considering its origins and its power through what it evokes:

music, space-time and the human being.

1. Introduction

The present work is based on a part of our theoretical statement of master of architecture at EPFL. We humbly attempt to retrace the history of undulating glass panes by proposing a detailed historical and architectural analysis of the ones present at the Couvent de la Tourette.

The analysis we propose is based on a survey of all the undulating glass panes of the Couvent de la Tourette in 2019. The latter enabled us to familiarise ourselves with the device, whose architectural intensity is in sharp contrast to its rationality and simplicity of implementation. Three years of reflection on undulating glass panes have enabled us to arm ourselves with the right tools to understand and interpret their origins, their mathematical genesis, what they evoke about space-time through music and the intensity of the relationships they weave in the architectural domain. To do this, we had to abstract the undulating glass panes to their very essence, define their intrinsic nature and what they represent. We will see that a discreet but nonetheless tenacious link connects the undulating glass pane to the ancient grooves of the Parthenon on the Acropolis in Athens.

When we first encountered the Xenakian architectural device, we instinctively sensed a strong link with space-time. We will therefore introduce the undulating glass panes by inserting them into a trajectory concerning the relationship between the human being and space-time, then into the architectural and musical trajectory of Iannis Xenakis.

Time is an abstract notion, an elusive dimension that human beings have tried to materialise. At first, it is eternity that fascinates, as can be seen in the Egyptian hieroglyphic representations and their constructions linking them to what is most eternal for them: the stars. For a long time in history, the constructions evoked robustness, stability and defied eternity in the image of palaces or other sacred buildings. Let us note here that an embryo in relation to space-time is embodied by the composition of the Acropolis where the buildings do not follow any rule of symmetry, between them. Jacques Lucan, and Auguste Choisy before him, noted a "parallax"[1] effect that the visitor perceives as he moves around the buildings on the Acropolis, bringing time into play in order to grasp the complex as a whole.

It turns out that the way in which we physically represent time depends fundamentally on the conception we have of it. While Newtonian mechanics was the only one known until the 20th century, an upheaval occurred with Einstein's relativity. The very perception of space and time changed, influencing the way in which art, architecture and music were composed. This upheaval was accompanied by a rare decompartmentalization of disciplines between physics and these arts. Exchanges multiplied and it was in this favourable environment that Iannis Xenakis and his personal trajectory intervened, also concerning space-time with creations born of successive musical and architectural abstractions.

Having just taken refuge in France after being expelled from Greece, Iannis Xenakis worked first as an engineer in Le Corbusier's office. His first project as an architect was the Couvent de la Tourette. At the same time, he experimented with musical composition, which had fascinated him since he was a child. Olivier Messiaen, his mentor, suggested that he inject his architectural and mathematical knowledge into his music[2]. Iannis Xenakis' career was born with the composition of *Metastaesis* in 1954, where the musical continuities and discontinuities embodied in his glissandi are reminiscent of the way architecture is composed. The undulating glass panes were born at the same time, with a similarity in the way they were composed with *Metastaesis*. Xenakis' conquest of dimensions begins...

[1] Jacques Lucan, Composition/Non-Composition, p.324
[2] Sven Sterken, Travailler chez Le Corbusier : le cas de Iannis Xenakis, p.215

2. Undulating glass panes

Towards the entrance of the Tourette Convent complex, a perspective opens up to us. We can see the undulating glass panes that let us guess their shape, through the multiple plastic layers of the convent. Silence reigns supreme in the complex, each step resounds like an echo in a mountainous valley. The undulating glass panes seem to be the only sounds allowed in this place: notes crystallized in concrete, iron and glass.

Figure 1: opening to the interior of the convent, near the entrance

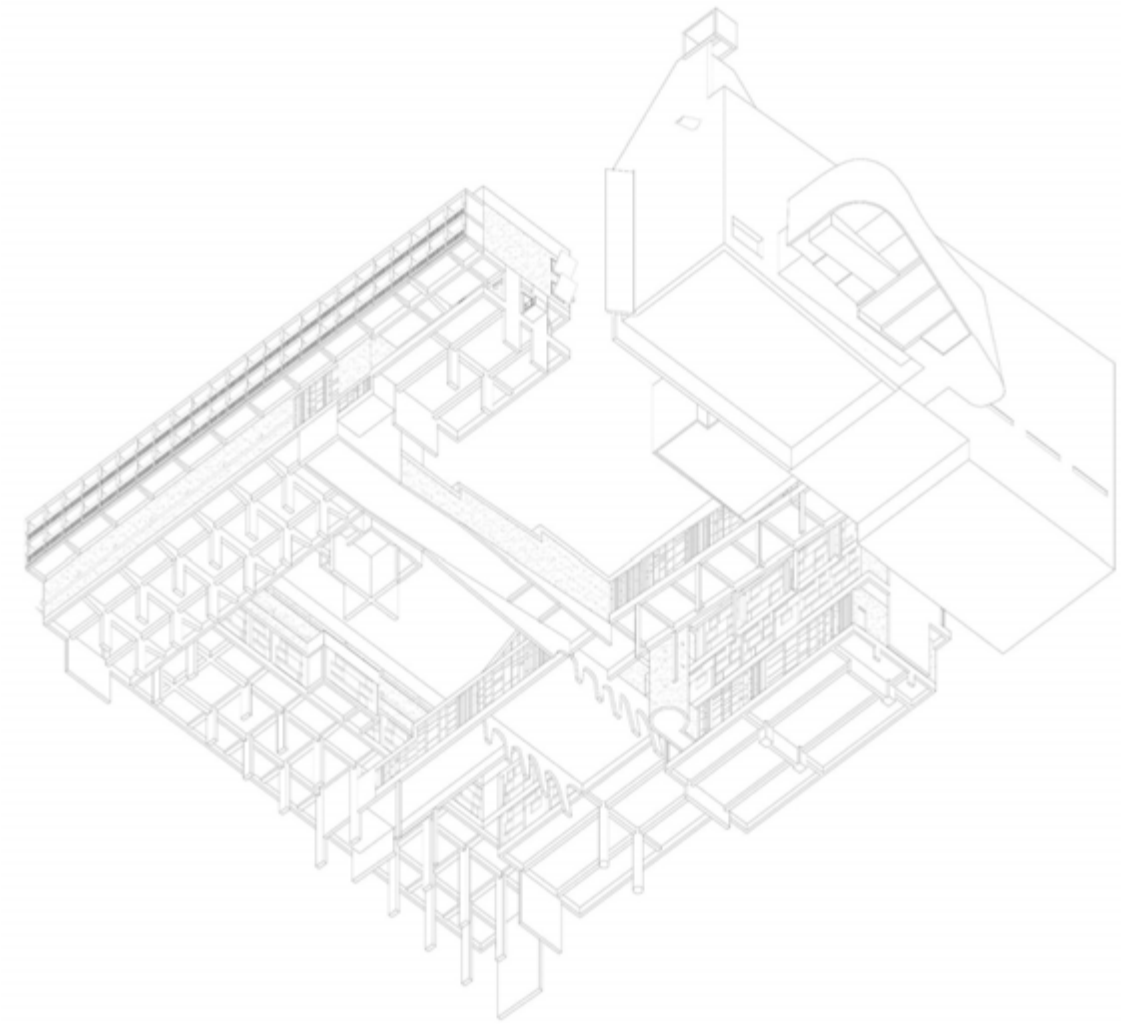

Figure 2: Alice Biber, Marilyn Brühlmann, Tamara Lobo, Abigaël Schaller, Alexandre Gameiro, Mathias Schopfer, Emmanuel Stump, Pierluigi Surano, Envelope – General Axonometry, 2019

Without going into the details of the complete composition of the project, we can nevertheless note the following points: the complex, contrary to what the classical monastic typology suggests, is articulated vertically. The spiritual life is experienced on the ground, followed by the community spaces and then the cells. The cloister, a major element of the monk's resourcing, is located on the roof.

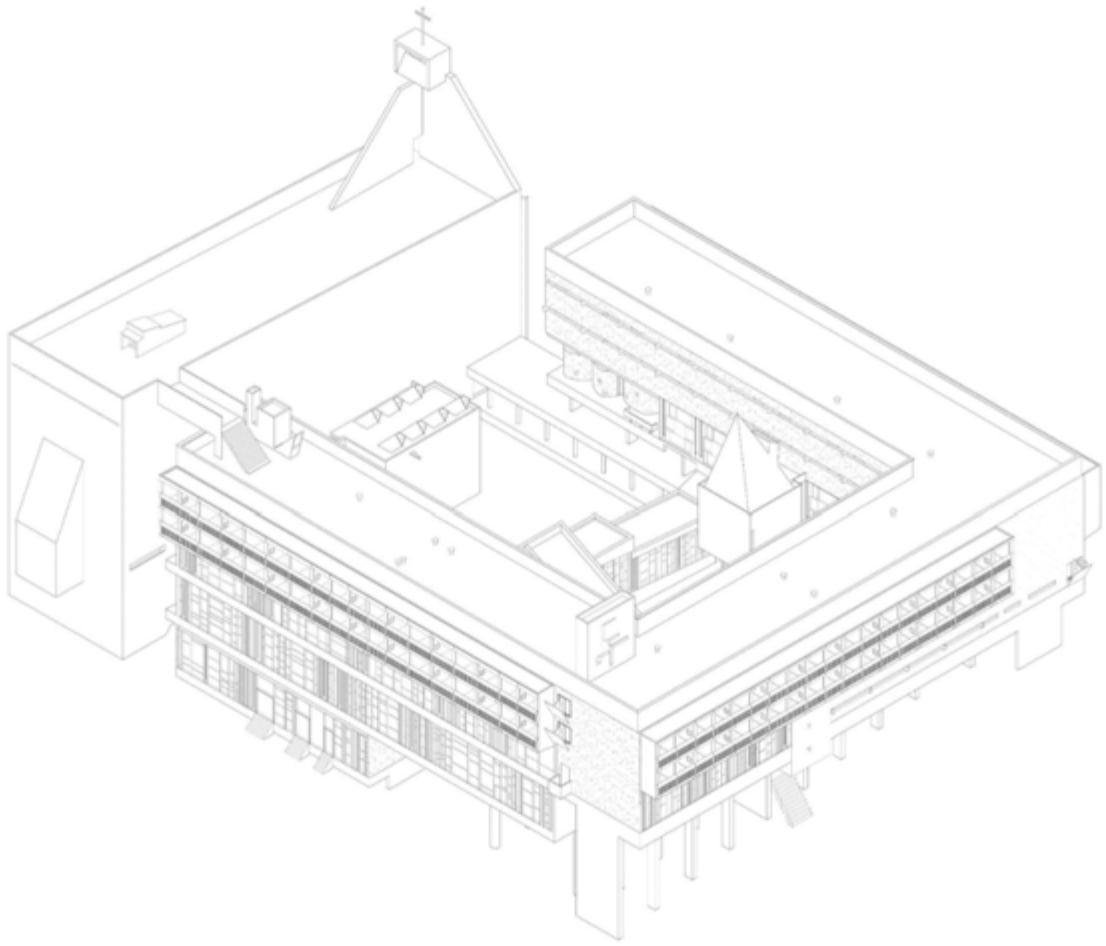

Figure 3: Alice Biber, Marilyn Brühlmann, Tamara Lobo, Abigaël Schaller, Alexandre Gameiro, Mathias Schopfer, Emmanuel Stump, Pierluigi Surano, Envelope – General Axonometry, 2019

Poverty, a fundamental element of Dominican doctrine, is found at every level of the project, both in its constructive and constitutive dimensions. Although modern in inspiration, the building takes as its reference historical complexes, namely the Charterhouse of Ema, in Tuscany, and the Abbey of Le Thoronet, in the south of France[3].

Let's not rush into anything: although medieval inspiration, the Couvent de la Tourette is dimensioned with the help of the *Modulor*, thus making human proportions resonate. Moreover, Le Corbusier spoke of "the workman's touch that leaves its mark" when he defended the poor quality of the building's construction[4].

From a structural point of view, the posts of the undulating glass panes of the Tourette convent are non-load-bearing, although their material and number may suggest otherwise. In fact, the task of carrying the building falls to the various posts set back from the façade. We can justify the use of concrete and glass for the undulating glass panes in order to inspire the rigour and hardness of the Dominican order in the eyes of the walker. The asperities in the element together

[3]Sergio Ferro, Chérif Kebbal, Philippe Potié, Cyrille Simonnet, Le Couvent de la Tourette, p.63
[4]Le Corbusier about marks left by the workers *in* Philippe Potier, Le Corbusier. Le Couvent Sainte Marie de la Tourette, p.110

give off a raw beauty that can be found in ancient ruins left to the four winds. The saddle bars, which represent musical notes, seem to shout while being silent. The visitor then becomes the cursor of the reading, playing the melody to the rhythm of his walk, each post mimicking the dull beat of the metronome. The various asperities of the concrete then begin to vibrate in unison, the light picking up every little flaw as it passes. If in good weather, the imprint of the posts is projected directly onto the ground, the diffuse light resulting of bad weather caresses the device, giving it an ethereal presence.

Figure 4: view of the undulating glass panes of the "grand conduit". The roughness of the panes is accentuated by the penetrating light.

Figure 5: close picture of one post

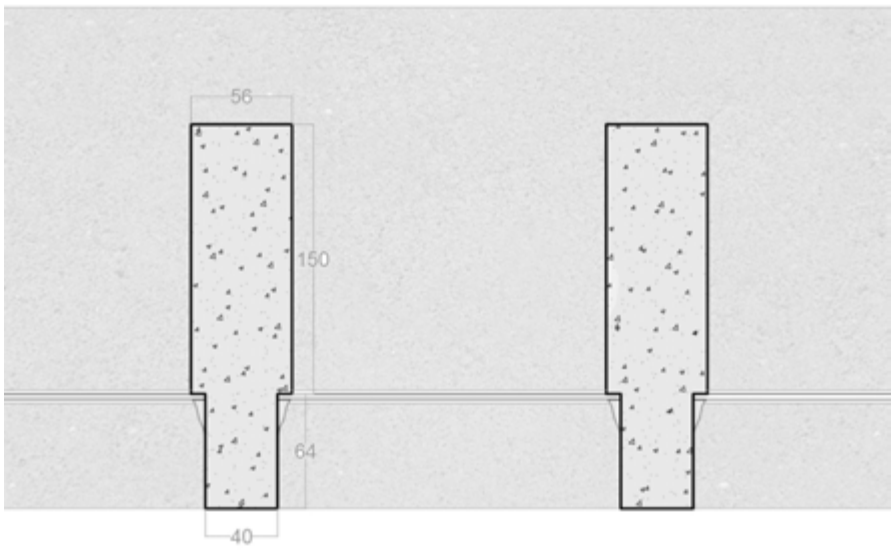

Figure 6: constructive detail of the undulating glass panes

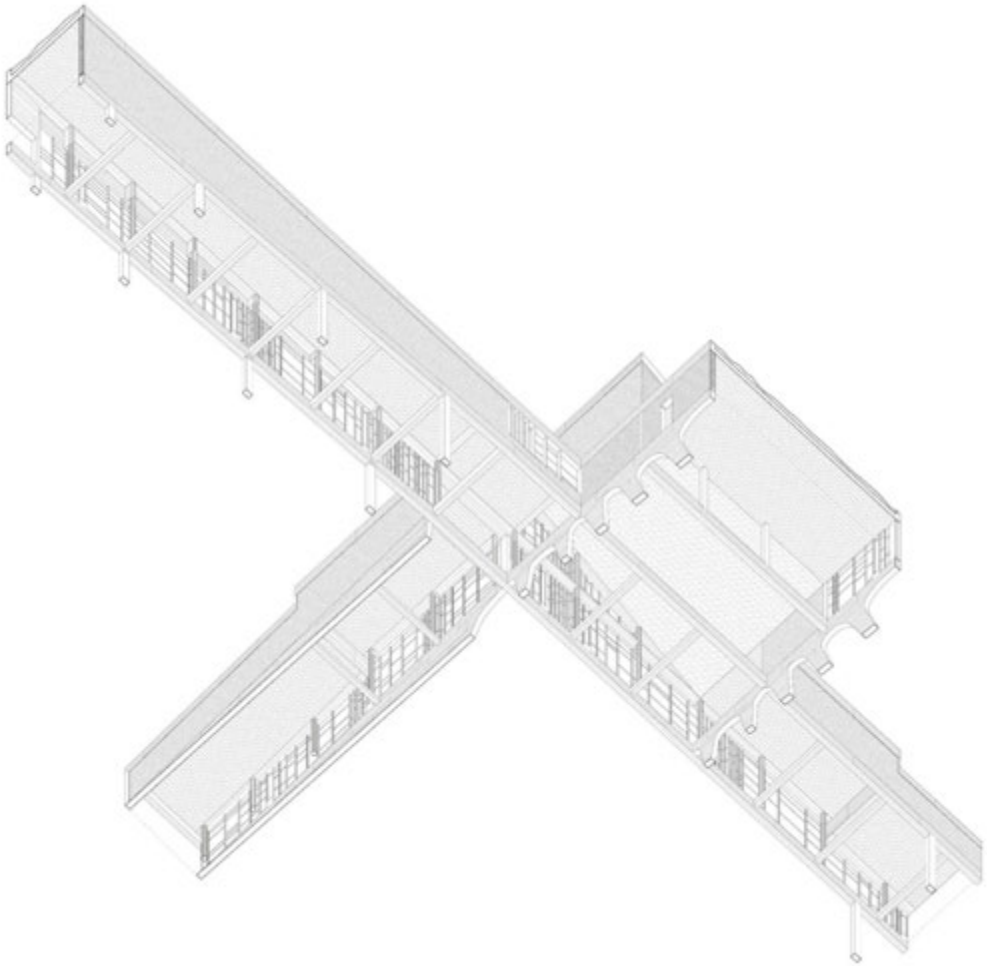

Figure 7: Emmanuel Stump, Couvent de la Tourette – Axonometry of the « conduits », 2019

> "Ainsi, c'est exactement cette plasticité de l'espace musical que Xenakis va transposer dans les pans de verre du couvent. L'opération sera d'autant plus aisée que c'est à l'aide des mêmes graphiques qu'il compose sa musique et ses pans de verre : en 1954, en effet, n'ayant pas encore les possibilités offertes par la combinatoire, le choix des transformations globales du mouvement 'ondulatoire' se faisait simplement à l'aide du crayon et de la feuille de papier, dont il grisait une surface plus ou moins étendue. Fernand Gardien, qui travaillait dans le même bureau, rue de Sèvres, se souvient d'ailleurs que Xenakis, composant et décomposant ses ondulatoires, battait systématiquement la mesure en chantonnant..."
>
> (Sergio Ferro, Chérif Kebbal, Philippe Potié, Cyrille Simonnet, Le Couvent de la Tourette, p.90)

2.1. The origin

The undulating glass panes were born on the Indian construction sites of the new city of Chandigarh, led by Le Corbusier's office. It was originally thought as a pragmatic solution to an ergonomic problem, namely to fill the large openings left by the structure with scraps of glass. Indeed, the recessed structural arrangement and non-bearing curtain wall proposed by Le Corbusier for the City Center buildings is probably unheard of in India. In fact, Le Corbusier is the architect of only the major buildings in the city. He is also responsible for the urban plan and gives global guidelines for the projected buildings, which he will not take care of afterwards. He simply applied his famous 5 points of architecture to them and the local workers took care of the rest, which is how the Indian glass panes were born. The undulating glass panes can be found on many buildings in the

city, whether they are earlier, contemporary or built after Iannis Xenakis' theorisation of them. The process and final object used by the Indian workers, noticed by Pierre Jeanneret, was transmitted to Le Corbusier through his correspondence. Le Corbusier then commissioned his young engineer, Iannis Xenakis, to harmonise and construct a method of composition for this element. With his musical experiments under his belt, the Greek architect first experimented and theorised it at the Couvent Sainte-Marie de la Tourette in Eveux-sur-L'Arbresle before integrating it into the pharaonic Indian project.

It is important to note that the first occurrences of the architectural element are in no way linked to any form of voluntary harmonisation but arise solely from a need for raw material to be rationed.

> "Ce fut pendant cette période calme que Xenakis mit au point l'idée des pans de verre ondulatoire. L'artifice technique lui avait été soufflé par Jeanneret (via Le Corbusier) qui, sur les chantiers en Inde, avait remarqué que les maçons noyaient directement les vitres dans le bâti de béton, sans les huisseries intermédiaires"
>
> (Sergio Ferro, Chérif Kebbal, Philippe Potié, Cyrille Simonnet, Le Couvent de la Tourette, p.32)
>
> "Bien des artifices sont pour ainsi dire 'testés' à la Tourette avant de s'inscrire sur le projet indien. Les pans de verre, par exemple, bien que le principe constructif ait été découvert en Inde, sont éprouvés à grande échelle sur le couvent avant de s'épanouir sur le Parlement et d'autres édifices ultérieurs ; les systèmes de rampes de Chandigarh également, que Le Corbusier a d'abord travaillés sur le projet du couvent."
>
> (Sergio Ferro, Chérif Kebbal, Philippe Potié, Cyrille Simonnet, Le Couvent de la Tourette, p.32)

2.2. The survey

Our 2019 survey could entirely be recorded in the form of a table of numbers. The different elements were articulated as follows: on the X-axis was the width of the pane measured between two posts and the dimensions on the Y-axis corresponded to the height of the glass, between two bars. Like the architectural element, these rough series of numbers allowed us to reconstitute the various undulating glass panes present in the Convent. It should be noted that the measuring is done from the inside. The constructive detail of the posts is thinner on the inside than on the outside (Fig 5). The role of this work was to try to understand the architectural articulation of the different architectural elements. As a bonus, it allowed us to enter the building itself and to confront it directly with the built ensemble, disregarding the existing plans. Moreover, although the documentation concerning the Convent is abundant, certain details contradict each other in the various drawings.

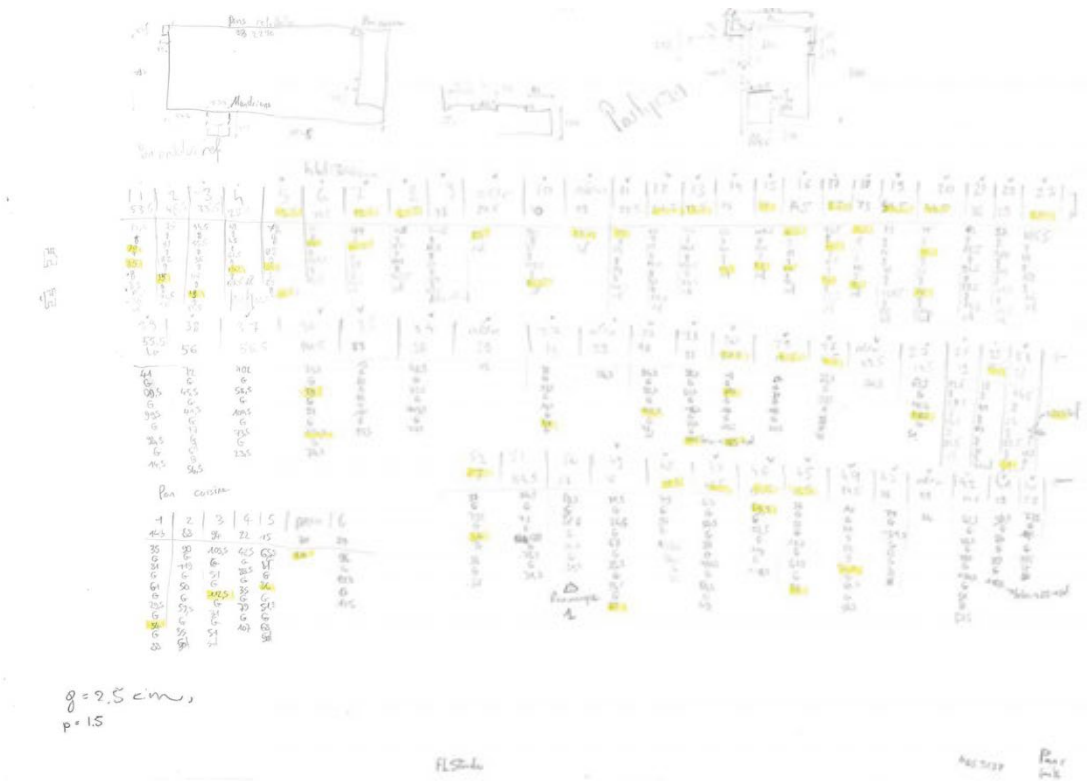

Figure 8: survey sheet of common spaces (from the inside). The values highlighted in yellow correspond to the Modulor values (+/- 1cm)

Figure 9: Emmanuel Stump, Couvent de la Tourette - axonometry "conduits", 2019

As in most of Le Corbusier's post-war buildings, the integration of *Modulor* values into the composition of the project is paramount. However, as shown in yellow on our survey sheets, the

accuracy of implementation leaves something to be desired (Fig. 8 & 10). In these drawings, the colouring of the value indicates the presence of a *Modulor* dimension with a plus or minus 1cm margin. A wider tolerance of 4 cm allows these reluctant values to fit into dimensions inherited from the *Modulor* series.

Of course, the questionable quality of the implementation of the undulating glass panes does not detract from their quality. Indeed, it is very likely that the glass panels were cut after the posts were in place and some had to be cut to fit in. Fernand Gardien's site reports give us a good idea of the chaos that the site represented, particularly concerning the undulating glass panes[5].

Figure 10: survey Notes from the Couvent de la Tourette undulating glass panes

We have transcribed the horizontal dimensions from the inside of the undulating glass panes below. Values that are not part of the Modulor or deviate from it by more than 4 cm are coloured orange. In blue and red you will find the highlighting of the two series of the Modulor.

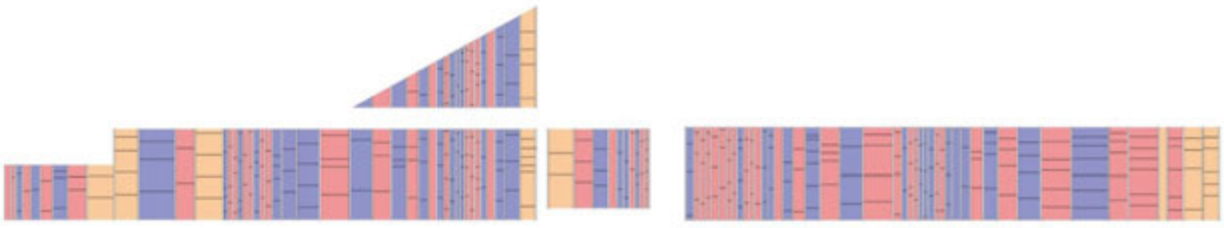

Figure 11: highlight of the « grand conduit » undulating glass pane, according the two Modulor series.

“Grand conduit” read from the South to the North towards the church, integrating the pane in front of the “Petit Conduit”:

25.5 - 15.5 - 22.0 - 29.0 - 33.5 - 45.0 - 54.5 - 72.0 - 104.5 - 92.0 - 141.5 - 74.0 - 107.5 - 14.5 - 16.0 - 15.5 - 14.5 - 17.5 - 17.5
26.6 - 16.5 - 20.4 - 26.6 - 33.0 - 43.2 - 53.4 - 69.8 - [illegible] - 139.7 - 69.8 - [illegible] - 12.8 - 16.5 - 16.5 - 12.8 - 16.5 - 16.5

21.0 - 17.5 - 25.0 - 34.0 - 55.0 - 87.0 - 114.0 - 85.5 - 71.0 - 56.8 - 43.5 - 34.5 - 29.2 - 23.0 - 18.0 - 20.0 - 14.0 - 14.5 - 15.0 - 17.5
20.4 - 16.5 - 26.6 - 33.0 - 53.4 - 86.3 - 113.0 - 86.3 - 69.8 - 53.4 - 43.2 - 33.0 - 26.6 - 20.4 - 16.5 - 20.4 - 12.8 - 12.8 - 16.5 - 16.5

18.0 - 20.5 - 29.0 - 34.0 - 56.5 - 60.7 – end atrium - 102.0 - 72.0 - 56.0 - 29.5 - 22.0 - 19.5 - 18.5 - 13.5 - 15.5 - 15.5 – end little pane
16.5 - 20.4 - 26.6 - 33.0 - 53.4 - [illegible] – little pane - [illegible] - 69.8 - 53.4 - 26.6 - 20.4 - 20.4 - 16.5 - 12.8 - 16.5 - 16.5 – begin church

[5] Sergio Ferro, Chérif Kebbal, Philippe Potié, Cyrille Simonnet, Le Corbusier - Le Couvent de la Tourette, p.50

30.0 - 18.5 - 18.5 - 17.0 - 28.0 - 25.0 - 17.5 - 15.0 - 22.5 - 18.0 - 15.0 - 25.0 - 20.5 - 21.0 - 29.0 - 35.0 - 44.5 - 54.5 - 72.5 - 85.5
33.0 - 16.5 - 16.5 - 16.5 - 26.6 - 26.6 - 16.5 - 16.5 - 20.4 - 16.5 - 16.5 - 26.6 - 20.4 - 20.4 - 26.6 - 33.0 - 43.2 - 53.4 - 69.8 - 86.3

116.0 - 29.0 - 19.0 - 15.5 - 15.5 - 14.5 - 14.5 - 22.0 - 15.0 - 18.5 - 22.0 - 30.5 - 33.5 - 46.0 - 53.0 - 73.5 - 87.0 - 115.0 - 142.0
113.0 - 26.6 - 20.4 - 16.5 - 16.5 - 12.8 - 12.8 - 20.4 - 16.5 - 16.5 - 20.4 - 33.0 - 33.0 - 43.2 - 53.4 - 69.8 - 86.3 - 113.0 - 139.7

73.0 - 114.0 - 60.0 - 71.5 - 62.5 - 58.9
69.8 - 113.0 - 60.0 - 69.8 - -

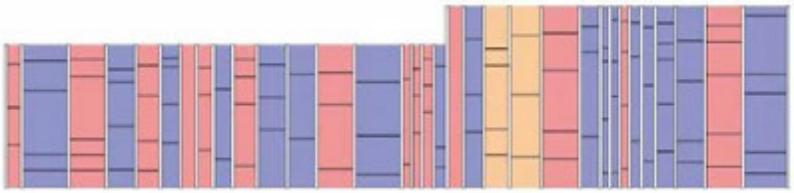

Figure 12: highlight of the « petit conduit » undulating glass pane, according the two Modulor series.

« Petit conduit » from the East to the West:
29.5 - 88.5 - 71.0 - 54.5 - 45.0 - 35.0 - 29.0 - 29.0 - 34.5 - 44.0 - 56.0 - 54.0 - 72.0 - 89.5 - 15.5 - 16.5 - 19.5 - 22.5 - 28.5 - 35.5
26.6 - 86.3 - 69.8 - 53.4 - 43.2 - 33.0 - 26.6 - 26.6 - 33.0 - 43.2 - 53.4 - 53.4 - 69.8 - 86.3 - 16.5 - 16.5 - 16.5 - 20.4 - 26.6 - 33.0

47.5 - 59.0 - 72.8 - 37.0 - 15.0 - 15.0 - 15.5 - 20.0 - 23.0 - 36.0 - 55.0 - 71.5 - 87.5
47.5 - 59.0 - 69.8 - 33.0 - 12.8 - 12.8 - 16.5 - 20.4 - 20.4 - 33.0 - 53.4 - 69.8 - 86.3

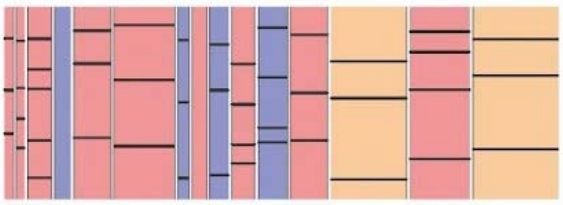

Figure 13: highlight of the Chapter's room undulating glass pane, according the two Modulor series.

The Chapter's room:
18.0 - 16.0 - 45.5 - 31.0 - 71.0 - 116.5 - 21.5 - 28.5 - 36.0 - 45.0 - 56.0 - 71.5 - 145.0 - 115.0 - 163.0

16.5 - 16.5 - 43.2 - 33.0 - 69.8 - 113.0 - 20.4 - 26.6 - 33.0 - 43.2 - 53.4 - 69.8 - - 113.0 - 182.9

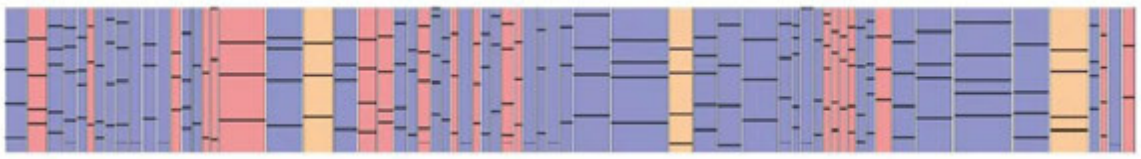

Figure 14: highlight of the Dining Hall undulating glass pane, according the two Modulor series.

The Dining Hall :
53.1 - 47.1 - 37.1 - 30.1 - 21.1 - 16.1 - 21.1 - 23.1 - 29.6 - 31.1 - 31.6 - 30.6 - 24.1 - 22.1 - 21.1 - 16.6 - 17.6 - 116.1 - 89.1 - 74.6
53.4 - 43.2 - 33.0 - 33.0 - 20.4 - 16.5 - 20.4 - 20.4 - 33.0 - 33.0 - 33.0 - 33.0 - 26.7 - 20.4 - 20.4 - 16.5 - 16.5 - 113.0 - 86.3 -

56.1 - 46.1 - 39.0 - 30.6 - 21.6 - 29.6 - 21.1 - 20.6 - 16.1 - 31.1 - 17.1 - 21.1 - 22.1 - 29.6 - 17.6 - 30.6 - 20.6 - 30.6 - 29.6 - 90.6
53.4 - 43.2 - 43.2 - 33.0 - 20.4 - 26.6 - 20.4 - 20.4 - 16.5 - 33.0 - 16.5 - 20.4 - 20.4 - 26.7 - 16.5 - 33.0 - 20.4 - 33.0 - 33.0 - 86.3

143.1 - 58.1 - 57.6 - 57.1 - 88.6 - 30.6 - 16.1 - 30.6 - 19.6 - 16.1 - 17.1 - 17.1 - 17.1 - 21.1 - 19.6 - 38.6 - 56.1 - 88.6 - 143.0
139.7 - - 53.4 - 53.4 - 86.3 - 33.0 - 16.5 - 33.0 - 20.4 - 16.5 - 16.5 - 16.5 - 16.5 - 20.4 - 20.4 - 43.2 - 53.4 - 86.3 - 139.7

88.0 - 94.0 - 22.0 - 15.0 - 30.0 - 29.0
86.3 - - 20.4 - 16.5 - 33.0 - 26.7

The match here is 91.7%.

"L'ondulation des pans de verre peut être décrite graphiquement si l'on

> affecte en ordonnées les valeurs du Modulor. Ce graphique nous montre comment, à partir d'une loi de croissance donnée (20-27-33-43-53-70-86-113-140), Xenakis crée des 'symétries', des 'ruptures', des 'accidents' selon son choix. On remarquera également que les éléments sont, de fait, traités en masse, (de même que les glissandi de Metastassis) expériences qui préparent sa théorie stochastique de la composition musicale. A cette composition horizontale des ondulatoires s'ajoute encore une recherche polyphonique des juxtapositions verticales des pans de verre." (Sergio Ferro, Chérif Kebbal, Philippe Potié, Cyrille Simonnet, Le Corbusier - Le Couvent de la Tourette, p.92)

It appeared to us, during our survey and drawing of the undulating glass panes that, although the values of the Modulor are present in the widths of the panes of glass, the heights of the different panes of glass have a random component and are not linked to the *Modulor*, as the authors of the monograph on the Couvent de la Tourette also point out[6].

Of course, some of the dimensions come close to the *Modulor* series, but in our opinion this is a matter of luck. It is likely that during the installation process, the various tiles making up the undulating glass panes were not yet cut. They were cut after all the posts have been installed. It should also be noted that it is easy to come across *Modulor* dimensions which are numerous between 15cm and 43cm depending on the tolerance applied. When these dimensions are exceeded, the correspondence to the model values is rare.

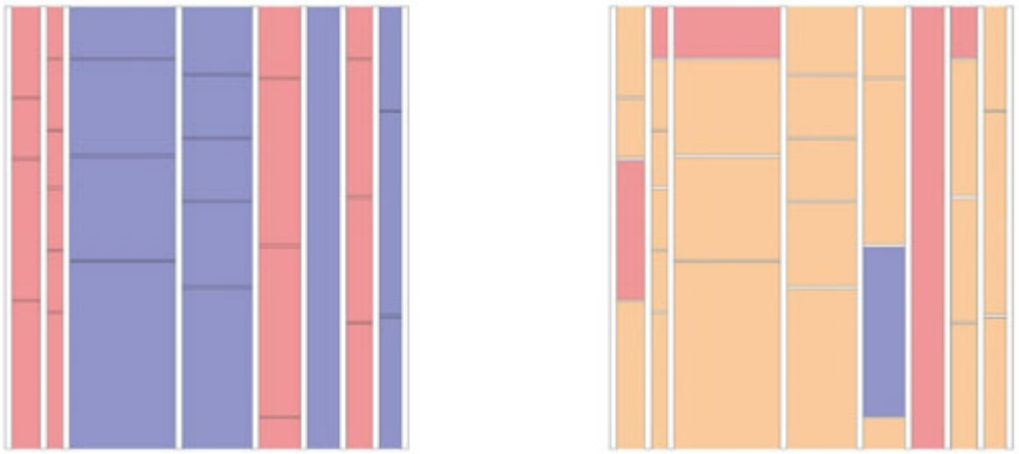

Figure 15: comparison of elements corresponding to Modulor values. The diagram on the left shows the Modulor differences between the posts, while the diagram on the right shows the height of the glass parts (tolerance 1.5cm).

Furthermore, the architectural composition of Iannis Xenakis' undulating glass panes shows the precise location of the concrete posts in the façade. On the other hand, the absence of the saddle bars on these elevations (Fig. 15 and 20) confirms our hypothesis: the saddle bars take on the vernacular characteristics of their Indian counterparts, namely an economic randomness in their layout. Indeed, if we follow a purely rational logic, it is the available glass scraps that would give the heights of the saddle bars.

Basically, the posts have a relationship to time and human dimensions. They fragment the space-time experienced, then, by the human being. The notes embodied by the saddle bars have no reason to be linked to the *Modulor*. For the heights of notes in music have nothing to do with human dimensions.

[6] Sergio Ferro, Chérif Kebbal, Philippe Potié, Cyrille Simonnet, Le Corbusier - Le Couvent de la Tourette, p.84

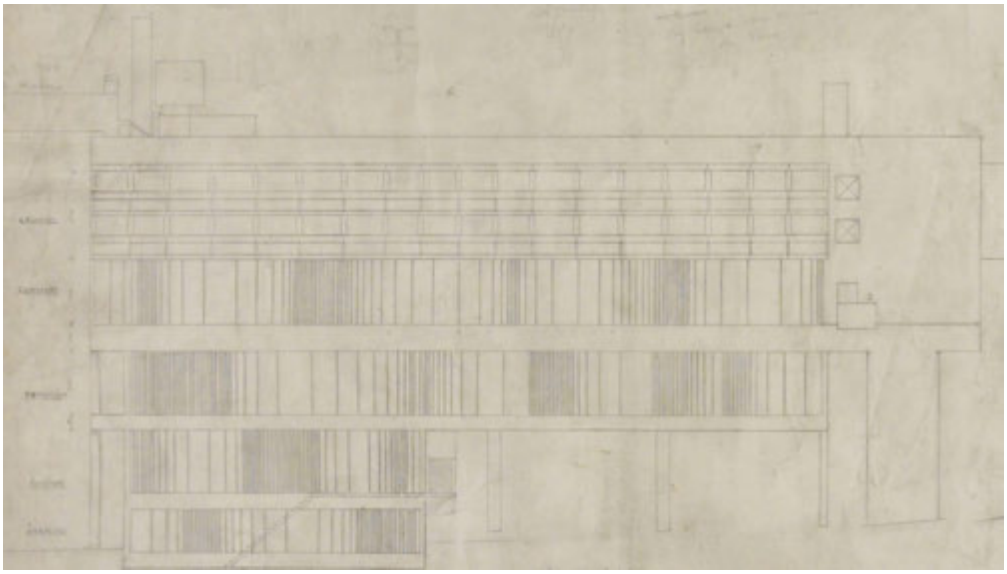

Figure 16: Le Corbusier, Couvent Sainte-Marie de la Tourette, Eveux-sur-l'Arbresle, 1953, Plan FLC 01340, [West facade elevation] (credits : © Fondation Le Corbusier)

In conclusion, it is interesting to note that this composition of undulating glass panes is the result of a reciprocal feeding of music and architecture in Xenakis' creations, starting with Le Corbusier's Modulor. In a transversal way, musicologists and architects find here a common ground for experimentation, breaking down the walls often erected between arts.

2.3. The music of undulating glass panes

During our survey in 2019, the following assumption was made by our group about the reason for the presence of saddle bars in the device in relation to the musical character of the undulating glass panels. We share it with you below:

"Our interpretation of the music of the undulating glass panels focused on a sonorous setting of the graphic score crystallised in the panels, for a classical keyboard of 88 keys. The tempo remains standard, one second per bar, and we have distinguished the musical parts in the "conduits", the atrium and the ones on the exterior façades. In our 2019 survey, we produced the following analysis:

The pane consists of glass panes set into the concrete post and metal and rubber saddle bars, initially the latter were made of foam. The metal bars are 25 mm high and the rubber bars are 14 mm high. Iannis Xenakis' undulating glass panes can be [interpreted] in a piano composition in the following way:

We take the height of the common undulating glass pane (i.e. 366 cm) and divide it by the number of keys present in a common piano. In this way, we obtain a kind of grid in which the concrete posts represent the duration of the piano note and the bars the actual notes. This interpretation makes it possible to transpose the façades of the undulating glass panes into a graphic musical score that can be read by digital music composition software.

The rest of this work was carried out with the help of Mr. Jean Pascal Cottier, an author-composer-performer from Lausanne, [Switzerland].

At the same time as the undulating glass panes, Xenakis composed his first work *Metastaesis* which he published in 1955. This musical piece was composed for a brass and string orchestra. It has a 5/4 rhythm, i.e. 5 beats for one bar on the score. The piece is part of the same movement as pieces by composers such as Pierre Schaeffer and Edgar Varèse. The characteristics of this movement are based on an analytical and mathematical approach to musical notes. The composition focuses on the presence of the notes in the score rather than on the harmony of the sounds as in traditional music. The duration of the piece is 8 minutes. The composition of the façade, at least the one we managed

to implement in our composition software, lasts 8 minutes approximately. According to Mr. Jean Pascal Cottier, the Xenakis façade can be considered as a summary or inspiration of the original piece, reduced to its simplest expression. The composition, hypothetically for piano, imposed a drastic simplification of the original piece, which may explain the heartbreaking feeling that the façade inspired in Xenakis. The piece is intended to be a sonorous ripple of glissandi throughout, a ripple that is impossible to achieve with the façade's straight saddle bars and reinforced concrete posts." (Emmanuel Stump Mathias Schopfer, Survey report on undulating glass panels, TSAM, 2019)

Iannis Xenakis, Music of the undulating glass panes, 1959

When we returned to the Convent in 2021, it seemed correct to assume that the notes in the conduits had no reading direction defined by the composer: it is the walker who, by wandering, activates them regardless of the direction of his path.

The undulating glass panes in the rooms and common spaces are read differently from those in the conduits. In fact, the user's experience of these spaces only allows him to read part of the overall composition. By observing the façades of undulating glass panes from the outside, the observer can see that the people present in these rooms are all playing the same graphic score in concert, at different speeds. Thus, the western façade, in contrast to the “conduits”, would make the community sing and the individual.

It is interesting to note that if the saddle bars form notes, the posts of the glass panels can symbolise the different beats of the metronome associated with the composition, thus defining a reading rhythm that varies in time and space. In a similar way to what Einstein's theory of Relativity explains, the posts are "grappled" around singular events attracting them, like stars distorting space-time by their mass. This effect seems to occur in the dining hall where the space between the posts expands when they are on the same level as the robust structural fluted piles (Fig. 18) as the space-time near massive objects physically do.

To close this chapter, let us recall the existence of the aerators, present at relatively regular intervals within the device. As a mechanical ventilation element of the device, their presence could be mistaken with sighs. These moments of silence, which are important in the musical field, allow the musician to catch his breath and continue the piece. The next chapter will give us an assumption for this name.

3. Analysis

3.1 Categorisation of the undulating glass panes

Before looking at the significance of the architectural element, it seems necessary to understand the use of each of the undulating glass panes in the complex. Following the survey, three categories seem to emerge:

- Circulation
- Thresholds and the transition between spaces.
- The representation of collective life.

The glass panels related to circulation are located in the walking spaces, whether vertical or horizontal. We find them in the “conduits” leading to the common and sacred spaces as well as in the staircases leading up to the different wings.

> "The holy men no longer turn around in circles, but their procession may now fill these glassed-in conduits with liturgical songs and burning candles.
>
> (Sharon Kanach, Music and architecture: architectural projects, texts and realizations, p.58)

The glass thresholds allow the transition from the profane to the sacred. Comparable to the medieval narthex, they form a filter that separates the religious space from the outside. In the case of the oratory, the undulating glass pane opening to the North makes the transition between the library and the oratory and separates the two spaces by light.

A similar use of this device can be found in the convent church. The two mono-panes separating the chapels from the main space and the monumental glass pane opening to the east use the same principle. The former allows the light to emphasise the sacred and communal volume, while the latter filters the light from the east, giving it its divine character.

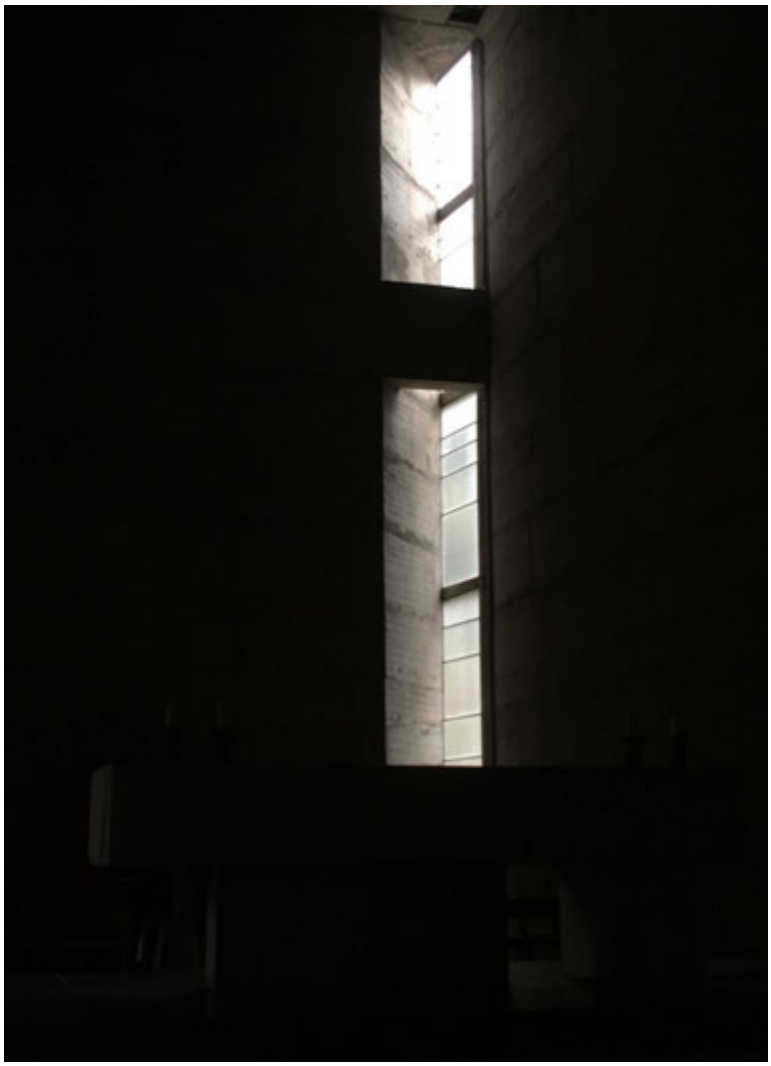

Figure 17: view of the monumental undulating glass pane of the church

The use of undulating glass panes in the common spaces finally reveals that the use of these elements always has a relationship to the staging of human life. Here, it is the community that is highlighted after the strolling and the thresholds. Thus, the spaces of the refectory and the classrooms offer a frontal relationship to the device and a strong contrast between the lightness, even fragility, of the undulating glass panes and the power of the fluted pillars supporting the west wing.

Figure 18: view of the dining hall with the expansion of the sides in line with the fluted pillars

One final element may interest us: the undulating glass pane in front of the spiral staircase in the atrium in front of the dining hall and the chapter's room. Its symbolism seems to be multiple: indeed, it accompanies the faithful when they go to the refectory or the chapter room, acts as a threshold between the ambulatory space of the conduits and the community spaces but also represents the community.

Indeed, in the extension of the opening is the cemetery of the Dominican friars of the chapter, which can be seen at the edge of the forest. It is possible that the architectural element serves to remind the surviving friars of their counterparts and to pay tribute to them.

Figure 19: the undulating glass pane facing the spiral staircase, facing the cemetery

Before starting the next chapter, it seems clear to us to precise that we have not found a different use for the undulating glass panes in convent. However, these different uses allow us to state that an intimate relationship exists between the human being, its proportions and the undulating glass panes. The device is related to music, however, one of its side effects is to ritualise the relationship the inhabitant has with the time and space contained in the place.

3. *Architectural analysis*

Figure 20: view of the undulating glass pane in front of the "petit conduit"

The pane facing the small conduit is quite crucial for understanding the relationship between music, human beings and architecture in the panes. Linking the large and small "conduit", this element functions as the shifted transition of the graphic score present in the "grand conduit" (Fig.19). The undulation of this pane forms a graphic continuity both for the "grand conduit" as a whole and from the "petit conduit" to the church. The elevations made by Iannis Xenakis as part of the study drawings also demonstrate that this is one and only one partition. By projecting the undulating glass pane against the opposite wall, the visitor, by passing from the "grand conduit" to the small one and vice versa, enters the music and even makes his human proportions resonate with the *Modulor* contained in the undulating glass panes.

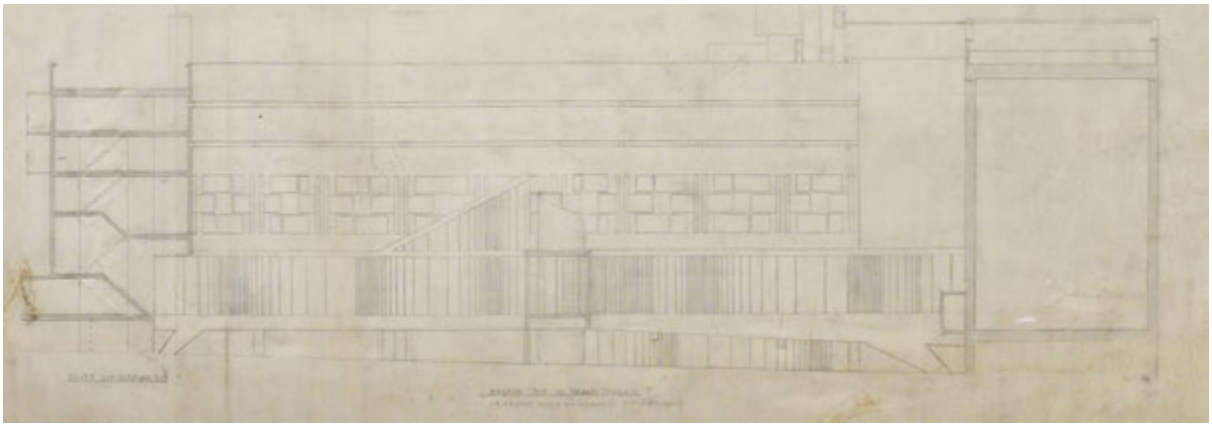

Figure 21: Le Corbusier, Couvent Sainte-Marie de la Tourette, Eveux-sur-l'Arbresle, 1953, Plan FLC 01340, [elevation of the « grand conduit »] (credits: © Fondation Le Corbusier)

Figure 22: axonometry of the crossing between the "petit" and "grand conduits" with the projection of the pane making the continuity of the device

Figure 23: the corner between the "Grand" and "Petit Conduit"

The “grand conduit” has also its peculiarities either. Its ceiling projections also correspond to characteristic values of the *Modulor*, namely: 226 cm, 366 cm and 732 cm. These measurements correspond, in the case of the model, to: one human being with his arm raised, two human beings on top of each other and finally four human beings on top of each other. The two values of 226cm are found at the beginning of the “petit et grand conduits” coming from the individual cell spaces. Then, we move on to 366cm and even 732. The *Modulor* values tell us that we are moving from individual life to collective and spiritual life.

Figure 24: overall perspective of the “grand conduit”

The rectangular triangle of the atrium seems to extend towards the church, accompanying the community in its spiritual life. Contrary to the western façade, the posts of the two floors are perfectly superimposed, indicating us that it is the same score, on the one hand, but also that the triangular disengagement would allow the score to expand and thus increase the number of notes architecturally, thus provoking a cluster. Indeed, the graphic score progressively increases from 366cm to 732cm, thus admitting more notes while keeping the same number of musical pitches. The triangle and this cluster would then represent the intersection of the individual, the collective and the spiritual.

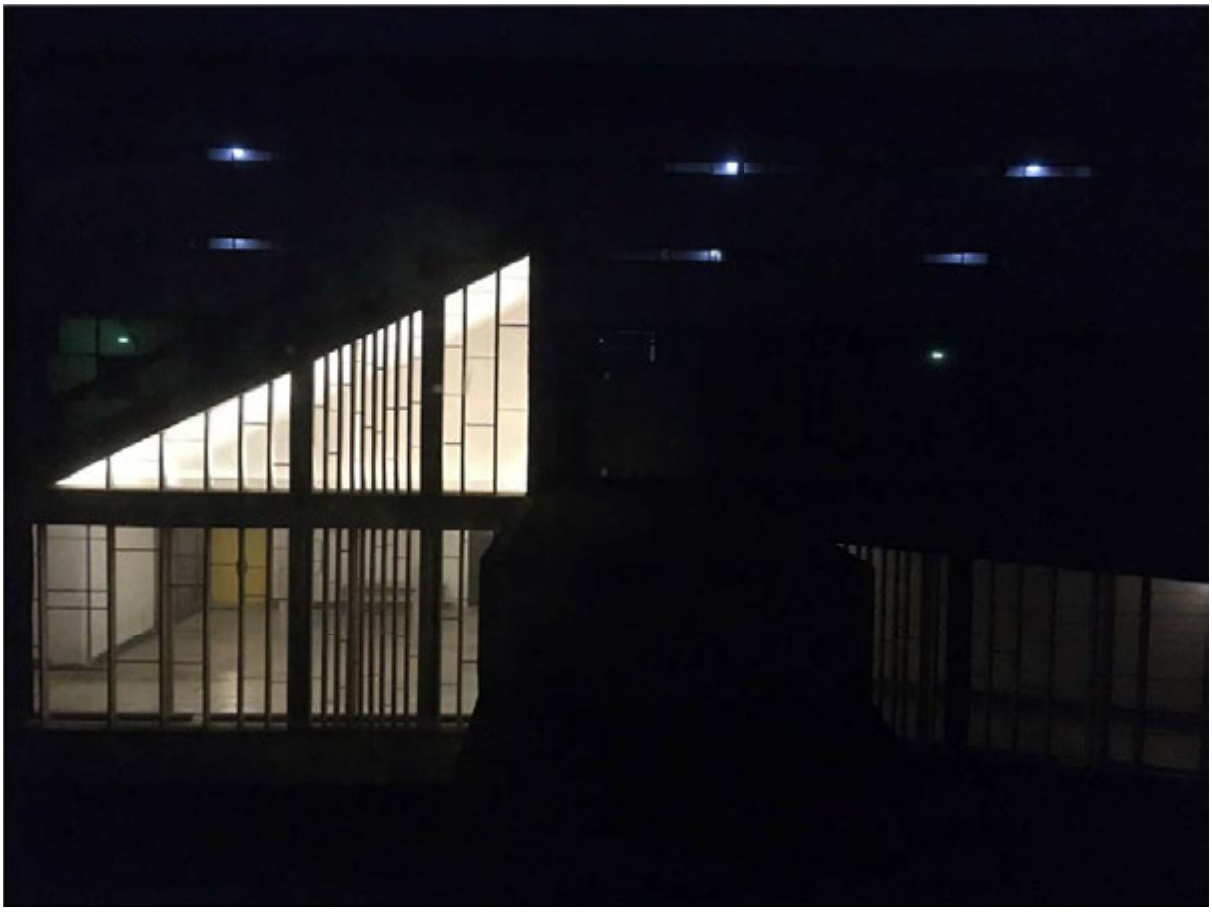

Figure 25: View of the atrium triangle with the posts on top of each other

It is now possible to include the undulating glass panes of the “conduits” in the category of thresholds. They act as a threshold between individual, collective and spiritual life.

3 Architectural abstraction

Figure 26: Frédéric Edwin Church, Parthenon, 1871

Our theoretical statement on which this article is based is to be used as a basis for our master project. Thus, we have sought to bring the undulating glass panes back to their very essence and primary function in order to, among other things, extract them from the architectural style and the modernist period in which they are embedded. It is through a process of successive abstractions that we hope to define the undulating glass panes of 2022.

Our journey begins with a simple comparison between the architectural and structural device of the ducts and the peristyle of the Parthenon (Fig. 27 and 28). The supporting columns of the "conduits" allow the curtain wall and the undulating glass panes. In front of the glass façade, there is always a solid wall, a device comparable to the peristyle of the Parthenon, which made us produce two initial collages to illustrate this intuition which, at the time of its discovery, still seemed weak.

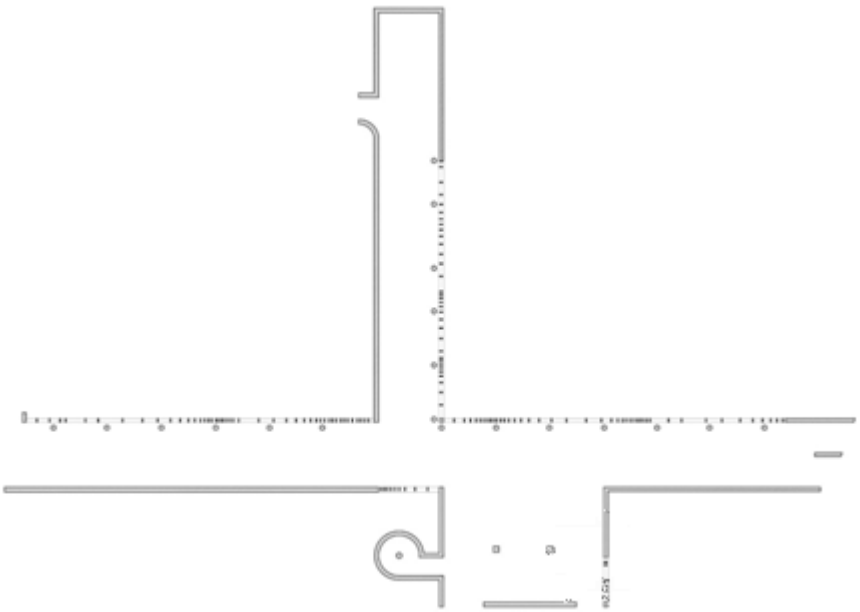

Figure 28: plan of the "conduits" of the Couvent de la Tourette

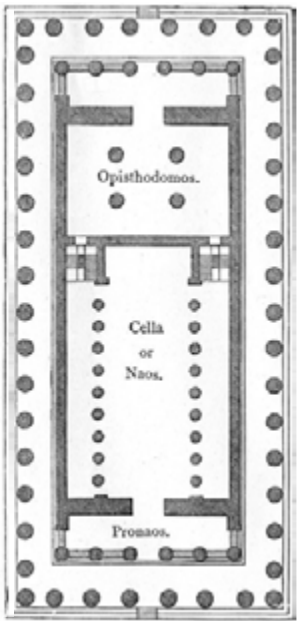

Figure 27: plan of the Parthenon

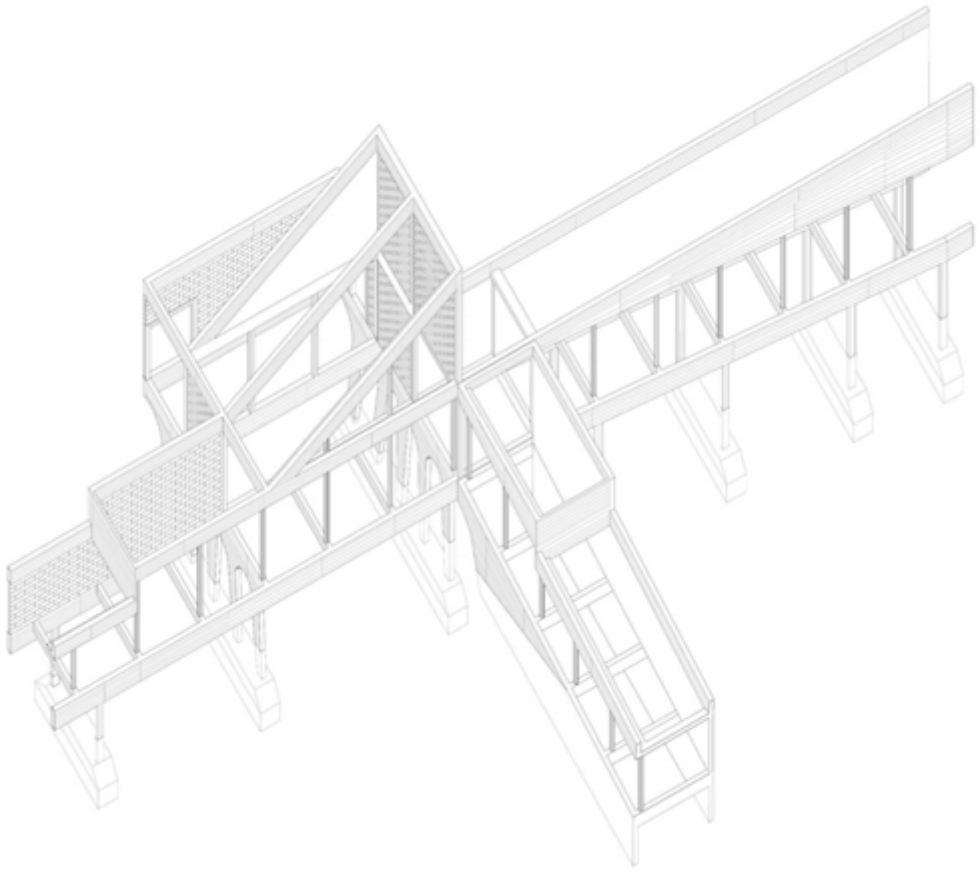

Figure 29: Mélanie Baptista de Sousa, Couvent de la Tourette - Axonometry - conduits, 2019

Figure 30: conceptual collage illustrating our interpretation of the undulating glass pane

Figure 31: conceptual collage illustrating our interpretation of the undulating glass pane

It turns out that the comparison does not end there. Let's recall here that Iannis Xenakis has Greek origins, has been expelled from Greece and will begin a sort of reconquest of his homeland through several projects such as the Villa Mâche, a project that will be piloted from Paris for example. Then, after the charges against him were dropped, Xenakis composed two Polytopes for this country: firstly the one of Mycenae, and then the one for Athens, which was unfortunately aborted. It is certain that this one would have completed this reconquest. His personal trajectory thus originates from Athens and also tends towards the Greek capital. A similar parallel presented in the introduction can be interpreted with the parallax effect of the Acropolis noted by Jacques Lucan. The Acropolis of Athens is a solid origin of the trajectory concerning architecture and brings into play the notion of space-time. Moreover, Le Corbusier's fascination with the Athenian monument is reflected in the numerous sketches he made during his "Voyage d'Orient" in 1911. He depicts the flutes with an intense vibration which reminds the ones present in the undulating glass panes. The comparison is even disturbing and supports our initial intuition.

Figure 33: Le Corbusier, Carnet du Voyage d'Orient n°3 p.115, 1911, [Sketch of the Acropolis at Athens] (credits : © Fondation Le Corbusier)

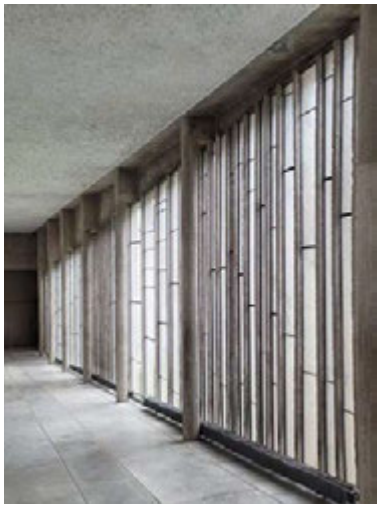

Figure 32: vibrant perspective of the undulating glass panes towards the church

A later reflection in the progress of our work occurred when we were asking ourselves the question of the temporality of spaces for our master project. Is it slow, fast, rhythmic or static for

example? During this reflection, we had the plan of the Parthenon in front of us. The intuition to apply this concept to the Parthenon itself emerged in our minds: the grooves of the peristyle columns can then be considered as a vibrant threshold between two temporalities. The visitor crossing between these grooves passes from the outside, subject to time, rain and astronomical cycles before entering the sacred space, which has a relationship to eternity. Let us now compare the church of the Couvent de la Tourette with the naos, pronaos and opisthodomos of the Parthenon. These are two rectangles of almost equal proportions. Here again, the same vibration as the Parthenon's grooves, this time in the form of undulating glass panes, takes us from a space literally subjected to time by the rhythms of the posts to an eternal, sacred space where time hits differently. The conduits and the undulating glass panes are like a peristyle unrolled in space that could be wrapped around the rectangle of the church in order to schematically reform the Parthenon's device.

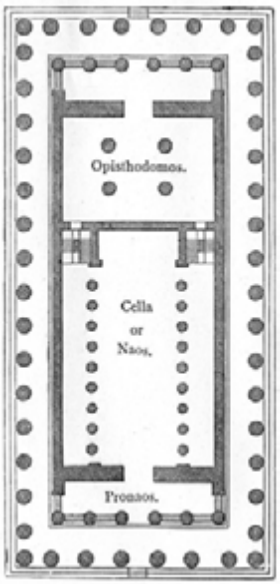

Figure 35: plan of the Parthenon

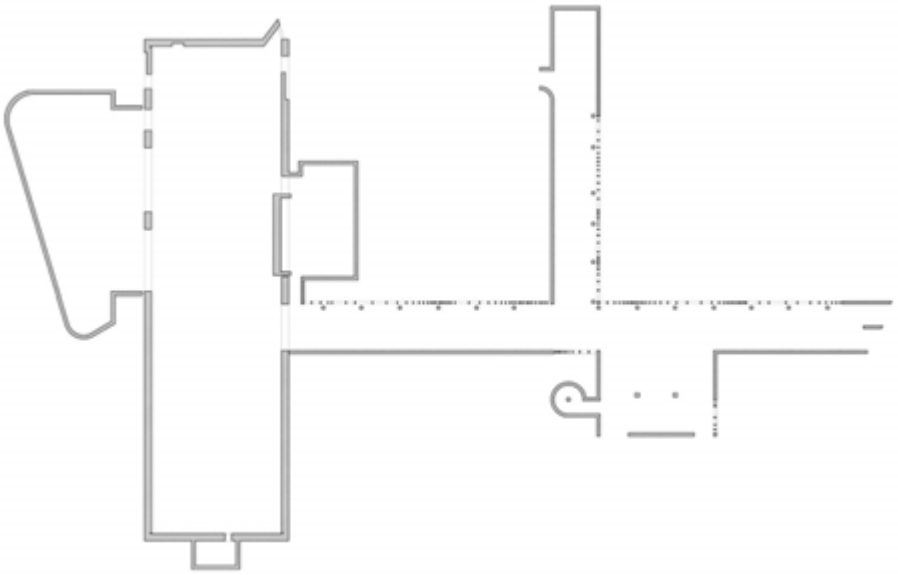

Figure 34: plan of the "conduits" of the Couvent de la Tourette with the church

The undulating glass panes would then be to the modern movement what the colonnade and the peristyle are to the ancient world: a filter accompanying the visitor from one space to another and from one temporality to another.

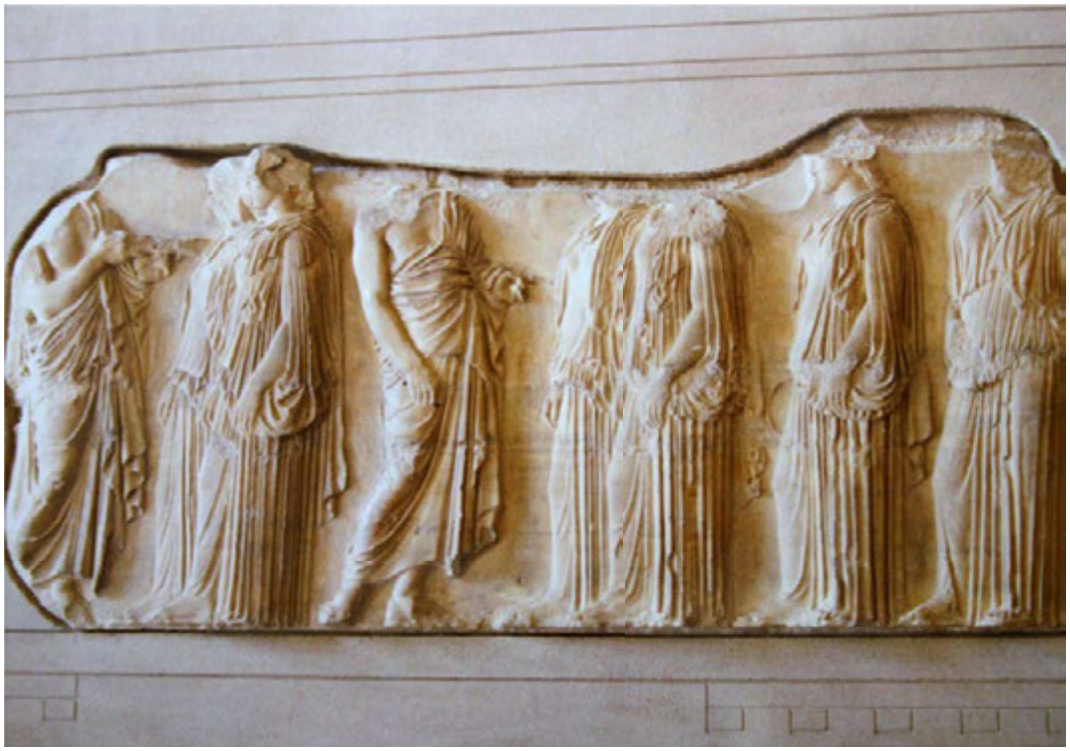

Figure 36: the Ergastines, detail of the friezes from the Parthénon, Louvre Museum, Paris

To continue the Greek metaphor, let us look at the Ergastines. This bas-relief, preserved in the Louvre Museum, comes from the eastern frieze of the Parthenon and shows a group of Ergastines during the Panathenees. These statues, in the book: "La Métamorphose des Dieux", written by André Malraux, are described as having retained their architectural character of columns through the drapery of their dress, rigid and straight. Thus, in the manner of the symbolic history of the orders, it is no longer characters that are represented in the work but personified architectural elements.

> "Présumons que au-dessus du brouhaha des vraies Panathénées, le cortège des Ergastines sembla une processions de colonnes"
> (André Malraux, La métamorphose des dieux, p.72)

> "Le mot sanctuaire ne désigne pas, à Athènes, le lieu où se trouve la déesse, mais l'Acropole même. [...] L'Acropole est une vaste offrande. Ses temples ne sont pas incomparables aux autres par leur architecture, mais par leur ostension"
> (André Malraux, La métamorphose des dieux, p.81)

> "L'arabesque joue ici le rôle transformateur - et non illusionniste - que jouent les verticales parallèles dans le drapé des Ergastines. [...] Les Ergastines sont belles, non comme leurs modèles, mais comme des colonnes - et comme la musique : ce qui exprime le divin"
> (André Malraux, La métamorphose des dieux, p.78)

The Caryatids also present on the Acropolis of Athens have the same characteristics as the Ergastines: they too are the personifications of columns.

Figure 37: caryatids from the Athens Acropolis

Let us now return to the undulating glass panes which, as we have shown, have a very strong architectural link with the grooves vibration of the same ancient columns. Let us also remember that the undulating glass panes are sized according to human proportions and make them resonate thanks to Le Corbusier's *Modulor*. The undulating glass panes can therefore be interpreted as being, like the Caryatids and Ergastines: personifications and modernisations of the ancient fluted column

Figure 38: vibrant perspective of the undulating glass panes towards the church

Figure 39: Le Corbusier, Carnet du Voyage d'Orient n°3 p.115, 1911, [Sketch of the Athens Acropolis] (credits: © Fondation Le Corbusier)

Figure 40: the Ergastines, detail of the Parthenon friezes, Louvre Museum, Paris

Figure 41: caryatids of the Athens Acropolis

The abstraction is done, the undulating glass panes are a vibration, a threshold and a motif that has human dimensions thanks to the injection of the *Modulor* into its proportions, expressing space-time by fragmenting it, dilating it and compressing it thanks to a musical component. This is what undulating glass panes are and what their 2022 version should express.

4. Conclusion

As we have seen in the course of this work, the undulating glass panes of the Couvent de la Tourette remain both a strong architectural element, guardian of a secular doctrine, and a musical artefact inscribed in a trajectory of Iannis Xenakis and the wider one concerning the representation of time. Indeed, the concept of the undulating glass pane is a two-dimensional transposition inspired by *Metastaesis*, into a graphic and architectural score. The undulating glass panes were used in the vast majority of Corbusean projects before and after that Iannis Xenakis left the office. In fact, the power of the undulating glass panes of the Couvent de la Tourette will find little echo in later projects. The device is now part of the post-war Corbusean motifs, which raises questions about its implementation today. The path we developed in the last chapter seems sufficiently solid to lay the foundations for our personal project, but also for anyone who wishes to evoke the same architectural force and intensity that Iannis Xenakis injected into his device.

Iannis Xenakis' trajectory does not end here and, in fact, has only just begun. In 1958, Iannis Xenakis took up the glissandi of *Metastaesis* as part of the composition of the Philips Pavilion project. Iannis Xenakis then used them to precisely define the isoparametric ruled surfaces

composing the walls of the object. Thus, he moved from a two-dimensional architectural partition with undulating glass panes to a three-dimensional architectural partition developing in space.

Figure 42: Wouter Hagens, View from the exit of the Philips Pavilion, 1958

The conquest of dimensions through successive musical and architectural abstractions continues. His later creations, in particular the *Polytopes*, share striking similarities to the three-dimensional transposition of the Philips Pavilion. If we compare the latter with the Montreal *Polytope*, for example, we see that the *Polytopes* are merely a higher stage and logical continuation of the Philips Pavilion, which is nothing more than a frozen *Polytope* remaining in three dimensions. The *Polytopes* are in fact a device of spatialized sounds and lights according to time where architecture is sometimes reduced to simple cables reducing the limit between architecture and music.

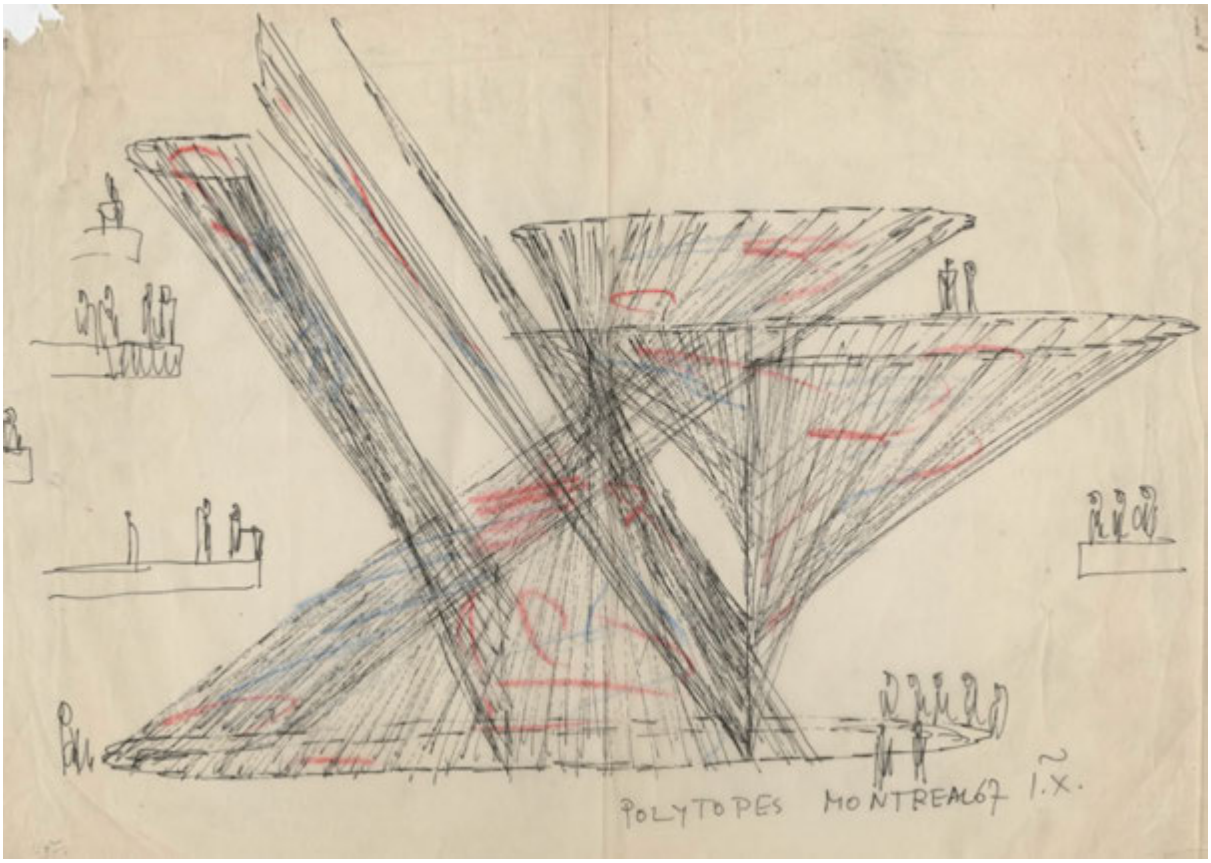

Figure 43: Iannis Xenakis, sketch for the Polytope de Montréal, 1967 (credits : © Famille I Xenakis)

Finally, it should be noted that this personal trajectory involves elements whose strength is remarkable each time: the music, the *Modulor*, *Metastaesis*, the undulating glass panes, the Philips Pavilion, and the *Polytopes* are, each one of them, accomplished creations. We wish to emphasise that they emerged from one and one person only, one genius, Iannis Xenakis.

Acknowledgments

We would like to warmly thank the staff of the Couvent de la Tourette for their welcome and availability. We would like to thank Brother Charles, architect and Dominican monk residing at the Couvent de la Tourette, for his patience, his listening skills, the interest he showed in our research subject during our discussions and the time he took to inform us about the life of the Couvent and its specificities. Our thanks also go to the various foundations that generously opened their doors to us, in particular the Le Corbusier Foundation and the association Les Amis de Xenakis. We would also like to warmly thank the EPFL library and its team, who allowed us to have all the books necessary to write our work. We would also like to thank Professor Roberto Gargiani for the time he devoted to answering our questions about the *Modulor* system. Finally, we would like to thank our follow-up team, namely Professors Franz Graf and Eric Lapierre, as well as Doctor Yvan Delemontey, who agreed to follow us on a perilous adventure at the crossroads of the arts and sciences. Finally, our gratitude goes to our relatives who supported us throughout our research.

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Fig. 37 : Thermos, A picture of the Porch of Maidens, 2006, https://upload.wikimedia.org/wikipedia/commons/5/5a/Porch_of_Maidens.jpg (consulté le 04.03.2022)

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Fig. 43 : © Famille I Xenakis

XAS DECODED

Author : Pantelis Lykoudis, BA of Hogeschool voor de Kunsten Utrecht , the Netherlands,
youtube.com/channel/UC6a-c2E9jEEyMVgojKTXsvQ – soundcloud.com/pantelis_lykoudis

Proceedings of the *Xenakis 22: Centenary International Symposium* Athens & Nafplio (Greece), 24-29 May 2022 - https://xenakis2022.uoa.gr/

Abstract

'XAS' (1987), the only original saxophone work of Iannis Xenakis, presents performers with a number of technical and interpretative challenges. These include the taming of an extreme dynamic range over an extended tessitura, the revelation of polyrhythmic patterns and combination tones in different parts of the piece, as well as the notational dislocation of notes from their stems in brief sections. The present workshop, addressed to individual saxophonists or saxophone quartets as active participants but remaining open to all symposium attendees for passive participation, aims to resolve these challenges, which start manifesting in the practice room and present seeming impossibilities during rehearsals. The ultimate performance goal is to transcend these challenges and present Xenakis's reinvented saxophone to the audience.

The centenary of Iannis Xenakis also marks 35 years since the premiere of 'XAS' at the Lille Festival by the Rascher Quartet. It belongs to his last compositional period, when sieve theory, initially used in 'Nomos Alpha' (1965), reached its zenith. Even though not many composers adhered to similar compositional principles, they certainly regarded 'XAS' as a point of departure from the traditional repertoire of the past, which was closely associated with the French Saxophone School. Its influence in saxophone quartet literature written since has been unparalleled. Xenakis showed the ensemble's true potential and in this workshop, you will receive guidance to unlock your own.

TETRAUQ were formed in 2020 with the sole purpose of performing 'XAS'. Their members met in the saxophone class of Johan van der Linden in HKU Utrechts Conservatorium and collaborated in many other occasions. After receiving guidance from their teacher, as well as studying Serge Bertocchi's extensive analysis of the piece (Bertocchi 2001, 179-184) they performed it in June 2021 at the Fentener van Vlissingenzaal. Their performance incorporated stage lighting in direct analogy to the form of the piece, transitioning from darkness in the disordered sections to light in the ordered ones. After an introduction to the formal elements of 'XAS', this workshop aims to introduce saxophonists into Xenakis's world, by exploring how performers can transmit his message to the audience as effectively as possible.

Pantelis Lykoudis will be presenting practice strategies and effective ways to reveal the inner structure of the piece. The limited number of extended techniques used in 'XAS' across all four saxophones, including quarter tones, multiphonics and overtones, will be addressed as well. Several details concerning the score and possible interpretations regarding minor mistakes or ambiguities of the text will be clarified by referring to and exhibiting appropriate solutions. Additionally, another important element of the piece will be put on the table, namely articulation which, when used efficiently, enhances the total impact of the work. As it will become evident, balance is key when approaching 'XAS' and all of the above are aimed to support a proper and well-balanced performance.

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Alfia Nakipbekova

Abstract for the workshop

Approaches to performing *Nomos alpha* and *Kottos* for solo cello by Iannis Xenakis

My workshop proposal concerns approaches to mastering and performing two works for cello, *Nomos alpha* (1965-1966) and *Kottos* (1977), by Iannis Xenakis. Although composed in the early second half of the twentieth century, these pieces are still considered to be extremely challenging from technical, conceptual and performative perspectives. In studying and performing both works, the interpreter is confronted with some idiosyncratic technical issues; facing and resolving these difficulties leads into the broader realms of philosophy of performance and spiritual quest – this is repeatedly confirmed by many performers of Xenakis' music.

In my workshop I will discuss *Nomos alpha* and *Kottos* from various angles, comparing their technical characteristics and the interrelated issues of interpretation, sound, and theatricality in live performance. I will also address the significance of these compositions from the perspective of the development of the cello in the twentieth century.

The question of 'expression' is particularly relevant generally in performing Xenakis' music and specifically, in relation to these works, and will be examined with some references to various research – for example, the analysis of Xenakis' electroacoustic music by Frédérick Duhautpas, Renaud Meric and Makis Solomos (2012) who affirm: 'To understand Xenakis' expressive approach, we need to step back from traditional conceptions of expression [...] the expressive issues in Xenakis' music are not dismissed, but they are redefined along new perspectives'. Developing further the question of 'expression', the article points to a singular quality of Xenakis' music: 'it does not aim at arousing emotions in particular, but visceral sensations resulting from the specific nature of the music'.

To elucidate various issues concerning specific techniques and interpretation I will discuss and compare the selected recordings of *Nomos alpha* and *Kottos*.

Rendering embodied experience into multimodal data: concepts, tools and applications for Xenakis' piano performance

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Proceedings of the *Xenakis 22: Centenary International Symposium* Athens & Nafplio (Greece), 24-29 May 2022 - https://xenakis2022.uoa.gr/

Abstract

Following-up from the four axes presented in our paper proposal, we propose a supplementary workshop for a small group of active participants and an ad libitum (within reason) larger group of passive participants. The ideal duration of the workshop would be about 4-6 hours (half-day workshop), but we will do it in the 1h45m available. We will be presenting the complete range of materials (hardware, software, data libraries and data analyses) and applications for both active and passive participants.

The main core of the workshop will be the presentation of the system *GesTCom*[1] (acronym for Gesture Cutting Through Textual Complexity), which has been developed since 2014 in collaboration with IRCAM (*interaction-son-musique-mouvement* team).

GesTCom is a sensor-based environment for the visualization, analysis and following of the pianist's gestures in relation to the notation. It comprises four modules, implemented in the form of Max/MSP[2] patches featuring the MuBu[3] toolbox and connected to INScore[4] scripts:

a) a module for the synchronized recording of multimodal data of a performance;

b) a module for the reproduction and analysis of the data;

1 https://medias.ircam.fr/x2253e1

2 https://cycling74.com/

3 https://forum.ircam.fr/projects/detail/mubu/

4 http://inscore.sourceforge.net/

c) a module for the processing of the notation on the basis of the data;

d) a module for real-time gestural interaction with the notation.

The end goal is a system of mutual reinforcement learning between human and machine. Such a system optimizes the piano performer's learning experience through longitudinal multimodal performance documentation, real-time activity monitoring with augmented feedback and guidance, and real-time adaptation of the complexity of the music notation, according to the user's developing skills.

The second point of focus will be the presentation of interactive tools for augmenting Xenakis' *Evryali* ("the extended sea") for solo piano. We present this work as an interactive scenography composed of a virtual space that hybridizes the musical score with the physical space in real time on stage.

The workshop will attempt to address all four axes presented in the 'Call for Papers':

1) *Presentation of tools and methodologies for capturing the Xenakian body in performance:*

The systems in question include:

Hardware: inertial sensors (BITalino R-IoT sensors5, Perception Neuron6 full-body motion capture), systems of capacitive sensing on the keys of the piano (TouchKeys7), EMG equipment8, Kinect, MIDI and sound recordings.

Software: Max/MSP patches and INScore scripts for the recording, playback, analysis, following and multimodal augmentation of data and of music notation.

Active participants will be invited to experience the affordances and constraints of these systems, trying out Xenakis' works for piano on the basis of existent recordings;

2) *Analysing the corporeal subtext of Xenakis' notation:*

This axis of the workshop will present analytical work on Iannis Xenakis' *Mists* and *Evryali* and methods to explore the relationships between musical score and multimodal data.

3) *Creating interactive systems for enabling learning through multimodal data:*

In this part of the workshop, selected participants will have the chance to explore the motion following possibilities of the *GesTCom* system and try out alternative notations for Xenakis' piano works, which might facilitate the first stages of the learning process.

4) *Augmenting Xenakis performance:*

Presentation of the system and active participation in the interactive control of the digital staging using the realtime 3D software Unity.

List of required in situ

Grand piano and/or keyboard with MIDI capabilities and sensitive touch

5 https://forum.ircam.fr/projects/detail/edit-in-administration-bitalino-r-iot/

6 https://neuronmocap.com/

7 https://touchkeys.co.uk/

8 https://developerblog.myo.com/

Audio equipment (speakers)

1 projection screen (3 meters x 2 meters minimum) or white walls

2 short lens projectors full HD 3000 lumen minimum HDMI

2 HDMI cables 10 meters

4 Power Strips 3-Outlet minimum

4 Extension Cord 10 meters minimum

3 Tables

4 Chairs

3 Black tablecloth

1 Black Gaffer 50 meters minimum

1 Touch Screen min 15 inches HDMI

The rest of the equipment will be provided by us (the workshop organizers).

Short CV (100 words)

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https://eur-artec.fr/projets/habiter-avec-xenakis/

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The Situationist Polytope

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Abstract

The Situationist Polytope is an artist-led workshop for ten participants which combines Iannis Xenakis' distinctive typology of installation – inclusive of sound, light and architecture (Sterken 2001) – with a psychogeographical approach to the exploration of the urban environment through acts of *dérive* and *détournement.* The workshop is informed by the etymology of 'polytope', as it draws from multiple sites across the city of Athens, transcribing the visual characteristics of various locations in music box notation form and, finally, condensing them into a single multimedia performance. If the scale of Xenakis' Polytopes was vast – with the *Polytope de Mycènes* being the most grandiose of all – the Situationist Polytope explores how architecture can be musically articulated in an intimate dimension.

The workshop consists of two parts, the first one of which is self-led. Following a set of prompts/instructions, participants will transcribe parts of the city and its illumination in the form of hole-punched music box scores. These present similarities with the light frames employed by Xenakis to compose the *Poème de lumière* for the *Polytope de Montréal* (1967) in their appearance and perforated structure. While Xenakis aimed at "creat[ing] a luminous flow analogous to that of music" (Fleuret 1988, 175) the music box scores attempt to capture urban illumination as architecture's *frozen music* in a subjective and intuitive way.

Starting with the observation of a building or a particular view of the city, scores are generated by copying patterns of illumination onto the music box paper and hole-punching accordingly. Each participant might adopt a variety of techniques for this purpose: from using paper stencils made from pictures to parametrically assigning visual patterns to the 30-note tablature matrix. The aim of this exercise is to produce "photographic scores" which are clearly derived through visual resemblance. Participants are encouraged to repeat the same scoring exercise from various perspectives and at different times of the day and night. Exploiting their subjects' "luminodynamism" (Schöffer 1996), the urban environment will be drawn as temporal architecture with its own intrinsic rhythms as well as an "energetic space […] defined by sensory qualities" (Sterken 2001, 263)

In the second part of the workshop participants will meet and work collectively to finalise their rolls of notation and assemble them with the music boxes as to form circular endless loops. They will also be able to personalise their devices with found materials and objects to augment their music box, experimenting with various resonant materials as sounding boards, as well as preparing the music box by inserting objects into the notes' lamellae. Augmenting the portable set up with small LED torches allows sound and light to be produced simultaneously – yet heterogeneously as counterpointed media parts – by hand cranking the music box mechanism. In this way the Situationist Polytope approach draws

a link with Xenakis' *Polytopes* where sound and light exist as two separate forms of music, one concerning the visual and the other the sensory apparatus where "the link is not between them but beyond or behind them" (Varga 1996, 114). The workshop shall finish with an audio-visual performance of all scores, leading to a re-work of the urban environment into a dynamic sound and light environment. Here each participant will be the interpreters of their scores and, together with the audience, will be able to move freely across the performance space.

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Creative mathematics: randomness, indeterminacy, unpredictability in music and architecture

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Abstract

The points of departure for this paper are two of the most important facets of Xenakis' work, namely his profound interest for the notion of randomness, which acts as both an inspirational force and an operational tool, and his attachment to mathematics, which is for him a kind of "guardrail", as Mâkhi Xenakis had once said. Randomness is often seen as indeterminacy, unpredictability, uncontrollability; as regularity or, on the contrary, as irregularity or singularity; as the impossibility of repetition; as the "mesure of our ignorance" – if we borrow the words from the mathematician Henri Poincaré –, or as the incapacity to recognize a subject in some circumstances… "Randomness is the subject of the verb 'to choose' when this subject is unknown, or impossible to know, or even does not exist", as the biologist Albert Jacquard puts it in this elegant and intriguing formula. The paper explores from a philosophical and a mathematical point of view the notions of randomness, indeterminacy and unpredictability, and questions their role in some creative processes in music and architecture, from the stochastic music by Iannis Xenakis using classical mathematics, to his algorithmic investigations and to some aspects of the "parametricism" and multi-agent systems in contemporary architecture. We will try to point out the differences between the three notions: randomness, indeterminacy and unpredictability, which are often used almost indistinguishably in common language, and question their capacity to motivate innovating design processes. Xenakis himself, in a late article entitled "Determinacy and indeterminacy" (1996), clarifies the meaning of these notions in contemporary science and explains their transposition and application in musical composition, without omitting to mention the semantic distance between the scientific definition and his artistic interpretation. We then will try to show the three levels of application of randomness by Xenakis in his musical compositions: first, as a particular type of indeterminism; second, the implementation of mathematical formulas coming from probabilistic theories; third, the use of random values. More generally, we will try to qualify the evolution in the use of mathematics in Xenakis' work both in music and architecture. Questioning the of mathematics by Xenakis, we will underline the profoundly structural role that he attributes to mathematical formalisation as well as the fact that he ultimately transforms a descriptive tool – the equations and functions to which are reduced some natural phenomena – to a generative one capable of producing aesthetical value and meaning. We will finally move from probabilistic theories and mathematical formalisation to cellular automata and computational procedures, and from top-down approaches towards bottom-up ones, trying to unveil the different tendencies that exist explicitly or latently in Xenakis' heritage and that can be found in contemporary architectural or artistic actions, or even inspire new ways of creation.

1. Introduction

Xenakis is widely known for having applied mathematical formalisation to musical composition in a quite sophisticated manner for a composer, and in particular for having introduced in music probabilities theory. Naturally, this aspect of his work is largely and often brilliantly explained, analysed, documented, first of all by Xenakis himself. So, we will try to present a line of thinking and an argumentation on this topic confronting it with some scientific questions relative to the basic notions conveyed by Xenakis' writings, and also with some issues linked to similar concepts in contemporary digital architecture, while trying to repeat as less as possible the already existing descriptions and analyses.

Our research has three parts. In the first part we will question the use by Xenakis of the notions of randomness, unpredictability and indeterminism. In the second part, based on the conclusions of the first part and also on his proper writings, we will try to interpret more generally some aspects of the relation of Xenakis to mathematics. In the third part, we are going to investigate how these notions and interpretations can be found in contemporary creative practices in architecture and design.

We are going, thus, to study here only one facet of Xenakis' work, namely his interest for mathematics and especially randomness and probabilities. Xenakis declares, especially with the publication of *Musiques formelles* (Xenakis 1963), the intention to establish musical composition on a formal basis as it happens with mathematics. This ambition in reality corresponds, as Makis Solomos states, to only a small part of his trajectory, identified in the period between 1963 and 1965 (or 1967-1968, if we consider the composition *Nomos Gamma*) (Solomos 1996, 26-27). However, the article "Determinacy and indeterminacy", published in 1996, which will be at the core of our study, shows that Xenakis had always in mind the basic principles of his first theoretical and experimental investigations.

2. Randomness, indeterminacy, unpredictability

As we know, Xenakis calls the music he composed using probabilities theory, "stochastic", term that expresses the randomness conceptually included in the process of composition. But it is interesting to question what randomness means in everyday life, what in science and especially in mathematics, and what in Xenakis' approach. We should clarify however that for Xenakis the stochastic music does not mean "aleatoric" in the sense of improvised music (Xenakis 1996, 144). In fact, we find randomness in the "strong sense" in some experimentations of John Cage or Karlheinz Stockhausen, where the musical composition is deliberately under-determinate, almost incomplete, open to different interpretations[1]. This is not exactly the case of Xenakis.

Randomness is generally linked to unpredictability and to indeterminism, however these terms are not synonymous. The word "randomness" is, besides, probably the most difficult to define since the scientific evolution has detached the three terms – Xenakis himself points out this difficulty (Xenakis 1963, 16). In fact, in everyday life we consider as random the phenomenon which cannot be predicted on the basis of a deterministic process, and the three notions – random, unpredictable and non-deterministic – are intimately tied together. As the mathematician Henri Poincaré had sated – before putting his statement into question – randomness is the "mesure of our ignorance" (Poincaré 1908); which means that what we consider as random is that which we are unable to know scientifically well enough to predict its evolution in time. Classical science aimed to abolish randomness and considered that deterministic systems – that is, systems described unambiguously by mathematical formulas – are predictable. This is true for some of them. However, Poincaré, with his solution to the famous three-body problem, was the first to put the basis of what is called Chaos theory, showing that there can exist deterministic systems which are not predictable because of their sensibility to initial or contour conditions – the famous "butterfly effect". Furthermore, quantum mechanics suppose an even

[1] See for example Daniel Parrochia, *Philosophie et musique contemporaine, ou le nouvel esprit musical* (Seyssel: Champ Vallon, 2006).

more profound meaning of randomness, a randomness that is irreducible; that is intrinsic and consubstantial to the phenomena studied at the atomic and subatomic scale.

Moreover, in physics and natural sciences we can state that a random phenomenon not only cannot be predicted but neither can it be exactly repeated: identical repetition is impossible because of the chaotic behaviour resulting from what is called the exponential drift (the effect of cumulating imperceptible divergences in the process).

In computer science, randomness is whole another subject: the algorithmic process in a digital computer is both deterministic and repeatable. Due to the discrete nature of the digital machine, the experience can be repeated identically as many times as we wish, because there is no place for exponential drift in such a device. Real randomness cannot exist in a digitally implemented algorithmic process[2]. Randomness is thus defined in theoretical computer science by Gregory Chaitin in relation to predictability in an algorithmic sense: a series of numbers is random if there is no algorithmic shortcut capable of describing it[3] (Chaitin 1975). Chaitin's line of thinking, which offers an interesting interpretation of predictability in the context of computer science as an algorithmic shortcut, is nonetheless justifiably criticized for identifying randomness to incompressibility (Longo, Palamidessi, Paul 2011, 6).

For Xenakis, randomness is a way to introduce indeterminacy in an otherwise deterministic compositional system (Xenakis 1963, 18-19). In a late article untitled "Determinacy and indeterminacy", he states: "Determinacy constitutes a very important and deep question, especially when considered against a background of physics and computer science." (Xenakis 1996, 143)

If Xenakis refers to both physics and computer science, furthermore he insists especially on physics and on the move from Newtonian mechanics to deterministic chaos theory. That said, and in spite of his article's title, between the three notions – randomness, indeterminacy and unpredictability – it is, in fact, unpredictability – in the common sense – that interests him the most. He praises, for example, "the unexpected variation of the rhythmic patterns" on some traditional music (Xenakis 1996, 143). According to him, "expectancy in rhythm" is a problem; the composer has to find variation inside repetition, a "kind of surprise" which "represents an important factor in aesthetics" (Xenakis 1996, 144).

Xenakis relates the problem of determinacy to that of repetition, or of symmetry (Xenakis 1996, 147), which is to space what is repetition to time, as he says (Xenakis 1996, 144). So, he doesn't pursue randomness per se, but for the results it may give to the form in terms of aesthetics. Thus, he doesn't exclude on principle deterministic processes if they can lead to unexpected forms, as he explains when he talks about the complexity that can be achieved even with the use of regular patterns (Xenakis 1996, 148). Probability distribution is then seen as an alternative to the methods creating irregularity out of initial regularities: it is a way to introduce a kind of irregularity from the beginning. It guaranties an irregularity which is mathematically controlled, the informal coming out of rather rigorous formalization. Xenakis insists on this point:

"We are not talking here about cases where we are contented to playing heads or tails in order to choose such or such alternative on details. The question is much more serious. It is about a philosophical and aesthetic concept governed by the laws of probability theory and by the

[2] Random numbers in a computer are pseudo-random numbers, resulting of specific operations upon an initial number called the "seed"; the same seed via the same operations will always give the same pseudo-random series. We should note that Xenakis, in 1996, is perfectly aware of this kind of contradiction in computers, he even says: "We start with a generator of random numbers such as a computer, although this may seem paradoxical, the computer being a deterministic machine" (Xenakis 1996, 144).

[3] Chaitin pushes the reasoning to its limits, disconnecting it definitely from the causal argument: according to his statements, we should not consider as a random series one presenting regularities that may permit an algorithmic shortcut to its description, even in the case the series has been randomly produced.

mathematical functions that formulate them, a coherent concept in a new domain of coherence[4]" (Xenakis 1963, 37).

So, what is the place of randomness and unpredictability in such an approach?

If we study the first important example of Xenakis' stochastic music, namely the composition *Pithoprakta*, we can identify three different expressions – or levels – of the application of the notions of indeterminacy and randomness. The first level is about a particular type of indeterminism in the creational process, as we explained it above: the basic components of the composition, i.e. the distribution in time of different individual sounds creating a mass effect, is not defined by the composer, but it is precised with the help of mathematical formulas. This procedure is, scientifically speaking, absolutely deterministic. However, it is not the composer who determines the elements, so there is a resemblance of randomness or, better, a kind of unexpectancy, from the subject's (the composer's) point of view.

The second level is the most important and probably the most original, but it is also the most ambiguous, because it involves a sort of semantic slip in the very concept of "stochastic". This level is, in fact, not connected to the first one, if not by a wordplay. As we said above, the composer delegates the sounds' distribution to mathematical formulas. These formulas could have been any equations or functions; the choice of the formula does not necessarily affect the kind of indeterminacy or the unexpectancy of the first level, resulting from the process. Xenakis himself accepts that the "procedures can be applied with distributions other that the logistic, for example with exponential and hyperbolic functions" (Xenakis 1996, 152). However, Xenakis uses, as we know, not any mathematical formalisation, but precisely those of probabilities theory. Randomness and stochastic functions, as he says, is a way to obtain the complexity he is searching for (Xenakis 1996, 153). Of course, here probabilities theory are not used to predict a physical or natural phenomenon, but to determinate the exact distribution of sounds: in *Pithoprakta*, where Xenakis uses Poisson distribution, he turns probabilities into certainty, he fixes them, in a way. Thus, even if it is precisely this part of his work that justifies the qualifier "stochastic", there is here rather a simulation of the randomness existing in some situations, evaluated statistically and described by the relevant mathematical formulas. This little paradox is evident when Xenakis says, in the chapter on Markov stochastic music, that some sound elements "are distributed randomly, according to a rule we are going to define" (Xenakis 1963, 71); there is then an oscillation between randomness and determinism.

The third level concerns the most literal acceptance of randomness in the process. Xenakis mentions the use of random values in his calculations, in order to avoid repetitive patterns and to achieve an interesting degree of variety and differentiation. These random values are obtained manually or with the help of a computer (they are, thus, pseudo-random values, but this has no impact in practice). This level, the most technical, is, as we saw in the citation by Xenakis above (Xenakis 1963, 37), the less important for him.

If Xenakis refers to physics, his use of the three notions, unpredictability, randomness, indeterminacy, consists, in big part, in an interpretation. We don't see here some incoherence: it is the privilege of the artist, the creator, to displace or to unsettle the canonical expressions of science and to get inspiration from them, for the value of a piece of art does not depend on the scientific validity of its creation process, neither on its conformity with some scientific model or argument.

3. Xenakis and mathematics

Contrary to what is sometimes stated, Xenakis was not a mathematician, even if he had certainly a good, probably very good, scientific background thanks to his studies as an engineer in the Athens

[4] "On ne parle pas ici des cas où l'on se borne à jouer à pile ou face pour choisir telle ou telle alternative de détail. La question est bien plus grave. Il s'agit ici d'un concept philosophique et esthétique régi par les lois de la théorie des probabilités et par les fonctions mathématiques qui les formulent, d'un concept cohérent dans un domaine nouveau de cohérence."

Technical University. He used mathematics – and also abused, we might say: if his practice in geometry or algebra and calculus are rigorous, his vision of mathematics involves also interpretation, sometimes over-interpretation, if not metaphor. Besides, his discourse on mathematics does not have the precision of a mathematician, and we can point some examples of approximations found in his writings: he says that the Modulor is an additive series, as if he meant that it is an arithmetic series, which it is not; he also says that the Modulor is a geometric series, while it is not one; he says that the ratio between two consecutive terms of a Fibonacci series is constant and it is the golden ratio, but both statements are false (Xenakis 1957).

Xenakis used mathematical formulas, but he didn't *do* mathematics. The philosopher Olivier Revault d'Allonnes said something similar in his commentary during the defence of Xenakis' doctoral dissertation: if art profits from mathematics, the reverse is not true; in other words, there is no scientific, mathematical inventiveness in the work of Xenakis (Xenakis 1979, 31-32) – what Xenakis himself recognizes willingly: "I was led to solve them [the problems in music composition] using almost ready-made mathematics […] I almost never did the reverse[5]" (Xenakis 1979, 42).

Xenakis not only uses mathematical formulas, but also is inspired by mathematical formalisation in general, and aims to transpose its principles to music composition. As Makis Solomos puts it, "it is about 'formalizing' music, in the way that mathematicians have, throughout this century, tried to 'put the foundations' of their discipline, that is to say, to find a concise axiomatic from which everything could be deduced[6]" (Solomos 1996, 26).

Nonetheless, Xenakis has recourse to mathematics considering it as a powerful, coherent tool but without considering it rational in absolute terms, metaphysically speaking. He even does, during his doctoral defence, a statement according to which in mathematics "axiomatic is a choice, an arbitrary choice[7]" (Xenakis 1979, 38) – statement which is a bit exaggerated, we might say. Xenakis has certainly in mind the upheaval caused in mathematics by non-Euclidian geometries, the Gödel theorem, Chaos theory and Quantum mechanics, which have successively undermined some of the historical intuitive certitudes regarding the foundations of science. Xenakis refers to them to put forth his conviction that there is no "absolute truth" neither in science nor in art (Xenakis 1979, 15) and he even thinks science is ambiguous, mentioning the failures of classical mechanics (Xenakis 1979, 59); he considers even mathematics "experimental" (Xenakis 1979, 15), and by doing so, we could say that he establishes a kind of fundamental equivalence between art and science.

At a practical level, Xenakis' work oscillates between direct application of mathematical formulas, as in some parts of *Pithoprakta*, and merely imitation of mathematical reasoning, as in *Jonchaies*. The latter involves that the process is closer to an algorithmic one, than to a mathematical one, since it concerns a step-to-step unambiguous and deterministic procedure. This algorithmic aspect is literally implemented in *Achorripsis*, for which Xenakis uses for the first time a computer in musical composition. That said, neither the application of formulas nor the algorithmic method, mechanised or manual, attain the status of a rational deductive process, as in mathematics. "There is no such thing as creation by rationality", says Xenakis (Xenakis 1996, 148).

We should then sketch how evolves Xenakis' relation to mathematics, taking as an example a short fraction of his trajectory, from *Metastaseis* to *Pithoprakta*. In *Metastaseis*, in the famous part with the graphic of curves formed by straight lines, sounds are generated by a pitch/time notation following a particular geometric pattern, namely parabolas defined by their tangents (approximatively). Geometry is translated into music, whatever the deeper meaning of that may be. It is about imitation of form, in a very elementary analogical manner. In *Pithoprakta*, we have in the same way, at first glance, the

[5] "[...] j'ai été conduit à les résoudre [les problèmes dans la composition musicale] à l'aide de mathématiques presque toutes faites […] je n'ai presque jamais fait l'inverse".
[6] "[...] il s'agit de «formaliser» la musique, à la manière dont les mathématiciens ont, tout au long de ce siècle, tenté de "fonder" leur discipline, c'est-à-dire de trouver une axiomatique concise d'où tout pourrait être déduit."
[7] "[...] l'axiomatique est un choix, un choix qui est arbitraire".

transcription – more sophisticated, that said – of mathematical formulas into sounds. But there is more. Mathematics is not imitated or transposed *per se*, as in *Metastaseis*, but it is the indispensable mediator between two distinct phenomena, the first coming from the external world and the second being the music composed. We recognise hence Xenakis' profound conviction that the mathematical formalisation is capable of modelling and carrying intrinsically the essential properties of a natural, physical or social phenomenon, so as to transmit them to forms belonging to other domains, such as, in this case, music written by a composer. Mathematics acquire, then, an eminently structural role. Xenakis turns equations and functions, from descriptive tools, into generative ones producing aesthetic value and meaning. The status and the role of mathematics differ, thus, between the two examples.

The above observations trigger us to question the possible contrast between Xenakis' methods coming from his architectural practice and those he forged specifically for his musical compositions, put aside the analogies existing between the two (Kiourtsoglou 2016). We think especially of the use he does of Le Corbusier's Modulor, a tool that discretises linear space with the help of a predetermined scale, in comparison to stochastic processes Xenakis uses later, aiming to fix the position of sounds in time by means of determinate formulas yet probably in a more supple way.

The two methods have the same objective, to achieve a resemblance of aleatory distribution throughout precise mathematical formalisation. In the first case we have the direct application of a rigid pattern, in the second an invisible, abstract formula with structural and generative capacities. However, mathematically speaking, both are, as functions, equivalent. The possible difference between the two methods is not the fact that in the Modulor's case an additional step is done towards numerical concretisation, as we could say at first glance, because all scale is relative and numbers have no importance as absolute values but in relation one to the other. The difference can only then reside in the particularities of each formalisation itself. The formalisation is less rigid in the case of stochastic processes if only there are more than one variables we can manipulate, if more than one random values can be introduced, or if we avoid discretisation at all (which is difficult to imagine in practice). Surprisingly, then, if at first sight we could oppose a rigid pattern (the Modulor) to a flexible function, the essential difference between the two methods is not always evident and it may be, paradoxically, rather quantitative than qualitative.

We would like to add here a note about the over-interpretation Xenakis does occasionally relatively to mathematical reasoning, taking as an example the analogy between the notation in *Metastaseis* score and the Philips Pavilion constructed in Brussels in 1958.

The famous graphic, already mentioned, in the *Metastaseis'* score resembles, in fact, to a projection of a hyperbolic paraboloid, like those which compose the Philips Pavilion. Xenakis himself does clearly the link between the two. In the same time, the curve of the graphic is (almost) a parabola formed by a family of straight lines; it is typically an envelope curve. This geometric principle is a tool of graphic methods in static mechanics. Such an inspiration is conjectured, plausibly, by Elisavet Kiourtsoglou in her PhD dissertation, showing such a graphic found in Xenakis archive, from the time of his studies in engineering (Kiourtsoglou 2016, LXXX).

So, the *Metastaseis* schema, is it an envelope curve, or a hyperbolic paraboloid's projection? Actually, in differential geometry, is demonstrated an equivalence between an envelope curve and the projection of a family of curves in a three-dimensional space. Xenakis mentions envelope curves, but did he know positively the aforementioned geometrical property? Not easy to say, but it is possible that Xenakis had found it out intuitively, or even not at all, the iconic resemblance being probably sufficient. In any case, it is difficult to imagine that he could have gone from the *Metastasis'* score to the Philips Pavilion without the previous knowledge he did have of hyperbolic paraboloids in the domain of architecture, thanks to Laffaille's and Candela's works, which he explicitly mentions.

Unlike most researchers, and even contrary to what Xenakis himself argues (Xenakis 1963, 20-25), we tend to see here rather an interesting coincidence than a direct inspiration or deliberate

implementation of an analogy between music and architecture. Besides, the fact than in the first sketches of the Philips Pavilion he uses not only hyperbolic paraboloids but also cones and conoids, depending on their position in space, shows that his formal research was primordially architectural, and that the analogy based on the hyperbolic paraboloid came probably afterwards. The mathematical description advanced by Xenakis acquires then an almost rhetoric function, over-interpreting the impact of the geometry in order to underline the continuity between the different artistic expressions (music and architecture).

4. Xenakis' approach and architecture in the digital era

We should point out the extremely generic character of Xenakis' approaches, which means that they can possibly be transposed on practices in other fields. Xenakis himself says so: "What is interesting to notice is that in other artistic domains the same sorts of things happen" (Xenakis 1996, 149) and he furthermore refers explicitly to examples taken from fine arts (Xenakis 1996, 149). His constant basic example in "Determinacy and indeterminacy" is the distribution of points in a straight line, which can be a basis for musical composition, but also for art or architecture. The same observation can be made for the main notions in his discourse, such as: repetition, symmetry, variation, pattern, regularity, complexity.

We may use here the – improper but simple – term of "digital architecture" to name architectural practices since the seventies but mostly the nineties, using advanced computational tools in an innovative way, giving birth to forms or design processes non-existing before, or forms particularly difficult to conceive and build without the help of a computer. These practices are also called sometimes parametric, algorithmic or computational architecture. Mathematical formalisation and, mostly, algorithmic morphogenetic processes play a key-role in digital architecture.

Curiously, we can identify similitudes between Xenakis' approaches, practical and theoretical, and those in digital architecture. First, they share a common frame of scientific references: chaos theory, theory of relativity, non-Euclidian geometries, amongst others; we can identify here a sort of attraction to scientific evolutions that seem to have a paradoxical aspect, and thus push the limits of scientific knowledge and unsettle some of the certitudes of classical science. Second, some of the main concerns of Xenakis[8] are the basic problems digital architecture tries also to answer: the mathematic formalisation of the informal; the creation of irregularity out of regularity; the pursuit of variation, in opposition to repetition, and even, sometimes, throughout a repetitive process; the search for continuity, as opposed to the discrete[9]. We cannot analyse here all these aspects, but in the case of Xenakis, all of them are, in one way or another, linked to the question of indeterminacy and randomness.

The very idea of Xenakis about indeterminacy regarding the creative process – i.e. the first level we have identified in the previous section about randomness – is found in architecture some years after the first experimentations of Xenakis with stochastic processes, in particular in the work of John Frazer in the United Kingdom since the seventies. The basic principle in Frazer's work is that, with the help of computers, the creator (architect, designer, artist) does not define the form itself, but he establishes generative rules applied to initial elements, from which the form results (Frazer 1995).

In what concerns indeterminacy, the two ideas, of Xenakis and of Frazer, are quite close in general. However, in stochastic music, Xenakis has in mind the global results towards which should tend the

[8] We refer here mainly to the article "Determinacy and indeterminacy" (Xenakis 1996) but the same motives are found in many of his texts.

[9] In the domain of architecture, see for example Cecil Balmond, *Informal* (New York: Prestel Verlag, 2002); Frédéric Migayrou and Zeynep Mennan (eds), *Architectures non standard* (Paris: Editions du Centre Pompidou, 2003); Leda Dimitriadi, "L'idéologie du continu et l'architecture hyper-standard", in *Thinking-Making. When architects engage in construction*. Edited by Pauline Lefebvre, Julie Neuwels and Jean-Philippe Possoz, 181-194 (Brussels: Editions de l'Université de Bruxelles).

composition, even if its components are calculated via mathematical formulas and are not defined directly by the composer. Consequently, the two approaches differ considerably relatively to the process. In the majority of Xenakis' work using mathematics – some experimentation on cellular automata put aside – there is a top-down procedure, in terms of the initial intention as well as regarding the means used, namely the mathematical method. In fact, regarding the latter, the top-down character of the approach is reinforced by the use of classic mathematical formalization, i.e. functions and equations, which means global control upon the elements.

On the contrary, Frazer's approach is typically a bottom-up process: there are defined the initial elements and rules, from which the form results, whilst the composer has no global control upon it. So, Frazer doesn't use functions or equations describing the form as a totality, but computable procedures such as cellular automata or genetic algorithms, where the behaviour of each element is defined and implemented individually. We should nonetheless underline the fact that, if Frazer and his collaborators use random (or pseudo-random) values in some of their processes, he says little about randomness: what interests him seems to be the fact that we can conceive an unexpected, unimagined form throughout a deterministic step-by-step design procedure.

The bottom-up approach is also found in contemporary digital experimentations in architecture using multi-agent systems. The epistemologist Franck Varenne even considers this kind of conceptual approach as a possibly new paradigm in architectural design (Varenne 2013), one that could be opposed to the homogenising and generalising top-down, modernistic we could say, approaches in architecture which aim to design form as a totality. In the same time, Varenne distinguishes, between the different types of bottom-up techniques or methodologies, the multi-agent systems from genetic algorithms. The first are completely detached from any notion of overall control, they maintain the individuality and the autonomy of each element, whilst the second typically do evaluate their state as a whole, relatively to a prefixed objective towards which they tend "through random trial and corrected error" (Varenne 2013, 102). We should however observe that Varenne's remark is true when genetic algorithms are used for optimisation, but it can be nuanced concerning their use in artistic projects, where there is not always an explicit objective for the algorithm. In any case, randomness Varenne talks about is in fact an important factor for the functionality of genetic algorithms, but it is completely absent from cellular automata and is not absolutely necessary to multi-agent systems. However, the absence of random values in cellular automata and possibly of multi-agent systems doesn't compromise their unpredictability in the algorithmic sense (Zwirn 2015).

We find the use of multi-agent systems in the work of the architect Marc Fornes – an example is the "Double-agent white", a little pavilion with seemingly aleatory patterns (Fornes 2012) – or in the projects of the architect Alisa Andrasek, for example the project "Agentware Research" (Brayer et al. 2009). These experimentations can stand in the opposite of Xenakis' top-down method. More generally, bottom-up processes cannot be described by classic mathematical formalisation, and even if they are deterministic, there is no shortcut which could permit to predict their evolution: they go a step further. In the same time, the kind of indeterminism they involve at the first level identified earlier, i.e. relatively to the creative subject, is in fact quite similar to the one to which Xenakis aspires.

5. Conclusion

After having clarified three different levels of application of the notions of indeterminism, randomness and/or unpredictability in some of Xenakis' work, we tried to comment some aspects of the way Xenakis sees and uses mathematics and we mentioned briefly the key-concepts conveyed by his theoretical positioning and argumentation. We made a parallel between Xenakis' approach and digital experimentations in contemporary architecture, leading finally to the essential distinction between top-down and bottom up processes. Of course, we should clarify that not all processes in digital architecture are bottom-up; on the contrary, most of them are not, and we can find in parametric architecture formalisations equivalent to those of Xenakis. But we insisted on the aforementioned distinction because it possibly implies a change of paradigm.

We can thus plausibly argue that Xenakis' approach in what concerns indeterminacy in artistic creation stands on the opposite of contemporary approaches in architecture having the same general objective, but using cellular automata, genetic algorithms or multi-agent systems, to name the processes mostly used in this domain.

And yet, the bottom-up approach is underlying in Xenakis discourse as well, it is latently there, as an inspiration or even as a conceptual potential. Xenakis describes his motivations for stochastic music in many of his writings, and he refers repeatedly to phenomena – natural or social – composed of autonomous individual elements whose behaviour can be interdependent but is not submitted to any kind of total control: insects' noises, a crowd's sounds, etc. (Xenakis 1981, 19); they correspond almost perfectly to the paradigm of bottom-up processes, since there is no global control upon them in the first place. Xenakis did not have the computational tools, at that time, to simulate such processes, so he deals with them statistically using classic mathematical formalisation, which gives him total control upon the entire mass of elements. The use, for the same goal, of bottom-up algorithms would have introduced a higher degree of unpredictability. Would he have experimented with such computational tools if he had the choice? It is possible. But this would have implied to move from mathematics to computational simulation, which means to turn towards a whole another epistemology, which is still to construct (Jebeile 2013).

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The BaXen, when Xenakis invites himself into a school of architecture

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Abstract

This paper tells the story of a new holistic creation: the BaXen (2011). This total work of art is intended to pay tribute to Xenakis on the tenth anniversary of his death. From its conception to fabrication, from the realization of an object of sound design to its setting, from the composition of a piece dedicated to a concert performance, BaXen is the architectural result of a five-day intensive workshop attended by 15 students of the Master of the National School of Architecture of Lyon, accompanied by a composer, a musician, a luthier and an architect. The project is experimental in several ways. Inspired by the figure of the mathematician-composer and the *instrumentarium* of the Baschet brothers, the students gave birth to an object that is a hybrid between musical instrument and sound structure and between microarchitecture and sound sculpture. The acoustic principles implemented have been an impactful lesson of acoustics for the future architects. At the heart of the project were students manufacturing vibrations of matter and sound waves transmitted to the diffusers. Engaged in a global process of creation, students participated in all stages of the project: integrating the gestures of the percussionist into the ergonomics of the structure, machining with precision the Baschet instruments under the wise advice of the luthier, staging the concert within the walls of the school, and participating as choristers in the world premiere of an André Serre-Milan's play specially written for BaXen and taking place in a musical program punctuated with pieces by Iannis Xenakis. The project is also experimental in its process. It was conceived on the occasion of a concert given within the walls of the School of Architecture of Lyon designed in 1985 by the architect couple Françoise-Helène Jourda and Gilles Perraudin. It was necessary to integrate the interior acoustics of the building with the general staging, in spite of the sound qualities of the atrium space and the interior street, which were neither conceived nor claimed for this use by the architects. The concert imagined by the artistic team was an opportunity to highlight the great reverberation of the place and to reveal to the public the potential of spatialization and sound localization via games specific to the spatial arrangement of the musicians in the stairs or passageways; spatialization that the original musical composition has been able to fully integrate. Music and architecture became one. Channeling the personality of Iannis Xenakis proved to be a very rich field of invention. In fact, the inspiration for BaXen lies within the mathematical sciences applied to acoustics, musical practice and architecture as space science. The collaboration with Le Corbusier as an engineer, shows Xenakis as the prototypical example of the architect-musician. Xenakis makes for a natural link between musicians and architects.

1. Introduction

The BaXen research-creation project resulted from a fortunate meeting between Cécile Regnault, an architect and professor at the École nationale supérieure d'architecture de Lyon (ENSAL) and Laurent Mariusse, a musician, percussionist who is passionate about sound art and contemporary music. From this first chance encounter, one autumn evening 2010, was born the desire to create an event to commemorate the tenth anniversary of the death of Xenakis in February 2001. The question was how does one commemorate a master of the correspondence between architecture and music? The first idea was to cross musical creation with architectural design. Joining artistic goals with pedagogical issues, the second idea was to register the event as an instruction dedicated to the learning of atmospheres[1]. The ambition was to include an experimental construction of an «architecture-instrument» through a research-creation, inspired by Xenakis' inventions. Subsequently, the idea emerged that this "sound microarchitecture", would be called *BaXen*, and it could be conceived, manufactured and played within the ENSAL itself, in a production worthy of the legacy of Polytopes' space-light creations.

The general organization of this project, called an «*Architecture percutée*» was set up on a pluridisciplinary collaborative desire: to organize a percussion concert by playing several emblematic pieces of Xenakis, with a program enriched by a double issue of creation: make an instrument - support for an acoustic pedagogy - and compose an original piece dedicated to this instrument.

Figure 1: Poster of the January 2012 concert at the ENSA in Lyon

[1] If, in French architecture schools, the teaching of the mastery of environments is historically anchored in the teaching of science and technology for architecture, it is by mobilizing the human sciences that the notion of ambience has been able to enrich the sensitive part of architectural projects. Teaching in Lyon since 2016, Cécile Regnault has consistently worked to foster connections between creations, constructive techniques and inhabited practices, through concrete experiments that seek to cross knowledge and knowledge-between the arts, physical sciences and life sciences.

Faced with this ambitious program, the project's initiators aligned themselves to the services of two others whose skills were essential to develop it: the composer André Serre-Milan and the contemporary instrument builder Frédéric Bousquet. With energy and availability, this newly-formed team took residence in the master's option «Construire l'événementiel» imagined and lead by Cécile Regnault in order to develop in young architects the knowledge and know how necessary for designing acoustical space. The relatively short and intensive learning sequence (40 hours) and its calendar had to be flexible enough to adapt to the realization of the event, while allowing time for the introduction of atmospheres' manufacturing to students. The team felt that the singular acoustics and theatrical architecture of ENSAL lent themselves to this type of sound and light experiment.

2. An inspiring work for architects

Working with Iannis Xenakis' personality proved to be an excellent resource and a prolific creative opportunity for architecture students. Indeed, the emblematic figure of this famous composer at the crossroads of mathematical sciences, music and architecture was ideally suited to this exercise. Because of his initial training as an engineer and his collaboration with the architect Le Corbusier, Xenakis is one of the most experienced French composers in spatial transposition of music towards architecture. These disciplinary correspondences are deeply rooted in his practice; whether animated by an architectural project or conversely starting from the sound to the visual, as evidenced by his interest in musical notation and the development of UPIC[2]. For several years now, Cécile Regnault has exploited the didactic richness of his thinking in her introductory classes to ambiences delivered in the first year of the bachelor's program. As such, from 2006 to 2012 she developed an educational sequence in immersion at Le Corbusier's Convent of La Tourette in Eveux-sur-l'Arbresle. The listening approach proved to be the foundation of the path of initiation of sensitivity to architecture at the very beginning of the learning cycle. Cecile Regnault found that if you take the time to stay at the Convent for at least three days, it is the ideal place to develop a sensitivity to the multi-sensority of space. Based on the concrete experience of analogies between musical and spatial rhythms, the "blind-course" exercises[3] offered to the students made it possible to divert for a time the gaze so that they experience the architectural space through the body, by focusing their attention also on the space generated by the ear. Although designed by Le Corbusier, it is well-known that this mid-20th century masterpiece owes much to Xenakis.

A valuable collaborator at Corbusier's Rue de Sèvres workshop, he reconciled both his engineering knowledge and his passion for mathematics. His contribution was fundamental in the drawing of elevations[4], where he worked with calculations to apply the numerical series of the Modulor. Moreover, the facade elements using the wave glass panels[5] owe their extraordinary rhythmic effect to his creative genius, owing to the fact that he was working on the composition of the piece *Metastasis* at the same time. Rhythmicity of elevation drawings and his graphic score of this piece present strong similarities, depicting glissando's principle, generated by a continuous variation of measures. The best way to make students understand this correspondence is to "ring" the waves of glass, to make themselves hear the influence of the dimensions of the lenses struck. This experience has also been widely repeated by several artists invited in residence at the Convent of La Tourette.

[2] The Polyagogic Computer Unit of CEMAMu (UPIC) is a computer-assisted musical composition tool invented by composer Iannis Xenakis. It was developed until 1977 at the Centre d'Études de Mathématique et Automatique Musicales (CEMAMu) in Paris. Xenakis used it for Mycenae Alpha (1978) and was also used by composers such as Julio Estrada, Jean-Claude Risset, François-Bernard Mâche, Takehito Shimazu, Horacio Vaggione, Carlos Grätzer, Mari King and Curtis Roads (excerpt from Wikipedia sheet (https://en.wikipedia.org/wiki/UPIC)

[3] During this exercise, the students wander through the spaces of the convent, one with his eyes blindfolded, the hand on the shoulder of the other who guides him. Deprived of the sense of sight, they must understand their relationship to space differently.

[4] Xenakis' contributions to this project are more precisely set out in the following book: Sergio Ferro, Chérif Kebbal, Philippe Potié, Cyrille Simonnet, *Le Corbusier: Le Couvent de La Tourette*, Marseille, Parenthèses, coll. « Monographies d'architecture », 1er mars 1988, 127p.

[5] Kiourtsoglou Elisavet. De la musique à l'architecture : Le mystère des pans de verre « ondulatoires » du couvent de La Tourette de Le Corbusier et Xenakis, *Intersections: Canadian Journal of Music / Intersections : revue canadienne de musique,* Vol. 35, n°2, 2015. https://doi.org/10.7202/1043822ar

2.1. Passing on Xenakis' legacy to architects

The aim of 2011 workshop's introductory course was to instill Xenakis' thought and work in students as an inspirational source that they could perform in a new order to produce an acoustic instrument staged in a musical event. Hence the broad and pragmatic starting question: How to qualify relations between the architectural conception and musical composition?

The students were thus able to decipher Xenakis' personality through two complementary sources: his writings and his concrete work.

The artist-designer - as he liked to designate himself - showed his double belonging to the artistic and scientific worlds. Initially, he practiced architecture as an engineer (with Le Corbusier from 1957 to 1971); then he was increasingly involved as a project manager in the overall design of the architectural work. For Xenakis, since antiquity architecture has been at the crossroads of science and art in a dialectical aim between the synthesis of the designed space and the detail of technical elements, for example structural or more or less dense light streams that allow leading to an "architectural synthesis". Xenakis has an intimate conviction that music is from Pythagoras in a similar dialectic and this is all the more evident in musical works if they break away from styles and or formatted languages to free themselves in new sound forms. If he kept this disciplinary ambivalence, that is to say being both composer-creator of sound and architect-designer of space, it is precisely to push ever further his research on morphology; it doesn't speak of acoustic dimension of architectural space but more to a creation of a visible form.

Few musicians have understood this dual vocation and synthesis that Xenakis sought by practicing together with the two disciplines. Olivier Messiaen, to whom Xenakis was very grateful for having opened the way for him, said:

"Contrary to my musical predilections, I pushed him to use mathematics and architecture in his music without worrying about problems of melodico-harmonico-contrapuntico-rythmics, he followed this advice which, it seems to me, succeeded him"(Messiaen 1986, 197)

But what did he find in common between music and architecture? Why did he pursue both paths simultaneously? How did this allow him to invent on both sides? To feed on each other? With these numerous writings, Xenakis answers this question theoretically. His synthesizing book "Arts/sciences: alliages" (Xenakis 1980) is the culmination of a maturing and vast process of his world's vision. Xenakis vows to establish a general morphology to a new science, by searching for "intimate structures" of the two arts. The latter, he says, "will deal with forms and architectures of the various disciplines of their invariants and the laws of their transformation." Morphodynamism or morphogenesis in current parlance.

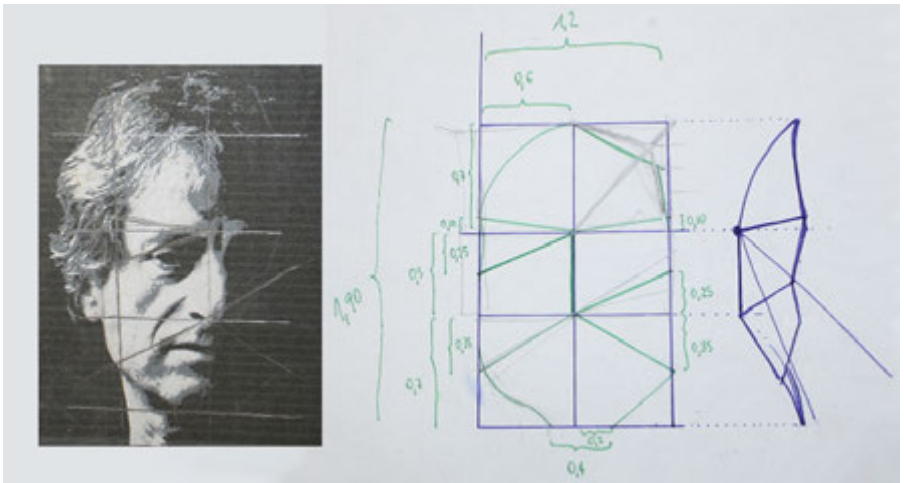

Figure 2: Portrait of Xenakis and the Baschet crystal diffuser sail project

However, going back to the BaXen's design, by immersing themselves in Xenakis' work and bustling life, students seized the ambivalence of this creator, an emblem of an intellectual juggling with multiple skills. They expressed the image of a dual-headed personality, which the composer's photographic portraits referred, with all the ambiguity that the tormented representation of his face raises; leading them unanimously to the idea of transposing the portrait of the composer into the sculptural form of the crystal diffuser.

In addition to performing two of his pieces during the concert[6], his presence throughout the event was ensured through this stylised figure, enthroned at the center of the music scene: the composer's attentive eye and ear were thus present in the midst of the spectators grouped around the BaXen.

Figure 3: Baxen from the front in concert, January 27, 2012 - Lyon

2.2. Common design operator schemes

To illustrate very concretely the intimate structures of the two arts, we have chosen from the beginning of the workshop, to deliver to the student operators schemes of design and their opposites. The first series of verbs "Spaces, graduating VS scaling, staggering" refer directly to an example of a drawing of glass panels which allows us to understand how the same philosophical thought can simultaneously generate a musical and an architectural form; so as to make students understand the principle; it is very didactic to juxtapose the first sketches on a 1954 layer with the geometrical technical drawing of 1956, where we see very distinctly the idea that prevails in this Xenakian invention (first implemented in Chandigarh): the gradation principle. Indeed, the rhythm created here is not that of the repetition of the same unit but search for spacing. Spacing the structural amounts of the facade in an irregular manner (without frames), creates a ripple that also plays with a progressive thickening in a scale that is clearly visible in a light and shadow play: gradual alternations of a modern dark/light crossfade. The graduation effect is directly perceptible regardless of the distances to the façade from the inside as well as from the outside.

[6] *Psappha* and *Rebonds B*

Without seeking direct transposition, just spacing research to organize the structural or musical elements naturally applied itself to the BaXen's design structure from lines generating triangular spatialized surfaces.

The second emblematic example is the project where Xenakis is literally inspired by music to generate an architectural form: the Philips Pavilion for the 1958 World Exhibition in Brussels. If we go back to the sources of its creation, Xenakis explains that it was also the Metastasis score (written in 53-54) and its mathematical model that inspired the form.

The response to the exhibition's order was the occasion for another level of encounter between these two arts, of which there is little regard in the many commentaries on this universal scope project. This time, the music composed by Edgard Varèse had to meet the architectural space in its acoustic and luminous physicality at the same time. The music projected to make the link between the light scenography and the audiovisual perception thus increased the architectural shell which is already formally very strong (very new surfaces set at that time).

3. Experimental acoustics of Baschet brothers

3.1. Baschet universe: between sound and visual

The second source of inspiration for BaXen[7] comes from the acoustic and aesthetic universe of the Baschet brothers[8], and their main invention: the Sound Structures.

Figure 4: Baschet's sound sculpture – Saint-Michel-sur-Orge – FR

[7] That's where come from the name of the instrument, quite rightly found by the students (*Ba* for Baschet, *Xen* for Xenakis)
[8] In close collaboration with the heirs of Baschet brothers, the Baschet Sound Structures association preserves the legacy they make available to the public (for more information: www.baschet.org).

François Baschet is an artist and musician who travels the world with his inflatable guitar, presented at the Lépine competition. In 1952, he drew his first sound sculptures. Bernard Baschet is engineer and acoustician. He sees in his brother's artistic and sound researchs a magnificent opportunity to invent sound objects of an unclassifiable new type. From indoor sound sculptures to sound furniture, monuments for public space, the success they will experience with non-musicians and children in particular, will lead them to develop a new educational tool: the *instrumentarium*, a true means of awakening to the sound universe[9]

Well-known throughout the world, the didactic interest of Baschet's work is to be part of what art historians call an «open work» (Mussat 2002, 84-86), , that is to say a mobile work within which everyone can build a learning trajectory, then of expression. This inspiring sound universe, conducive to transfers between disciplines, proved very relevant to stimulate the invention of a free architectural form.

Figure 5: Baschet's Instrumentarium: sound palette panel

[9] Set of 14 instruments available at the end of the 70s, designed to be accessible to children, following the philosophy of the Baschet brothers: to make sound art accessible to all.

3.2. A discovery of matter through play

To immerse themselves in the sound and visual aesthetics of the Baschet brothers' work, the first stage of learning was to test the instrumentarium, allowing the students to play with incredible sounds; to immerse them in new forms of listening, rub their ears as close as possible to the sound produced by the resonance of metal or glass. This experience of collective listening was able to highlight the richness of the direct confrontation with the sound game, from an individual discovery of the sound effects to the awareness of the power of the collective game. Being not melodic, sound structures give a great freedom of expression of matter. They bring to the beginners the invention of sonorities through three modes of games: metal's percussion with bare hands or with links, plucked strings, and crystal played with wet fingers.

The percussionist's presence was intended less to transmit a playing technique than to take measure of the ergonomics of future instruments: test the maximum sizes and possible variations to size all possible registers to be assembled on a rigid and stable structure.

3.3. Acoustic experimentation as a formal design mode

After practicing with the ear on sets of instruments lent by the luthier, the second step was to realize a prototype. The students were first sensitized to acoustic principles of vibratory plates[10] revisited by the Baschet brothers to create their sound structures. They are based on the production of acoustic vibrations in the metal and rubber damping when it comes to breaking the sound transmissions in the carrier structures. The vibrating element is a metal rod embedded by a single end in a relatively heavy plate. The sound is then radiated outwards (by air) by diffusers that modulate the tone.

Settled by complex acoustic calculations that did not have the formulas or the skills to apply them, the various mounting modes and their associated vibrating properties have simply been tried by ear. By testing the different thicknesses of plates, diameters and lengths of the threaded rods, the students were able to understand and exploit the sound possibilities offered by the material; the rules of manufacture of metal parts (drilling, proportions) have been implemented without the aid of the nomenclature of any parts. The luthier's knowledge in this area was transmitted orally.

3.4. The design-manufacture of a sculptural structure

The design of the instrument's supporting structure was guided by three principles: lightness, stability and ergonomics.

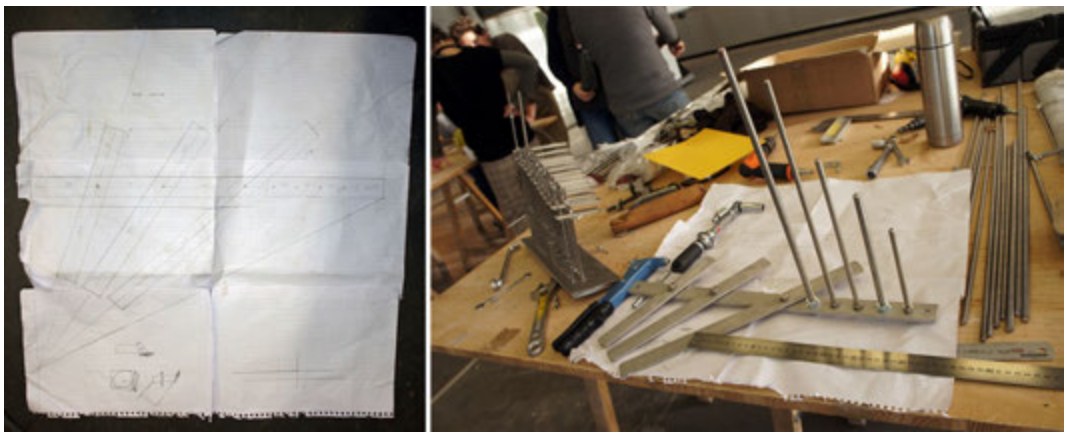

Figure 6 - Elements of Baxen being assembled at the Grands Ateliers de l'Isle d'Abeau

[10] The main sources of scientific inspiration of Baschet brothers are the writings of the French acoustician Henri Bouasse whose studies on vibrating plates had not given rise to organological creations

Figure 7 – View of structure in production at the Grands Ateliers de l'Isle d'Abeau

Drawing on the panel of about fifty sound sculptures created between the 50s and 90s of last century, the triangular shape that emerged from the sketches offered the advantage to provide three sides to hang the *instrumentarium*, pre-sized with the composer, according to the sound registers integrated into its musical creation.

The transition to manufacturing was a real test of the matter at service of acoustic result, which was tested continuously. If the machining of parts presupposed a high precision in the measurement and the anticipated drilling on the drawing, the installation on the real scale allowed to readjust the positions of equilibrium of the various instruments as well as the correctness of their fixation and above all to adapt the cantilevered weights constituted by the mask-veil and the acoustic diffusers.

The delicate gesture of manual stamping of the stainless steel sheet made use of the experience of the luthier, himself initiated to this technique in the Baschet studio.

This experimental project has shown all the richness of making students' work in an intensive workshop for fifteen days, in a dynamic of back and forth between the workshop and the future staging at the ENSAL. Thus, the design choices of the set were continually put to the test of the careful manufacture of the different parts of the instrument. Although this concept of design-manufacturing continuum is familiar to many artists, it is also very efficient in situations of learning or transmission of architecture, participating in the renewal of certain architectural practices.

Figure 8 - Stamping of the metal diffuser on the workbench of Grands Ateliers de l'Isle d'Abeau

4. A collective public experience

4.1. Organize and participate in a concert at an architecture school

The ambition to create a «playable» sound sculpture was the students' first goal. The second, involving thinking and organizing the concert with the composer and the percussionist within their school was also very formative and in line with the idea of creating a *total work of art*. As a result, this experimental project has taken on another dimension, to become a complete cultural project between architecture, music, scenographic sound design and composition, like the Xenakis' Polytopes or the Baschet brothers' sound sculptures, installed in architectural spaces. It also helped mobilize the ENSAL community, especially the administrative services, unaccustomed to this kind of performance. In the end, the event was a success, in particular due to the extraordinary synergy generated by the project. It is indeed the pooling of all the institution's skills that has made it possible to train students in the organization of such a project, bringing them far beyond their canonical activity of learning architectural design, to ensuring synthesis of a cross-design/co-design.

A very intensive coordination work was therefore set up with the General Secretariat, the Directorate for Research and Partnerships, the Digital, Audiovisual and Multimedia Service (SIAM), the Logistics and Broadcasting Service, to cover all the organizational, financial and communication aspects that such an undertaking required.

4.2. Become an "actor" of his project

Indeed, the preparatory step of the concert made it possible to mobilize the students in an active way, by defining together the different roles to play to anticipate, prepare and ensure the unfolding of the event. This included designing communication documents (posters, letters, program, etc.) in connection with the Communication Department, preparing a booklet showing the genesis and the development of the project, defined and implemented with SIAM a scenography and lighting project for ENSAL. The ambiences of different percussion sets and the definition of a public course put the students' spatial skills to the test.

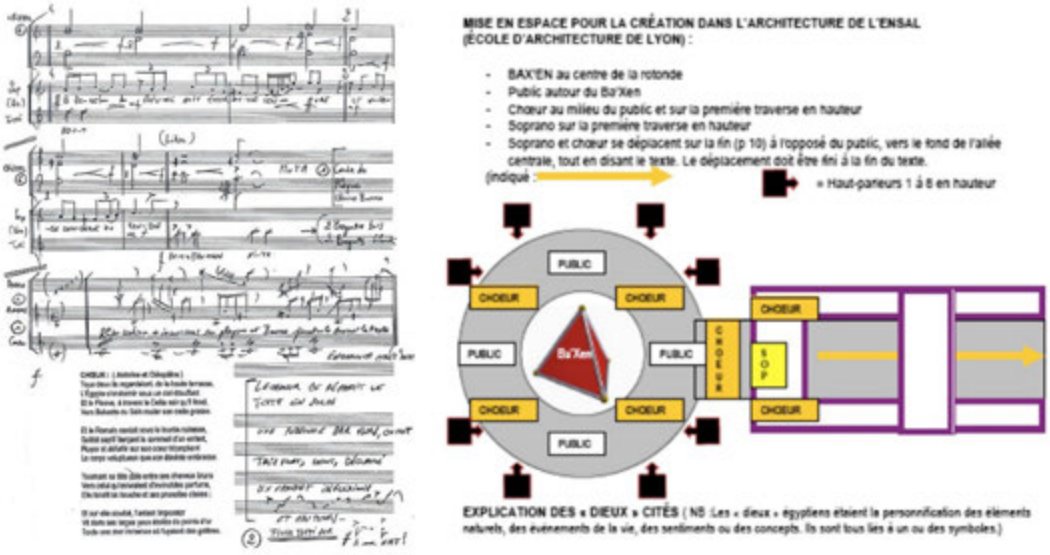

Figure 9 – Excerpt from André Serre-Milan's musical and space scores.

The division of tasks opened the door to closer collaborations with the professionals involved at each stage. In addition, the solicitations did not just focus on the event's organizing roles. André Serre-Milan, composer of the piece *Pyramid*, specially written and played on the BaXen, offered the opportunity to students to participate in the sung parts integrated into his work. One of them was provided by a professional soprano voice, while the other lines of the partition were addressed to amateur singers. Enthusiastic about the idea of going all the way to the musical expression of the project, three of the students, accompanied by their teacher and his daughter/singer, took part in the event by actively participating in the choirs and their staging in the vast space of ENSAL's atrium.

Figure 10 - Repetition of the sung parts of the work written for BaXen.

This participation in the interpretation of the holistic creation of the work, performed that evening on BaXen, has undoubtedly allowed them to enter more intimately into the understanding of the work of Xenakis.

Figure 11 - Voices in the corridors of the atrium serving as a musical scene.

4.3. The spirit of Unesco Sound Week

By approaching the spirit of the total works of art imagined by the Bauhaus School; by offering the opportunity to discover and share the incredible sounds resulting from a thought crossed between architecture and music, the project «Architecture percutée» is part of the wider societal missions that UNESCO Sound Week carries today:

> "*.. To make every human being aware that sound is a fundamental element of personal balance in his relationship with others and the world, in its environmental and societal dimensions, medical, economic, industrial and cultural…*"[11].

With this all-public open concert, the 2012 January 27th event produced by ENSAL has logically inserted itself into the universal spirit of UNESCO, thus responding to the growing concerns of society about attention to the sonic world in which we live. Relatively speaking, the ambition of universalism nevertheless aligns with Xenakis who was repeatedly involved in the design of the Brussels Philips Pavilion in 1958 and the Osaka Hibiki Hana Ma piece in 1969.

4.4. A staging by ambiences

The students were confronted with a classic question for a musical show: how to combine image and sound while reconciling the balance between lighting and sound setting without any bonus from one to the other. They were thus able to build proposals of light scenography directly with the percussionist, starting from his gestures, sound productions, also taking into account the indications of the composer; In addition, it was necessary to reconcile the technical requirements of lighting effects with the lighting facilities available to the ENSAL. Based on their detailed knowledge of the place, they were able to renew the atmosphere of their own school.

11 Excerpt of resolution 39C/59 of Unesco, sign by 195 countries in 2017.

4.5. Valuing the BaXen

This type of research-creation raises the question of its valorization: how to produce sensitive traces able to archive such an experimental architectural project? The challenge of documenting the experiential approach as it progresses is sometimes contradictory with the required spontaneity and the spirit of freedom sought through such a device. Although experimental, the scientific aspect brought by Cécile Regnault could not escape the approach: the choice to relate the chain of experiences lived from the students' point of view naturally became a method proven elsewhere by the researcher (*Architecture à l'écoute*, forthcoming). The organizational system put in place required a critical feedback of the benefits of the back and forth methodology inherent in this incremental project approach.

The traces' accumulation made it possible to organize the necessary material to produce a booklet of the concert for the public, restoring the process of BaXen's design. In addition to its public vocation, highlighting the specificity of the event between architectural design and musical creation, it made it possible to install good practices with students aiming to learn how to restore the work of an entire team. Healthy and didactic reflex, especially for future candidates for the architectural practice where the scientific part of the project approach could be more usefully put forward in multidisciplinary projects that they will have to lead.

Figure 12 –Concert's views -January 27th

The communicational aspect of valuing the work involved keeping track of the event. Two students were commissioned to take photographic shots during the entire preparation and conduct of the concert. In parallel, the ENSAL audiovisual service took charge of the video recording of the concert, which was then edited and posted on the ENSAL website.

Finally, several students put their graphic skills at the service of the publicity of the project with the realization of the poster and flyer, advised and guided by ENSAL's graphic designer.

Figure 13 - Extract of the communication file produced upstream by the students.

Two public lectures accompanied the concert, which were given before the performance.

The first lecture was oriented towards the project's aesthetic approach, wherein the three «artisans» of the project, the musician-performer Laurent Mariusse, the composer André Serre-Milan and the instrument factor Frédéric Bousquet, in turn expressed their aesthetic vision of the project «Architecture percutée».

The second lecture developed a theoretical reflection on the relationship between music and architecture; Cécile Regnault proposed a critical reading of the notion of analogy present in the genesis of the Philips Pavilion, designed for the 1958 Universal Exhibition by Le Corbusier and Xenakis, to magnify the avant-garde soundtrack consisting of original music by Edgard Varèse created specifically for the Pavilion) and overlapped with the Philips company's technical advances in lighting.

4.6. A multidimensional and multi-sensory project

By carrying out a general mapping of all the actors involved throughout the project, we were able to take the measure of the growing interest in pedagogy to think about the human and material organizational context of the architecture project, as a key element of its success, particularly in the conduct of design-manufacture and the monitoring of its acceptance.

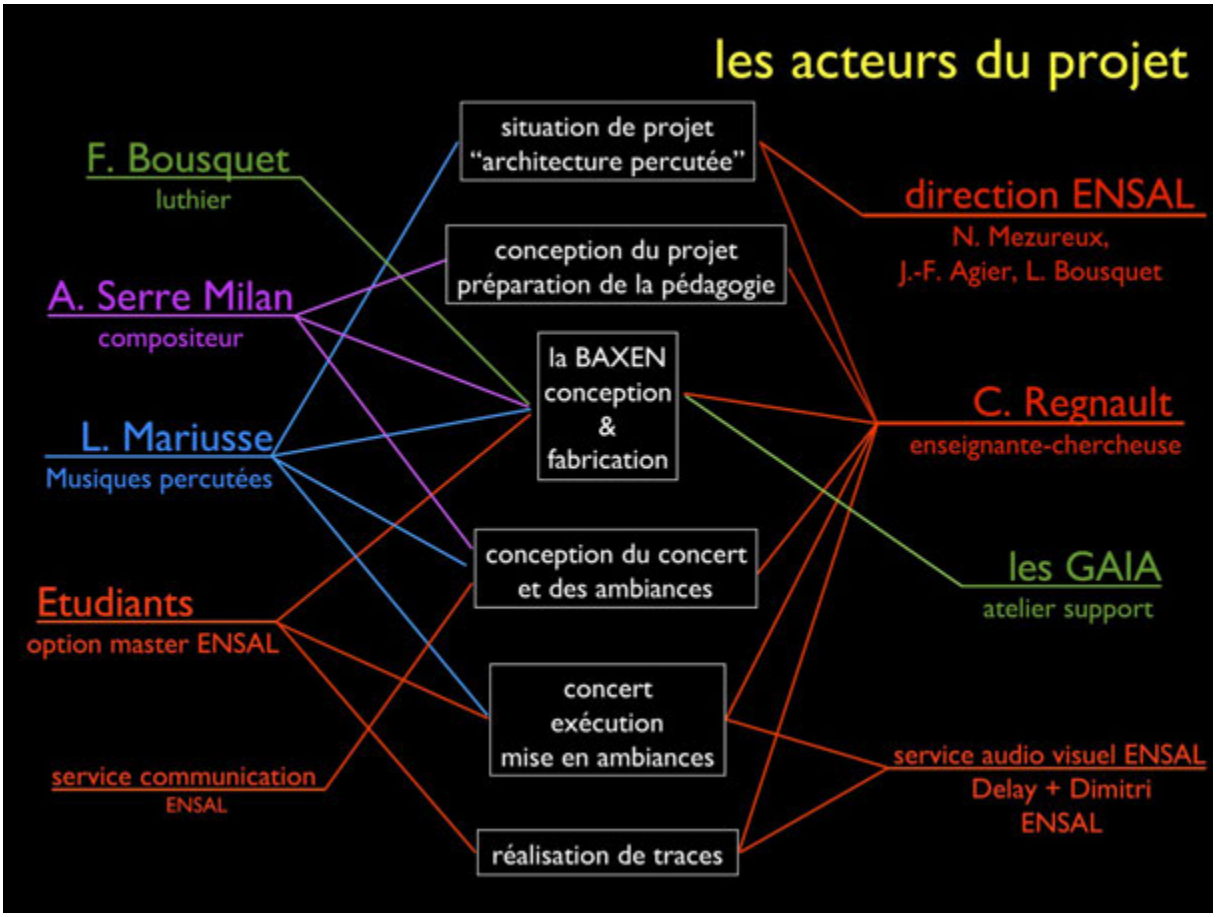

Figure 14 - Schematic mapping of the actors throughout the project

This diagram highlights the decisive place of various professional skills necessary for the collective realization of this project, combined with the strong involvement of students at each stage, performing tasks carefully divided between actors, whether they be initiators or followers.

It must be noted that the unconditional commitment of ENSAL's management, related to the project's transdisciplinary nature, exceeded its classical missions of transmission by promoting the realization of this musical project. Without this commitment, the event would not have been possible.

At last, the holistic ambition to mix in the same pedagogical action, constructive innovation, musical creation and architectural valorization, crystallized in a shared musical moment that allowed everyone to rediscover the architecture of ENSAL.

For this evening concert, participants were asked - or rather proposed – to experience the space by listening before watching. This attention to listening was even more active as the audience had to move with the musician, as the program unfolded. This ambulatory concert proposed to discover the percussion instruments and acoustic effects that modulated the sound space of ENSAL's "inner street" with each piece chosen accordingly.

Moreover, the sound power of percussions and the prominence of their resonance in the reverberating space of the atrium and the monumental inner street, combined with the possibility of the close proximity to the instrumentalist the public grasped, as shown by the audience's positioning in the first row. The size and freedom of movement did not prevent anyone from finding refuge in the diffuse field of reverberated music.

Immersed in this enveloping sound bath, listeners reported physically feeling the sound pressure throughout their body; the sound path offering everyone the opportunity to feel the space outside the prevailing "empire of the gaze" and to better appreciate the other sensory dimensions of a space that had become «space-time» lived in all its senses.

The project thus finds its fulfilment in the accumulation of lived experiences and strong auditory experiments, i.e., to share the powerful evocative capacity of the sound space and capable of transcending architecture.

Since this memorable concert in 2012, BaXen has been staged twice in other places. It only asks to be played again, in echo to the work of Xenakis.

Figure 15 – View of the concert organized for Le Revard viewpoint's opening in Savoy (2012 July 6th).

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Pour la Paix. Analysing the piece and preparing its performance

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Abstract

Pour la Paix (1981-82) has a particular place inside Xenakis' production: it is his unique radio composition (Hörspiel). The composer drew extracts of texts from two books of his wife, to tell the story of two young boys, stemming from the same village, but recruited in two enemy armies. This text is read by four narrators. It is musically commented by sounds produced by the UPIC. In parallel, ten choral sequences open more speculative spaces, and propose a musical extension. Put in a tape, these three components can be diffused on the radio. However, the work was created in concert, and it is doubtless why Xenakis also proposes concert versions.

After the examination of the project and the genetics of the work, we will analyze the components one by one (text, choral sequences, UPIC sounds). Then, we will examine their assembly, by emitting the hypothesis that the fragility of this assembly explains why the version concert (in particular the one with the narrators and the choirs on stage) is the more interesting for the listener. A particular attention will be devoted to the performance of the version concert, as we will perform it with the vocal ensemble Soli Tutti on April 2022 at University Paris 8.

(A preliminary version of this article is M. Solomos, 2015).

1. Introduction

In the musical production of Xenakis, *Pour la Paix* occupies a unique place. Combining four reciters, mixed choir (32 voices minimum) and UPIC sounds on tape, this work is one of his rare mixed pieces. Moreover, it is the only radiophonic creation of Xenakis, which explains the very great importance of the text (which is by Françoise Xenakis) read by the reciters, whose UPIC sounds partly constitute a commentary, the choirs being able to be apprehended as choruses of ancient tragedy. Finally, no doubt because of the complexity of its project, it is little played or broadcast, and remains unknown.

Composed in 1981-82, *Pour la Paix* was commissioned by Radio France (and INA-GRM) in the form of a radiophonic work, a *Hörspiel*, i.e. a piece to be broadcast on the radio. The work was to be presented at the Prix Italia, a competition organized by RAI since 1948 – and still existing –, giving priority to radio and television programs. But that was not the case. On this point, Xenakis has bitter words: "*Pour la Paix* should have been entered for the Prix d'Italia. As it happens it was never sent because I was betrayed by French Radio. They asked me to write this piece but it turned out that the competition that year didn't cover that particular category" (Xenakis in B.A. Varga, 1996: 171).

The piece was created in concert, on April 23, 1982, at the Grand auditorium of Radio France (Paris), as part of a concert entitled "Tribute to Pierre Schaeffer". Originally a radiophonic work, but finally created in concert with part of the live cast: we can already see an interesting ambiguity slipping into the circumstances of the creation. The Xenakis' catalog at Salabert prolongs the ambiguity. Not hav-

ing a section “radiophonic works”, it includes *Pour la Paix* in the section “electroacoustics”, indicating: “Version for choir, reciters and music”. But the piece also appears in the “Choir” section, which offers four versions: I. mixed choir a cappella; II. mixed a cappella choir, 4 reciters and stereo tape (UPIC sounds); III. 4 reciters and stereo tape (including recorded choirs and UPIC sounds); IV. tape only (bringing together choir, reciters and UPIC sounds).

There are therefore five possible versions of the piece. The first is its radiophonic form, which does not exist as such in the catalog in question. The other four are concert versions. The first contains only the choir parts, placed end to end, it lasts about 7' (and not 10' minutes as indicated in the catalogue). This may seem surprising, but, at the same time, expresses the importance Xenakis attached to choirs at the time. The other three versions, which include all the parts, are concert versions, which range from a version where both the narrators and the choristers are on stage to an acousmatic version (everything is on tape) through the version where the narrators are on stage and the choristers on tape. It should be noted that the acousmatic version corresponds to the radiophonic version (or electroacoustic according to the catalogue), but differs from it since it is to be broadcast in concert.

This article offers a first approach to *Pour la Paix*. Without going into all the details of the analysis, it wishes to go around certain questions and outline some lines of thought that other work could extend. It wishes to do justice to this piece which, just as it is little performed and broadcast, is still too little commented on by specialists. With regard to the latter, here is the list of some works that refer to them: Rudolf Frisius (1986), Jean-Marc Bardot (1999) and James Harley (2004) offer a general introduction; Kostas Tsougras (2005) analyzes the pitch structure of choral parts.

2. Genetics of the work

As material in the Xenakis Archives, we have a file which contains in particular the editing of the texts of Françoise Xenakis with some indications on the music to be composed as well as the program of the creation. The digitized tapes of the Xenakis Archives are more consistent. Next to several copies of the piece in several tracks or in reduction, they contain the recordings of the choir parts in several takes or in the final version, the recordings of the reciters as well as the UPIC sounds.

The documents contained in the Xenakis Archives allow us to understand in what order the piece was composed. A first document consists of 20 pages where Xenakis has made a montage of selected extracts from texts by Françoise Xenakis. He probably made photocopies of these extracts, cut them out, then pasted them on the sheets. Then, on these same sheets, he distributed the text to the four reciters (named by their first names – but not throughout the text) and, in the right margin, he noted the “blue” UPIC sounds. On a second document, consisting of 14 sheets, there is a copy of the assembled text. It says “complete final version” and “in pencil the cuts for a shortened version”. Indeed, in the final version, the text is abridged and a few words are changed. On these same sheets, there are indications for the music: the planned interventions for the choir parts are indicated (“choirs”); UPIC sequences, named M1, M2, etc. – also including an indication of their duration – correspond globally (but not entirely) to the final version; in some passages, there are annotations on the type of sounds necessary; finally, certain sentences of the text are assembled in paragraph, others separated (in order to illustrate a word musically).

Thus, the first step consisted in creating the text, by editing excerpts. Then, Xenakis thought of associating certain passages with some UPIC (“blue”) sounds perhaps already composed. Finally, he added to the text the precise moments when the other musical elements will intervene: choirs and other UPIC sounds, which probably had to be composed.

Two elements are striking. First, we see that the text is the primary support and that it remains so until the end, even if the choral parts and the most consistent UPIC sequences create purely musical moments. Next, note that Xenakis proceeds by editing (this is already the case with the text), gradually adding the various elements.

3. The text

Pour la Paix is the only piece by Xenakis that calls on reciters and where the text – read by two men and two women – is so important, as evidenced by the score, which gives the choral sequences and the UPIC sequences in relation to to the text.

The title is of course related to the text: it talks about the horrors of war. (Note that in Xenakis' catalog there are two other "For" in the 1980s, *For Maurice* and *For the Whales*, and that one of the young Xenakis' unpublished works was called *Dove of Peace*.) To Bálint Varga's question: "This piece has some of the simplest, the most innocent and lyrical music you have written (in 1980 we agreed that lyricism was not part of your make-up!) but it has also terrible visions and hallucinations. Perhaps you wanted to conjure up all the horrors of war as a warning and in order to remind people to appreciate peace?" (Xenakis in Varga, 1996: 171-172), Xenakis replies: "It's based on a text by Françoise which is not about any specific war but about war in general, the unjust treatment of people. Two friends find themselves in two opposite camps and have to fight each other. They find each other eventually but are killed in an explosion" (*ibid*.).

Xenakis used two books by Françoise Xenakis, from which he chose a few extracts. From the first, *Écoute*, there is first the sentence: "Listen to the wind in the top of the trees. The wind that ruffles the dead, helmets rolled away. The wind that caresses faces and ruffles hair" ("Écoute le vent dans le haut des arbres. Le vent qui décoiffe les morts, casques roulés au loin. Le vent qui caresse les visages et décoiffe les cheveux"), sung by the choir and read by the reciters, which he also uses in *Nekuïa*. Moreover, he takes the beginning of the back cover of *Écoute* to make it the very beginning of the text: "[A war.] By chopped sentences, by images, by verses, here is war in its horror. Atrocities, massacres, tortures, infinite suffering of men and women. We are anywhere. Where one hangs, shoots, massacres" ("[Une guerre.] Par phrases hachées, par images, par couplets, voici dans son horreur la guerre. Atrocités, massacres, tortures, infinie souffrance des hommes, des femmes. Nous sommes n'importe où. Là où l'on pend, fusille, massacre"). Finally, he isolates a few descriptions of the horrors of war, descriptions that punctuate Listening, making this little book a poignant work. For example: "Squatting by the crazy river a woman in a bowl of calmer water washes her child. Her pink skirt stretched between her legs, a hammock for the naked child. She has one hand under her head while with the other, cup, takes the water and gently pours it over the little body. Sometimes she spreads the fingers of her cup hand. Refuse the water. Wants only water, pure water to wash her dead child" ("Accroupie près du fleuve fou une femme dans une cuvette d'eau plus calme lave son enfant. Sa jupe rose tendue entre ses jambes, hamac pour l'enfant nu. Elle a une main sous la tête tandis que de l'autre, coupelle, prend l'eau et la fait doucement couler sur le petit corps. Parfois elle écarte les doigts de sa main coupelle. Refuse l'eau. Ne veut que de l'eau, de l'eau pure pour laver son enfant mort").

The rest of the text (larger in quantity) is taken from *Et alors les morts pleureront*. This book tells, among other things, the story of two young boys, who were friends before being enlisted in two opposing armies. The narration opens great parentheses allowing happy memories to emerge, while advancing ruthlessly towards the sad ending. The book is also mixed with other stories, which Xenakis does not keep – for example the story of a woman who speaks on behalf of the resistance fighters.

The montage carried out by Xenakis is judicious. He fleshes out the story of the two boys from *Et alors les morts pleureront* with some descriptions of the atrocities of war borrowed from *Écoute*. The original extracts are very little modified. As we have insisted on the use of editing by Xenakis, it is important to emphasize that the writing of Françoise Xenakis in these two books is itself a writing that proceeds by montage: several parallel stories are woven. The montage effect is reinforced by the fact that the writing itself is also characterized by a laconic, choppy tone.

We can read the text assembled by Xenakis as a manifesto against war. Xenakis himself, in the notice of the creation, gives a more general scope:

> "Individuals are unconscious prisoners of societies and states that use them, like pawns, blindly, in its machinery to destroy lives and destinies. The nostalgia of two childhood friends taken as soldiers by two enemy camps

> is so fragile, it is nothing in front of the atrocities of the incessant wars. So much suffering for nothing. These sighs of their memory do not prevent them from running to their premature death" ("Les individus sont des prisonniers inconscients des sociétés et des États qui les emploient, tels des pions, à l'aveuglette, dans sa machinerie destructrice de vies et de destinées. La nostalgie de deux amis d'enfance pris comme soldats par deux camps ennemis est si fragile, elle n'est rien devant les atrocités des guerres incessantes. Que de souffrances pour rien. Ces soupirs de leur mémoire ne les empêchent pas de courir à leur mort prématurée") (Archives Xenakis).

For Xenakis, it is undoubtedly also a painful memory of the Second World War and the beginnings of the Greek Civil War. In any case, this text, as we will see, also refers to the tragic events of December 1944, in Athens, which almost cost the composer his life. Moreover, the theme of death that runs through it also colors other works from the same period: *Aïs* (1980) or *Nekuïa* (1981), but also *La Légende d'Eer* (1977).

4. The choir

Second element: the choir. Great is the importance of the choirs for Xenakis during the time of *Pour la Paix*: they appear in *Cendrées* (1973), *À Hélène* and *À Colonne* (1977) and in the two pieces composed just before *Pour la Paix*, *Serment-Orkos* (1981) and *Nekuïa* (1981). It should be noted that there is a certain kinship with this last work. Both pieces share the first sentences of Françoise Xenakis extracted from *Écoute* ("Listen to the wind…"). There is also the question of death which is, as we have said, common to both plays. Moreover, we find the same alternation between sequences playing in a linear way (ascending or descending scales) on screens and sequences which constitute gesture-sounds, although in *Nekuïa* the former tend to dominate. However, while *Nekuïa*, through its orchestral writing in particular, has a slight leaning towards neo-expressionism, *Pour la Paix*, due among other things to the presence of UPIC sounds, sounds quite different.

The role of the choir in *Pour la Paix* fulfills a dual function. On the one hand, it is a question of commenting on the text, by seizing, among other things, important words such as "die". However, unlike the UPIC sounds, it is not a case of a punctual and descriptive commentary, but of sorts of long parentheses, which invite a properly musical expression. Therefore, the second role could be, precisely, to open up a musical space. This is probably why Xenakis authorizes, among the possible versions, the performance of the choral parts alone, placed end to end – quite astonishing otherwise, given that, without the reciters and the UPIC sounds, the piece is considerably shortened, as it has been said. Finally, note that there is no relationship between these choral parts and the UPIC sounds: the two are thought out in relation to the text, but independently of each other, even when they overlap.

Pour la Paix includes ten remote choral sequences. For an overview of these sequences, see Solomos (2015). In terms of importance, by their duration, the last two stand out: in a way, the music ends up prevailing (the work concludes with the last choral sequence). In terms of writing, we will see that they sum up practically the whole of choral Xenakis: with regard to the relationship to the text, they oscillate between comprehensible words and phonemes; as for their textures, they alternate, as has been said, sorts of scales (or melodies) and sound-gestures.

These sequences can be grouped into several types. First of all, sequences 1, 2 (cf. **figure 1**) and 7, which consist of melodies in unison (sequence 1) or in two voices (sequences 2 and 7) on the text "Listen to the wind…". They are based on the tetrachord of interlocking fourths evoking the famous Indonesian pelog scale that Xenakis used in many works of the late 1970s and 1980s. The second voice of sequence 2 plays on another tetrachord with a major third in the middle ; as for the second voice of sequence 7, it deploys a chromaticism within a tone, C-C#-D. Moreover, in the original recording – reproduced on the Fractal CD – the choirs of these sequences are accompanied by strange synthetic sounds, created by Daniel Teruggi.

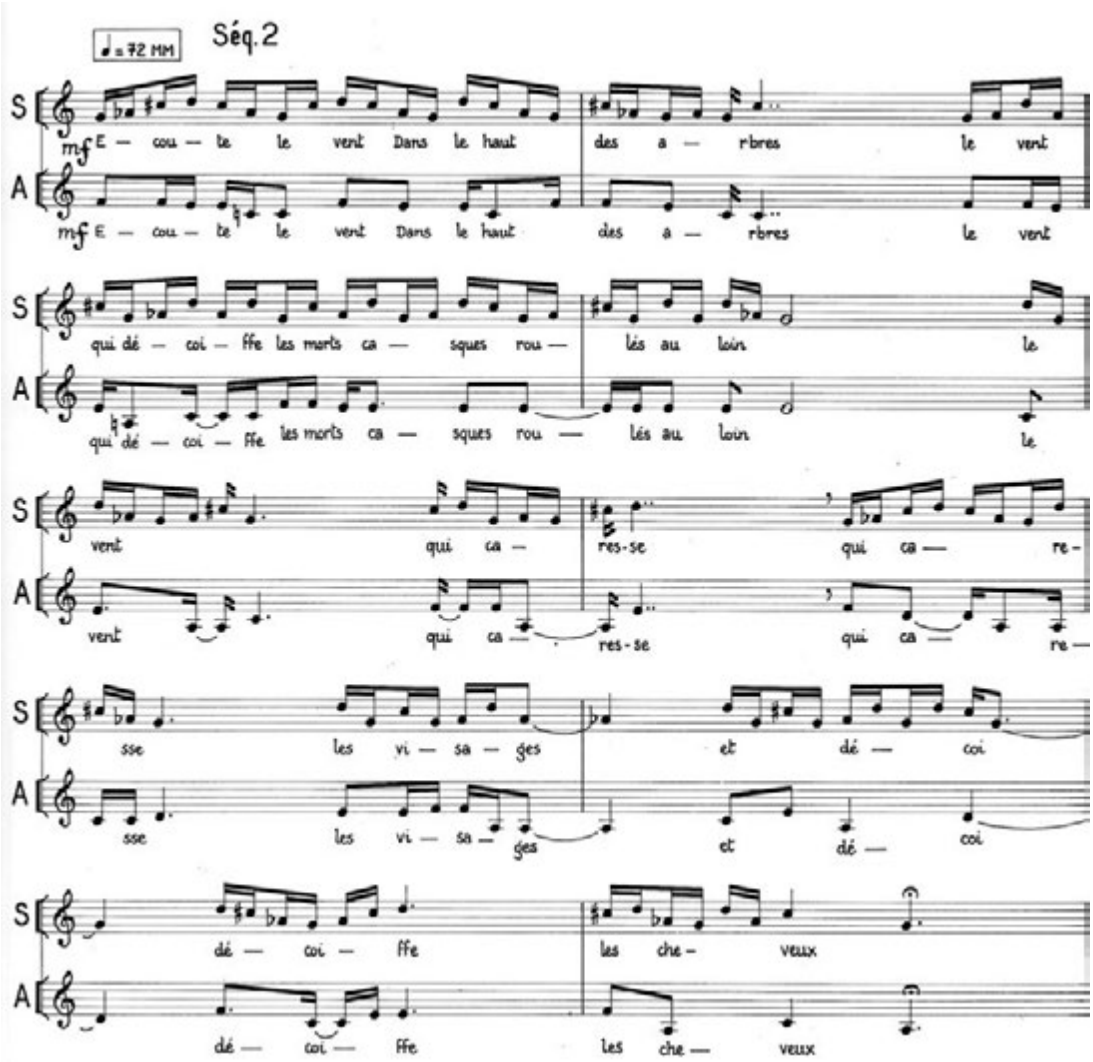

Figure 1 : Choir, sequence 2.

We can then group together sequences 3 (cf. **figure 2**) and 8, because there dominates each time a word, respectively “jackal” and “die”, as well as the rhythm double dotted quaver – triple quaver. Sequence 3 connects a repeated chord, descending then ascending scales on a sieve (each voice starts from its note in the previous chord), the repeated chord with glissandi and a final rise. All the notes belong to sieve 1 (see **figure 3**), which can be considered as the main sieve of the piece (the highest note, Bb, is not played in this sequence). As such, this sieve does not present any symmetries. Kostas Tsougras suggests certain modifications (cf. **figure 4**: removal of low Eb, addition of a C# and G# in bass clef, substitution of B for Bb in the treble), which allows it to be analyzed as a sieve symmetrical on two octaves. Sequence 8 uses the notes of what could be called sieve 2 (cf. **figure 5**) – but the word “sieve” is probably too strong, because, apart from the fact that only this passage uses these notes, that these are obtained by embroidering a chord.

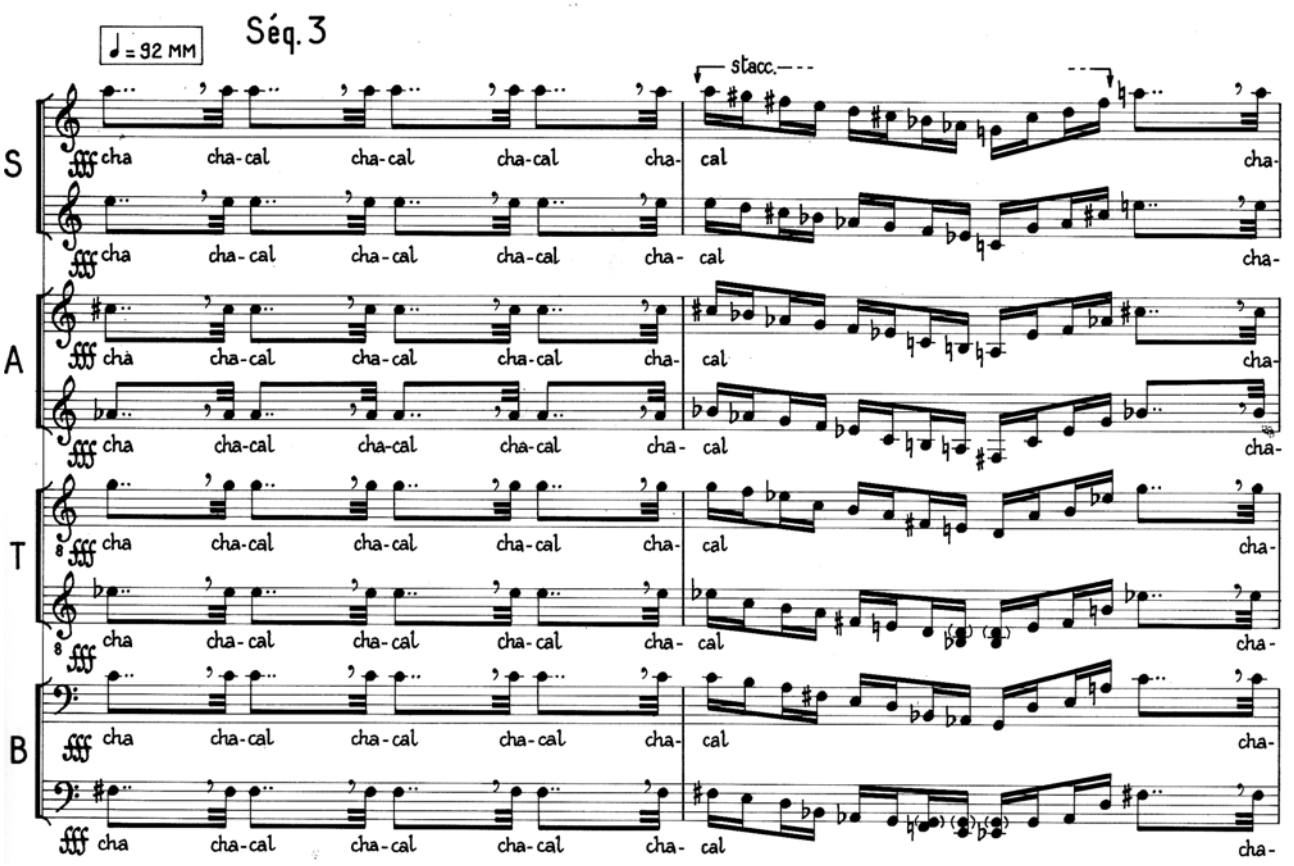

Figure 2 : Choir, sequence 3: beginning.

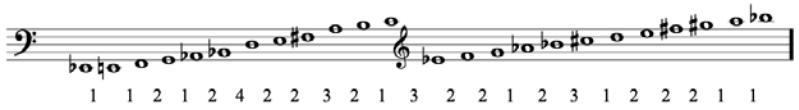

Figure 3 : Sieve 1.

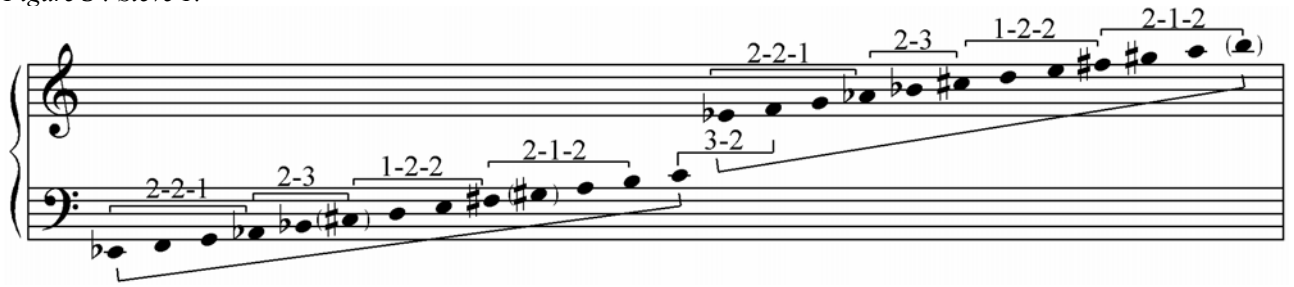

Figure 4 : Sieve 1 modified by Kostas Tsougras.

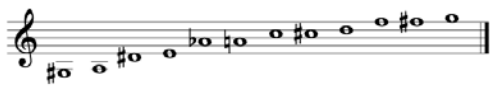

Figure 5 : Sieve 2.

Third type: sequences 4, 5 and 6, which play with pure phonemes and are composite. They include alternations or repetitions of chords, ascending-descending scales with rhythmic shift and glissandi. They all use sieve 1. Sequence 4 (cf. **figure 6**) begins with two chords, then it alternates scales and chords; it uses neither the low Eb nor the high Bb of the sieve. Sequence 5, the shortest with sequence 3, uses only a few notes from sieve 1: it alternates a diminished seventh chord F#-A-C-Eb in the low of the female register and the chord D-E-A-Bb in its treble (this is the first time that the Bb has been used), before polarizing on an Eb. Sequence 6 features brief glissandi over chords. Then, she gives us to hear "horrible unrhythmic cries" (indicated by the score) on relative pitches. The glissandi resume, and the sequence ends with a "very strong 'H' from the back of the throat" and a "continuous modulation of the breath: 'H'A by inhaling then exhaling alternately".

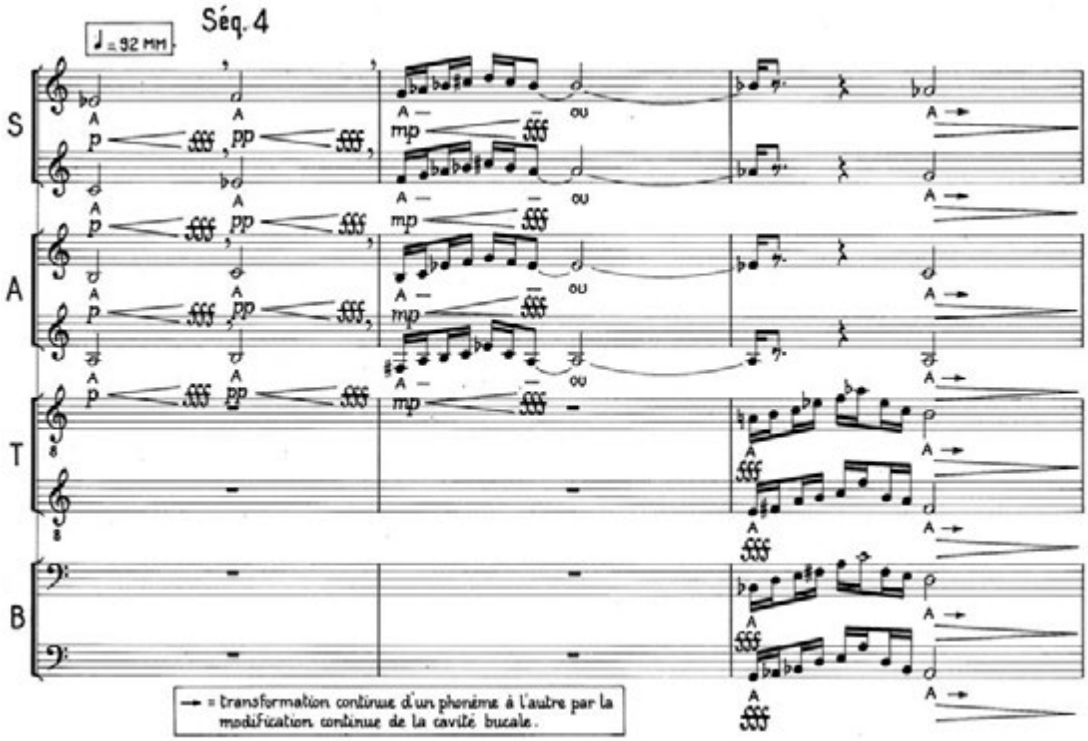

Figure 6 : Choir, sequence 4: beginning.

Sequence 9 – the longest, as we said, with the tenth – is unique: it almost forms a small musical work apart. It consists of repeated phonemes as if they were forming a word: "KO-OU-A", always on the dotted eighth note - triple eighth note rhythm, the texture gradually thickening (passage from 2 to 8 voices, then additions of triples quavers). **Figure 7** completes it. In terms of heights, it deploys what could be called screen 3 (**figure 8**) – here too the word "sieve" is probably too strong –, which has some affinities with the screen of sequence 8 (sieve 2) .

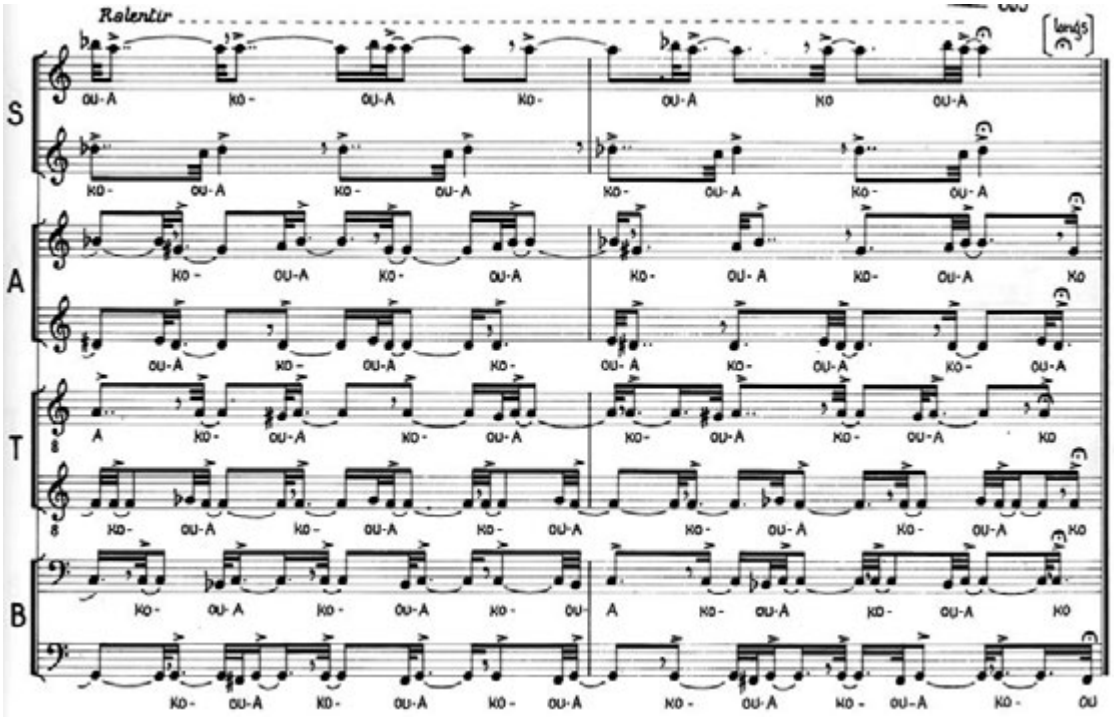

Figure 7 : Chœur, sequence 9: end.

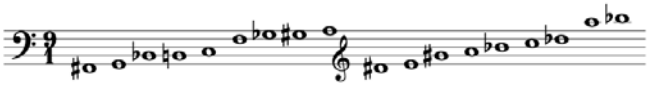

Figure 8 : Sieve 3.

The last sequence (cf. **figure 9**) also constitutes music in itself: a lament. The two sopranos embroider in the treble each o a semitone (the whole forming two interlocki major thirds F-Gb-A-Bb) o the words “mourni the dea”. The other voices, each divided into two, move p or down scales o phonemes. The set of notes probably forms a new sieve in its own right, named here sieve 4 (cf. **figure 10**).

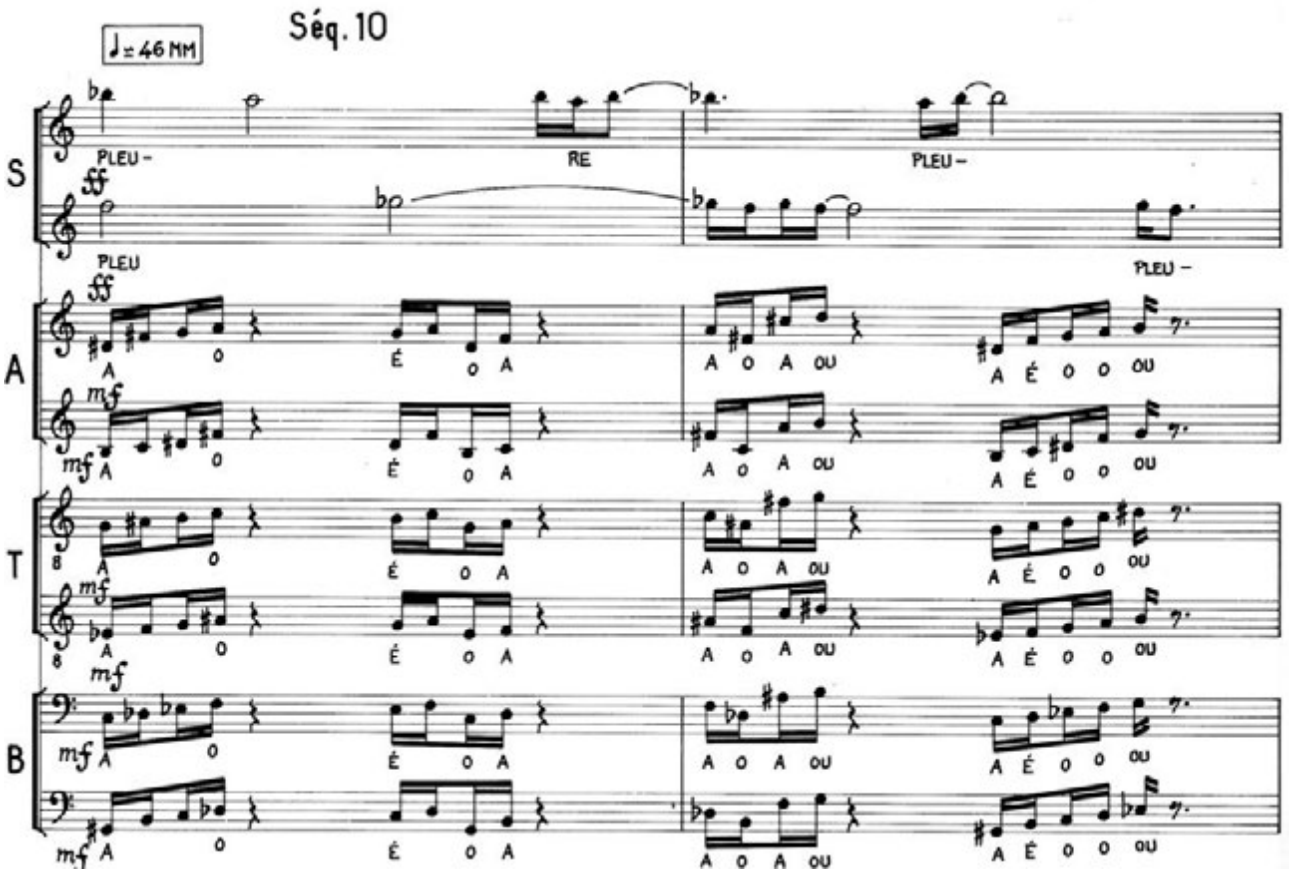

Figure 9 : Choir, sequence 10: beginning.

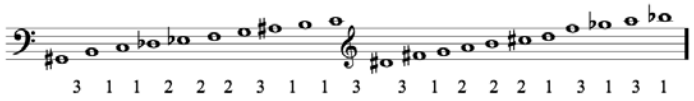

Figure 10 : Sieve 4.

5. UPIC sounds

5.1 CEMAMu and GRM

UPIC sounds occupy a very important place in *Pour la Paix*. Divided into 30 sequences of very unequal duration (from 0.5" to 5'37"), they total 18'24", for an overall duration of the work of just under 27'. Although the order came from Radio France, Xenakis chose to use only UPIC sounds, and not to use the GRM to produce sounds, but only for the final mix. We have said that the composition of the UPIC sounds was done in two phases. As Daniel Teruggi explains in the interview he gave us: "Xenakis had 2 or 3 reels of sound that he had prepared beforehand, we spent a lot of time listening, premixing and gradually building the continuity of the artwork. But he lacked a lot of sounds and that's why he left in the evening quite early to go to UPIC to make new sounds, this time with a precise function in relation to the narrativity of the text". For the sounds composed in the second phase, that is to say parallel to the mixing with the recorded voices, Teruggi specifies: "The choirs

and the actors were there from the start, it takes a lot of sounds to last for 26 minutes, hence the need for new sounds all the time".

5.2 Names of UPIC sounds

Regarding the names of UPIC sounds, it seems that there were "UPIC long" sounds, "UPIC red", "blue" and "green" sounds. Moreover, as shown in the sketch provided by **figure 11**, which reproduces one of the two documents which accompany tape Xenakis 574, several types of names were used for each sound. In the **table 1**, we copied the names and the durations of the second document which accompanies tape 574 (it is the same document as before, with the addition of this list at the bottom of the sheet) .

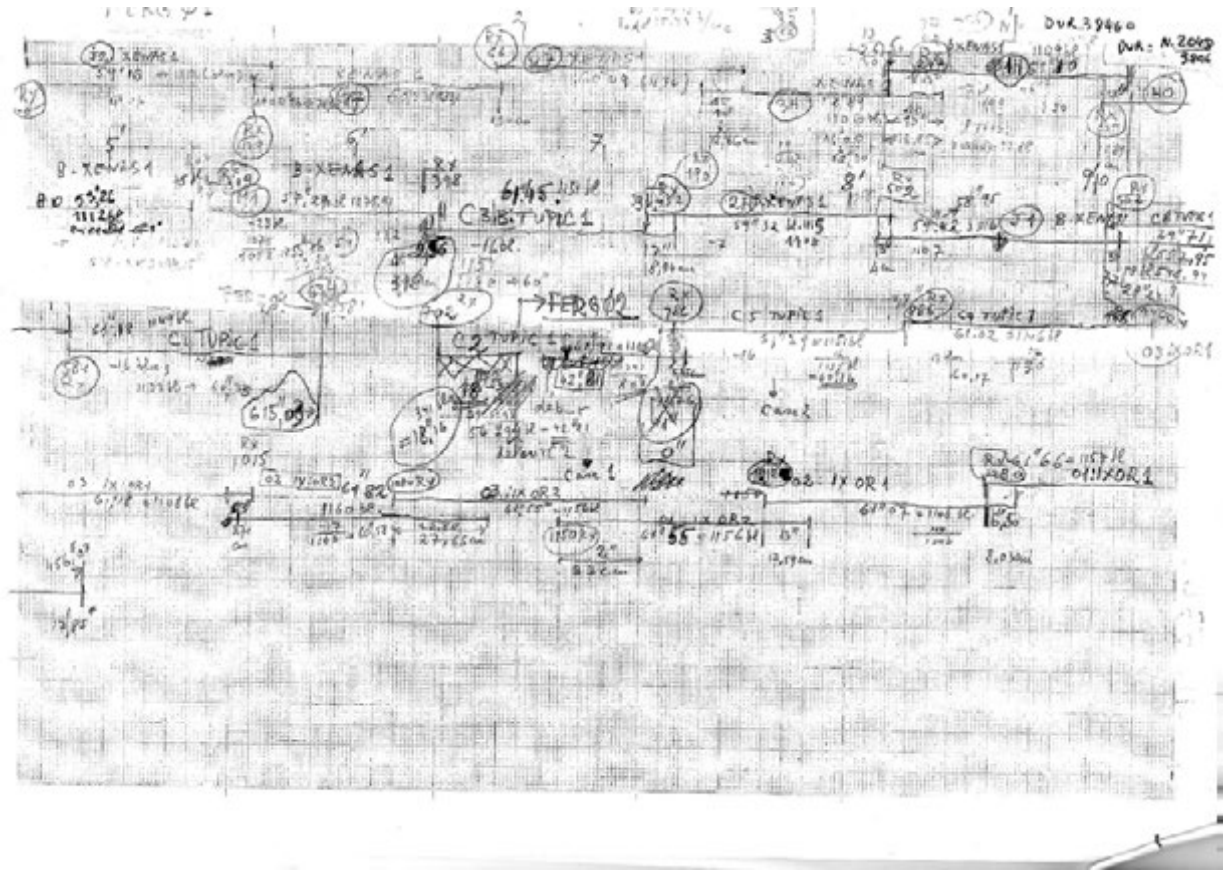

Figure 11 : Archives Xenakis (Tolbiac), Xenakis 574: document on graph paper accompanying the tape.

Sons	durations according to the A3 sheet that accompanies the tape: this duration corresponds to the durations of the 21 sounds of the Xenakis 574 tape	sound name from the A3 sheet that accompanies the tape
1	59.16''	XENAS1 – J2
2	60.33''	XENAS1 – G7
3	60.49''	XENAS1 – U7
4	58.89''	XENAS1 – 3H

5	59.10''	XENAS1 – 1H
6	44''	XENAS1 – HO
7	57.29''	XENAS1 – M1
8	61.45''	TUPIC1 – C3
9	59.32''	XENAS1 – 2H
10	59.42''	XENAS1 – J1
11	29.71''	TUPIC1 – C8
12	61.18''	TUPIC1 – C4
13	60.91''	TUPIC1 – C2
14	61.29''	TUPIC1 – C5
15	61.02''	TUPIC1 – C7
16	manque [60'']	IXOR1 – 03
17	61.82''	IXOR2 – 02
18	61.55''	IXOR2 – 03
19	61.55''	IXOR2 – 01
20	manque [55'']	IXOR1 – 02
21	manque [60'']	IXOR1 – 01

Table 1 : From Xenakis Archives (Tolbiac), Xenakis 574: second document on graph paper accompanying the tape.

5.3 Analysis

Two characteristics are immediately striking in the UPIC sounds of *Pour la Paix*. First of all: their roughness. This is due to the UPIC itself as well as the fact that Xenakis took these sounds as they were and did not try to smooth them out during the mix. We find this roughness in the other pieces for UPIC (*Mycènes alpha*, 1978, *Taurhiphanie*, 1987-88 and *Voyage absolu des Unari vers Andromède*, 1989). However, in *Pour la Paix*, the roughness is accentuated by the presence of the narrators, and, even more, of the choirs.

From the morphological point of view, these sounds are very varied, ranging from quasi-harmonic spectra to noises of various types. This is an important difference compared to other UPIC coins, in particular *Mycenae alpha*, which is more homogeneous. For an overall analysis of UPIC sounds, cf. Solomos (2015). Here, let us only note that there are several types of noises (for example noises close to those that Xenakis will produce later with the GENDYN program: this is the case of sequence 6), several sound morphologies (sliding or static sounds in particular) and several types of textures (isolated sounds, polyphonies, tree structures, etc.). Note also that there may be recorded and reprocessed sounds (notably a harpsichord in sequences 5, 7 and 26).

It is also interesting to note that sometimes the combination of short sounds produces sorts of sound objects – in the Schaefferian sense of the term – which are exceptional in the electroacoustic music of Xenakis. For example, sequence 12, very short (3''), repeats the same short compound sound three times, consisting of a kind of explosion followed by a rapid glissando towards the treble leading to a

fairly simple high sound. Or, sequence 28, longer (17") consists of three parts that form a sound object.

Finally, note that some sounds are included. In the table, repetitions or similarities are indicated by underlining the sounds. In some cases, a sound can be transformed: this is the case with sequence 18 (which slightly speeds up sequence 14).

5.4 Relation to the text

The second thing that strikes is the illustrative side of some of these sounds. The genre of radio creation seems to impose it: the narrators read the text, the UPIC sounds, to a large extent, illustrate parts of the text. Insofar as certain sequences are very brief and interspersed just after a sentence to illustrate it, the piece even produces an effect that can do it a disservice. Be that as it may, Xenakis has totally indulged in his descriptive vein, perhaps more than in any other play. To Bálint Varga's remark: « The UPIC material has a way of ending abruptly, as if cut off" (*in* Varga, 1996: 172), Xenakis replies: "Yes, it's a kind of comment in between sentences and it illustrates indirectly the message of the words" (ibid.). We can speak of illustrative, descriptive or figurative sounds; one could also use the expression "sound commentary" that Xenakis used for *Oresteia*. As it has been said, the first work consisted first of all in making the collage of the selected texts of Françoise Xenakis. Then he added some hints about the music. These indications often go in the direction of the illustration.

A few examples: in sequence 2, the choppy sounds at the beginning and the end wonderfully illustrate the sentences "By chopped sentences" ("Par phrases hachées") or "Where one hangs, shoots, massacres" ("Là où l'on pend, fusille, massacre"); the very brief sequence 4, with its noisy sliding sound, could illustrate the words "the sand covers them" ("le sable les recouvre"); the sounds resembling voices in sequence 18 clearly evoke the "grinic of joy" referred to in the text (the same sound, transposed, in sequence 22, illustrates the "he laughs"); in sequence 29, the part between 00'29" and 1'28" could correspond to the text "the bubbles are the bottom of the pond that opens" ("les bulles c'est le fond de l'étang qui s'entrouvre").

However, not all UPIC sounds are illustrative. Rather, entire sequences constitute pure music. This is the case of the first, which lasts 1'. As for the very long sequence, the 29th (5'37"), if there are descriptive passages, others are not: this is particularly the case of the long end (from 3' 06'), which prepares the final explosion, whose role is rather dramatic: through a stable sound, it provokes an anxious expectation.

6. The assembly / about the performance

Pour la Paix is a mixed piece (electronic and voice), but of a complex mixity, because there are three totally heterogeneous elements: the narrators, the choir, the UPIC band. In fact, Xenakian project does not consist in putting sound universes together, but, starting from the text, in framing it musically – either by illustrating it in an almost literal way, as is the case with certain UPIC sequences, or by extending it musically, in particular with the choirs – by using these two sound and musical means which are the human voice and electronics. Between these three entities, a game of combinatorics is woven, exploring all the possibilities: alternation, superposition of two or three. The diagram of **figure 13** provides the sequence of this assembly.

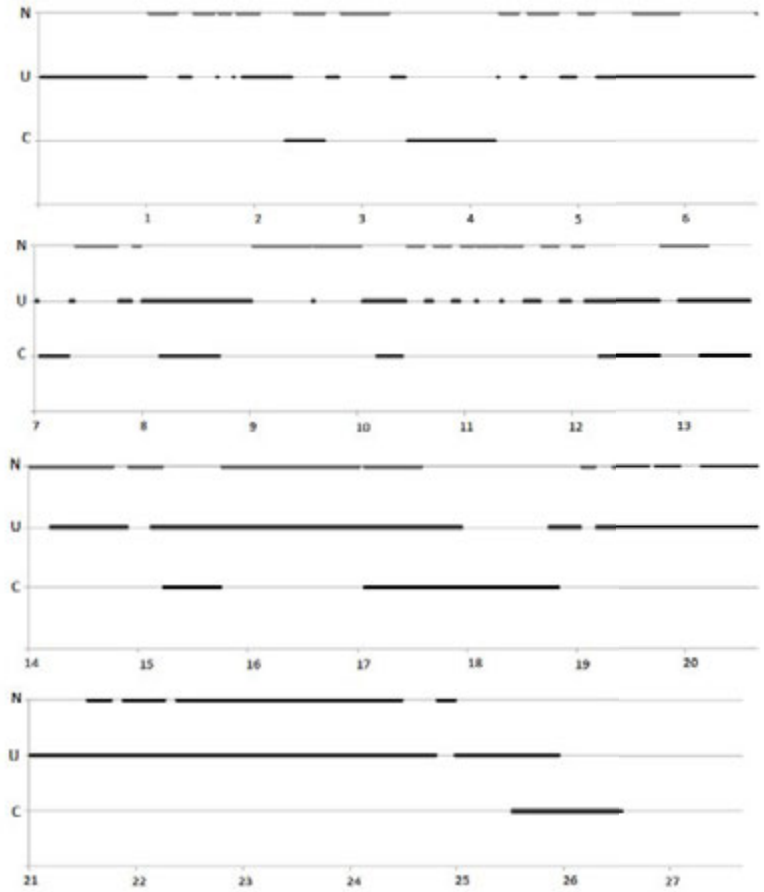

Figure 13 : Overall progress of Pour la Paix: assembly of the three components.

This assembly is very fragile, it sometimes hangs by a thread. Indeed, if the text provides an overall unity, the UPIC sounds and the choruses do not merge together or with the narrators. The risk is always great that each sequence becomes autonomous and that the work appears as a simple succession of heterogeneous moments. It will be noted, however, that there are two elements which contribute to give unity to the whole. On the one hand, of course, the narration, which leads to the final explosion. On the other hand, the fact that, from the fourteenth minute, the interventions of the UPIC band and the choirs lengthen, thus ending up making the impression of collage disappear.

Nevertheless, the assembly is fragile. This is perhaps why some listeners sometimes doubt the very tenor of the piece. This may have been the case with Xenakis himself. Let's listen once again to Daniel Teruggi in the interview he gives :

> "It must be said that *Pour la Paix* is an extraordinary work for Xenakis, it was radiophonic, text-based narration, an area in which he did not excel. He was quite tense and even worried during the production (it's an impression, I don't have any other references on the way he worked). At the end of the first minute of the work, we listen and he asks me the following question: 'Is it good? What do you think?'. I didn't feel able to give the slightest opinion, as the personality (or the image of his personality and background) was so important to me. This continued until the end; the day before the concert we finish around 9 p.m., Françoise arrives to listen, she makes positive comments and we go have a drink at the Ondes (the only time he has invited me to something). There it was quite hard, he was completely depressed, wondering about the very interest of the piece, that surprised me so much, but hey, not knowing him, it may be a regular attitude with him at the end of each work.

You have to temper this feeling of failure. It is to a very large extent due to the radio version of the premiere, which is the version included in the CD from Fractal. Indeed, as James Harley (2004: 142) observes:

> "In spite of the intensity of the texts, *Pour la paix* is rather disappointing as a radiophonic presentation. The sequences of material mostly succeed each other with little overlap, though the electronic sound do appear at times in conjunction both with the spoken and sung parts. There is also a lack of sonic depth and spatial organization that is troublesome considering the level of sophistication common in all kinds of bradcasts, not to mention other electroacoustic works including Xenakis' own".

More generally, it may be the radio version itself that may not be the best version. Indeed, a version on tape, frozen, will always tend to highlight the fragility of the assembly, that is to say the risk that the overall development of the piece may appear as an assembly without overall dynamics. The UPIC sounds contrasting sharply with the reciters and chorus, with the chorus parts often being worked out as self-contained musical entities (as well as some UPIC sound sequences) and therefore also contrasting in their own way, the fully concert version (reciters and choirs on stage) is preferable, because it provides a dramatic tension in which the contrasts in question can better take place. A scenic version, with dramatic elaboration, can amplify this tension and temper the editing effect, giving a dynamic. In any case, we must try to go in this direction: this is what we will try to do at the concert on April 19, 2022, at the University of Paris 8, with the Soli Tutti choir, under the direction of Denis Gautheyrie. For *Pour la Paix* is one of the most unique and perhaps most touching pieces by Xenakis…

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Making possible the impossible: performative ideas and solutions in some Xenakis' percussion works

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Abstract

This paper presents two brief reflections on performative and musical ideas from the percussionist's point of view in relation to the work of Iannis Xenakis. Two emblematic works of the percussive repertoire, *Rebonds* (1987-1989) and *Okho* (1989), are used as a way to exemplify the issues to be addressed here. Through the discussions raised on this paper we hope to contribute to further considerations about the performance relationships established between the percussionist and the work of Xenakis for percussion, often permeated by the myth of the impossible as a poetic feature of the composer. The perpetuation of this myth is the main justification for the practices of simplification and self-indulgence by the percussive community on Xenakis' repertoire. The first work (*Rebonds*) brought about a more direct reflection on technical solutions for an expressive form determinant in the musical text: the double appoggiatura (in the percussive universe called drag). The second work (*Okho*) is inserted in a different discussion context, for it was written for the west african drum djembé, played with bare hands. Thus, we sought to demonstrate the dynamic process of searching for timbres on the djembé, observing the tension of what was called 'transplantation' of compositional material from a piece with mallets (*Rebonds*) to a bare hand drum piece (*Okho*). Having Irlandini (2020), Solomos (1996), Soteriou (2011) and Stasi (2011) as bibliographical references, the main goal of this article it is to make an approach about how the notion of 'impossible' can drive original solutions on percussive performance in Xenakis' percussion works.

1. Introduction

One of the most common ideas associated with Xenakis' music is "the impossible", going so far as to consider it as one of his poetic traits. In this context, Xenakis' percussion music explores a complex universe in relation to musical performance. If we can say, in a way, that this idea can be considered completely contradictory and utopian in itself (bringing an integral performance trying to traditionally obey the signs of the written music - beyond a subversive performance - in opposition to a sensitive musical result) perhaps what instigates the musical work of Xenakis lies exactly in the point in which the path chosen by each performer as a way to "transform or achieve" the "impossible" could bring to the artistic sensorial field an original contribution built, architecturally, on musical gestures expressed by sound, the performer's body, configuration and other elements that permeate the musical performance.

The very notion of impossibility, in a sense, is based on a transcendental approach to thought that is, in a sense, utopian. In examining Lyotard's definition of postmodernity and the consequences of

giving up modern meta-narratives (such as identity and meaning), Aylesworth (2015) says that discussing Art with a postmodern bias deal with "(...) a sensibility that there is something non-representational that demands to be put into sensible form and yet bypasses all attempts to do so."

That said, we will seek through a look at the works *Rebounds* and *Okho* to observe and point out original performative means by which we can identify different paths taken for the solution of musical passages considered, at first, as 'impossible'. The idea that there are distinct performative constructions that can indicate musical solutions to 'unattainable passages' may help us understand the technical difficulties and musical ideas suggested through Xenakis' discourse from another artistic and human perspective - rather than unattainable - plural, tolerant and variable in its nature.

2. Drags on *Rebonds B*

For Xenakis (*apud* Yoken, 1990), percussionists are always on the path of developing and building new instruments and performing means, allied to technological innovation, in order to seek to improve their performance with originality. The percussionist works in constant partnership with composers, luthiers, and manufactures and his role as an innovative agent, not only in the act of performance but also in the production of instrumental engineering, becomes more and more evident in the contemporary musical scenario. Reed (2003) states that "In the pursuit of the new and unusual, percussionists are frequently asked to collaborate within the compositional process in terms of learning to play a new instrument or being asked to design and build that instrument" (Reed, 2003, 48).

The passage about "learning a new instrument" draws our attention, something that induces us to think about the possibility of new or unknown sounds approached in the percussionist's performance. Sometimes the idea of a "new instrument" also goes through the possibility of exploring or proposing unusual approaches to instruments already legitimized, in ways - until that moment - not yet considered. The development of new performative means to reach the desired musical result in works by Xenakis written for percussion are, in this way, a constant for the percussionist. The idea of the 'impossible' becomes not only a performative issue (eventually), but a matter of not being able to predict the results that will be achieved in the construction and presentation of this performance: "I also take risks when proposing new solutions, whose result is impossible to predict" (Xenakis *apud* Solomos, 1996, 90).

This risk can also be assumed by the percussionist, trying not to fall into the trap of establishing as a goal setups/performances traditionally legitimated by the musical/percussive community. It is not a matter here of forcing the percussionist to limit itself with a specific approach to Xenakis. But to dodge 'common places' and always keep searching something that can contribute in an original way to the musical making.

Written for solo percussion, we can say that *Rebonds* (1987-1989) is one of the most emblematic works of the repertoire for multi-percussion, being widely performed by percussionists around the world. Divided into two parts (A and B) this work exposes points where the climax and the exposition of relatively less powerful themes instigate the percussionist to seek innovative solutions for its representation. At first, certain passages may seem 'impossible' to be performed. If the percussionist is treating the work in a traditionalist perspective, he/she will hardly make the work feasible (at least within Xenakis' poetics). The development of new techniques and the search for instruments that can 'respond' to these demands need to be considered for the representation of the musical idea to become tangible for the performer and the audience.

Rebonds has been subject of several dissertations, theses and articles since its composition. It is a widely discussed work in the percussive milieu. Thus, we bring here a very particular aspect of *Rebonds B*, which unmistakably characterises the construction of motifs and phrases: the double appoggiatura (drag). *Rebonds B* is initiated with a rhythmic *ostinato* in the high bongo where, every

two beats, a sixteenth group is coloured by a drag (Figure 01).

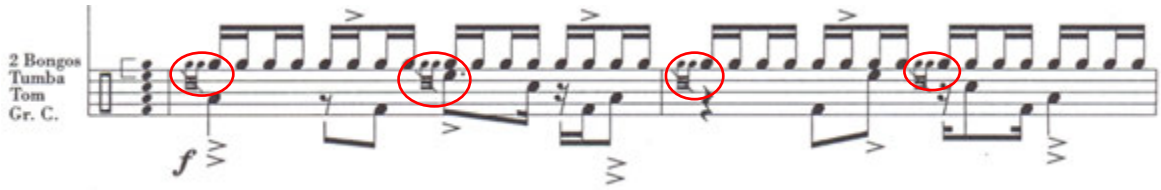

Figure 01: Rebonds B (Xenakis, 1987-1989). Bars 1-2.

During the course of the piece, the drag will undergo through displacements, as well as changes of voices and instrument groups. Due to the instrumentation of *Rebonds* (which requires two bongos, conga, tom-tom, bass drum and 5 wooden blocks) and the physicality required in the performance, the ways to achieve a satisfactory result on these appoggiature are not an easy task for the percussionist.

2.1. Bars 01 to 64

In some performances we observe percussionists abdicating the natural character existing between the drag and the main note (where the first two notes should sound with less intensity in relation to the third one). In these cases, the percussionist chooses to play with one mallet in each hand and tries to play three notes (drag and main note) as a triple stroke with a single movement with the same mallet (Figure 02).

Figure 02: Example of drag sticking either with the right or left hand using one mallet.

The result is a *decrescendo* between the first and third note. The relation between the bongo and tom-tom voices is lost in the very first gesture because, although the tom-tom has double accentuation, the main note of the bongo should sound strong. This problem is perpetuated in the voice relationship between bongo and the other drums, and it is difficult to identify the voice relationship between them. As much as the bongo voice is stable and hardly changes for long periods, it does not necessarily have an accompanying function. The voices are parallel, articulated in a heterophonic texture, aided by variation in accents. One of the difficulties in playing the drags stems from this irreconcilable parallelism.

Some percussionists argue that this way they can play the piece in a faster tempo (as if this were some kind of advantage). Others ponder that playing with two mallets brings more energy and physicality to the gestures required by the piece. In this specific point we agree. However, neither tempo nor physicality should overlap with the motoric and gestural construction of the drag and main note.

Other performances of *Rebonds B* make use of the option of playing the piece from the beginning with 4 mallets. In these cases - if the *ostinato* is being played with the right hand - the drag is performed with the outter mallet (n.4) and the main note with the inner mallet (n.3) or vice-versa (Figure 03). Here we notice that the sonorous relationship between appoggiatura and main note is more faithful. However, the work loses considerably energy, sonic depth and physicality, extremely relevant points in Xenakis' works for percussion. We also notice that performances that opt for this technical solution tend to play in a faster tempo than the one suggested by Xenakis.

Figure 03: Example of drag played with the right hand using two mallets (also can be played with left hand).

As the piece progresses, the passages that require drags become more complex, making a homogeneous execution even more difficult. At the moment this articulation leaves the bongos and starts to transit through the other instruments (tom-tom and bass drum mainly), the rebound of the mallets becomes more difficult due to the physical characteristics of the instruments. In other words, the idea of a main-note flourish fades away. This occurs mainly between bars 61 to 64 (Figure 04).

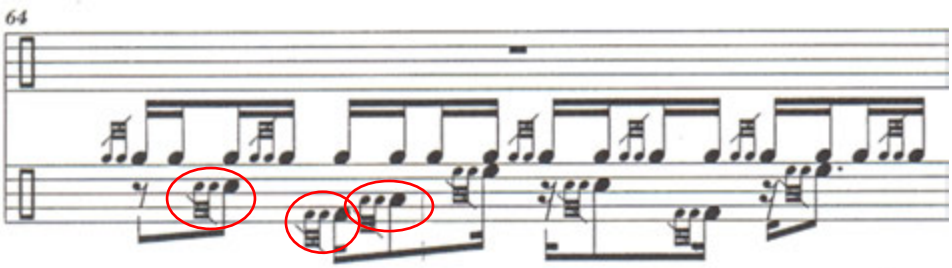

Fig.04: Rebonds B (Xenakis, 1987-1989). Bar 64 showing drags on the conga, bass drum and tom-tom.

From the beginning of the work until bar 65, the percussionist has the challenge of maintaining the energy and physicality of the performance without giving up the relationship between the drag and the main note, that allows the transmission of something essential to the work: the relationships of voices that are established between low drums and the high bongo through the relationship of pitches and accents. Thus, we suggest a third hypothesis of performance that seeks to preserve this characteristic of the work. The idea is to perform the whole section (bars 1 to 65) with two mallets, but modifying the sticking. We seek to use the premise of the technical study of the double stroke (where, by convention, the second stroke is accentuated as a way to exercise the musculature so that later the sound can, in a natural way, be balanced to the sound of the first stroke - which spontaneously, by habit, sounds stronger). Having said that, if we think that the *ostinato* is conducted by the right hand, we suggest the drag as a single stroke (l-r) followed by the main note (R) having then the following sticking in the high bongo: l - r - R (Figure 05).

Figure 05: Example of a drag and main note sticking with the right hand using two mallets (this can also be played with left hand).

The 'accentuated' strike of the second note played by the right hand will highlight the main note on the bongo, ensuring a two-voice relationship with the other drums. The energy and physicality of the performance in this section is also guaranteed by the use of only one mallet in each hand.

The percussionist's gesture needs to be fast enough for the left hand (or right, depending on the set-

up) to play accurately on the other drums. At first glance the sticking solution presented here would also allow to play the work in a faster tempo than indicated by Xenakis. But, as the passages with drags become more complex (mainly between bars 61 and 65), the unfeasibility of the body movement above 60 bpm becomes a factor working against the performance. Therefore, if we seek a performance that ensures this relationship of voices between the drums added to the relationship of the drag with the main note, and a physicality that gives energy and musicality to the performance, we seek to maintain the tempo suggested by the composer.

2.2. Bars 65 to 72

The wood instruments section, from bars 65 to 72, is one of the most challenging moments in the piece for the percussionist. Three technical aspects are worked on in this short section: single stroke, drags and rolls on a surface with little to no rebound (Figure 06).

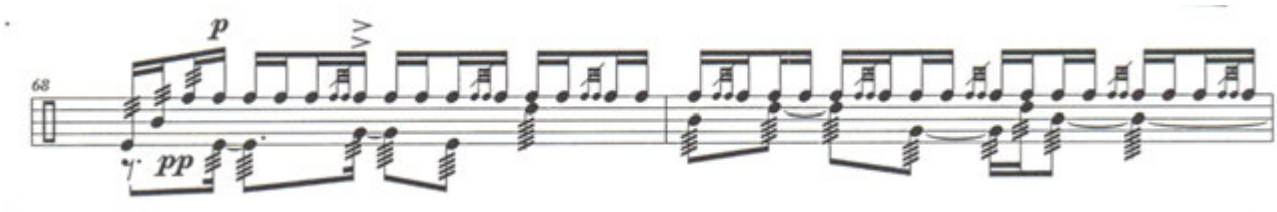

Figure 06: Rebonds B (Xenakis, 1987-1989). Bars 68-69. Single stroke, rolls and drags on pieces of wood (or wood-blocks).

An important factor that often goes unnoticed is the set-up and choice of instruments for this section. Unlike *Psappha* (1979), *Rebonds* has a well-defined list of instruments, where there is little margin for great 'adventures'. However, the percussionist, in the path of an original thought, should seek to distance himself from the common place of certain instrumental groupings legitimized mainly by musical instruments industry. Instruments such as "temple-blocks" or "wood-blocks" are commonly associated with specific groups marketed by recognized manufacturers in the musical instruments market. Several percussionists offer quite original solutions for their setups, as a way to ensure that their decisions about mallets, sound and physicality are preserved. In some cases, percussionists build their own set of wood planks, duplicating or triplicating the pieces and arranging them one on top of the other. This arrangement takes place basically in two ways (Fig.07):

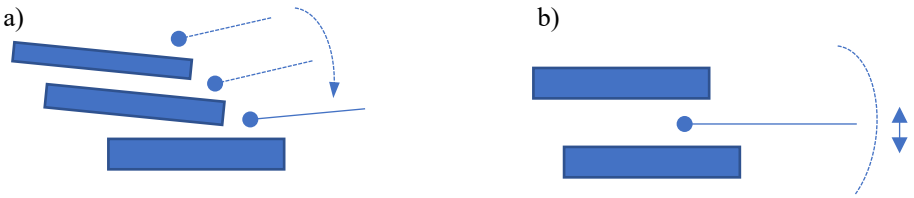

Figure 07: Suggestions of set of pieces of wood, where: a) drag (pieces above) and main note (piece below). b): roll.

Opting to use only one mallet in each hand, the setup 'a' suggests two strokes on the plank above (inclined), playing the main note on the plank below, both tuned to the same pitch. The downward direction of the gesture has gravity as a strong ally for the main note to differ from the drag. The 'b' arrangement allows the percussionist to make rolls between the two pieces of wood with only one mallet.

For setups that use standard wood-blocks - or that have resource/logistics limitations to build their own materials - we suggest another possibility, using four mallets. Considering that we begin *Rebonds* with two mallets (section from bars 01 to 65), we perform a short breath (caesura) in the middle of bar 65 as a way to start the wood instruments section. This caesura is then used for the mallets

changes, as a continuous flow of the performance. Being the first part of bar 65 the climax of the drags in *ff* dynamics, we understand that the woods instruments entrance in *pp* dynamics - in the second half of bar 65 - is enriched by the *drama* of this *poetic license* to which we allow ourselves (a brief silence between the climax of drags and the beginning of *pp* section in woods) (Fig.08).

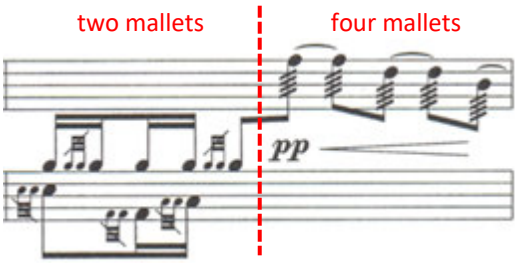

Figure 08: Rebonds B Part (Xenakis, 1987-1989). Bar 65. Change of mallets, during a brief caesura, starting a new section on woods.

For this excerpt on we then suggest the use of four mallets (two mallets on bongos - Figure 09) as illustrated in Figure 03. In this case there is no loss of physicality and energy by opting for four mallets, due to the characteristics of the wooden instruments themselves and also due to the musical text of this section.

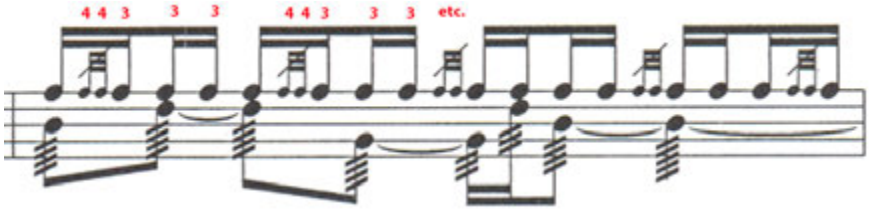

Figure 09: Rebonds B (Xenakis, 1987-1989). Bar 69, sticking using four mallets, two mallets on bongos.

Here the drag and main note of the highest wood, if we consider the right hand, could be made in the following order: 4-4-3. The rolls will be made with the other hand (mallets 1 and 2) The following picture (Figure 10) illustrates our suggestion:

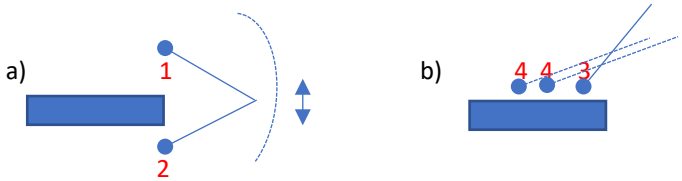

Figure 10: Suggestion of sticking using four mallets on pieces of wood: 'a' roll (using mallets 1-2). 'b': drags (double stroke 4-4) and main note (3).

There are also setups that 'mix' the two ideas of Figure 07. and Figure 10, adding only one piece of wood to the higher pitch (example 'a' of Figure 07) and using only one piece for the other voices (example 'b' of Figure 07). In this case, the hand that conducts rolls must use two mallets1 (in case he started the work with only two mallets).

In the same way that the beginning of this section allows for a *poetic license* that gives space for change mallets, we notice that - at the end of the same section - the same occurs. As a way to 'deliver' the music to the new section - that will seek to merge skin and wood instruments - through a

[1] Doing a *poetic license* as Figure 08.

pianissimo diminuendo, we understand how to explore the work's drama with a brief silence for the return to drums (Figure 11).

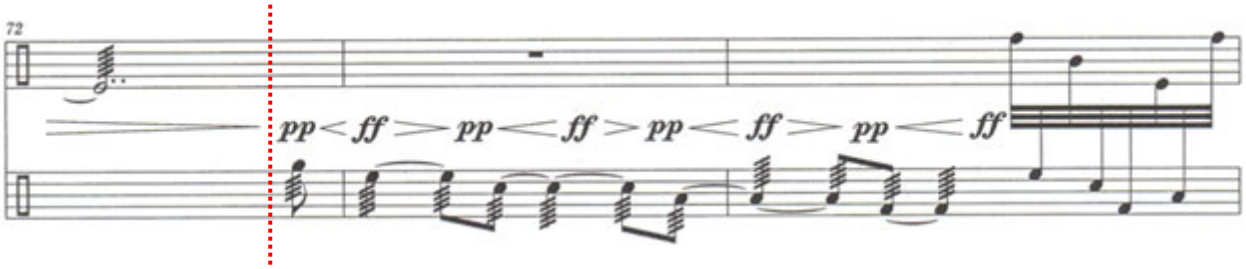

Figure 11: Rebonds B (Xenakis, 1987-1989). Bar 72. End of wood instruments section and beginning of next section.

Once again, this brief breathing (caesura) can be accompanied by the change of mallets, returning the percussionist to his original performance state with just one mallet in each hand and giving sequence to the drags on drums respecting the initial idea. If we think that the drum rolls that anticipate drags on the wood in this new section (only 4 between bars 82 and 84) could be slightly shortened, there is no harm in choosing the two drumsticks. This will ensure greater physicality and energy on the touches directing the work towards its apotheotic end.

3. *Okho*

Written in 1989 for the Trio Le Cercle, this piece for three djembés and a big african membranophone (marked in the score as *Basse profonde*) presents all sorts of challenges for the percussionists. To begin with, the percussion programs that offer hand percussion technique2, be it under the very problematic label 'World Music' or programs that actually seek to decolonize percussion education by means of integrating the traditional indigenous knowledge with the academic praxis, most commonly teach conga hand technique and not djembé specifically. According to Irlandini (2020),

> [...] the incorporation of djembé traditional hand strokes, rarely displayed by classical percussionists, calls for a deeper or more complete engagement with the drum rather than just playing it with mallets or a culturally uninformed hand technique. In fact, for contemporary classical percussionists, the step is not so small as it might seem. It requires from the performer new muscular resistance and a new development of the ear, so that it does distinguish the subtle timbral and indeterminate pitch differences. (Irlandini, 2020, 22)

The two techniques have points in common, but the hand shape is completely different for playing the two instruments. Considering the techniques that could are generally used to play *Okho,* the open tone on the conga is played with the fingers barely touching each other and the metacarpophalangeal joint hitting on the rim of the drum; the slap is played with the fingers completely touching each other, a slight curvature on the hand and the tip of the fingers almost at the center of the drum. The djembé has three basic tones: the bass tone played with the fingers slightly open and the metacarpophalangeal joint hitting between the center and the edge; the open tone is the same as the conga, but with the fingers a bit more spaced out; and the slap tone, which is a harmonic of the skin, is played with the hands relaxed, making the fingers spread a bit more and giving them a natural arc. So, even before a percussionist can begin learning *Okho*, one has to master the proper djembé technique and get used to playing on a very hard tightened skin, which can be painful in the beginning.

The xenakian approach for the djembé, while taking in consideration the traditional technique of the

[2] As commonly happens when teaching traditional knowledge in academia, there is a standardization of hand techniques for each instrument that does not encompass the complexity of variations of these techniques in each territory and within each socio-cultural context in which they emerged.

instrument, is quite unusual. The composer works with an abstract timbrical model of the instrument, converting the physical object djembé into an *hors-temp* structure of sonic events3 capable of being worked with automated *stochastic music* procedures. As Makis Solomos states, '(...) *Okho* (1989), uses only African djembes. The only concern here, too, is the most abstract, most universalizing rationalization: the classification of instruments according to register4'. (Solomos, 1996, 56) Xenakis splits the instrument in two halves/types of sound: *bord* (high pitched) and *basse* (low pitched). Each half is then further subdivided into three types of timbre, each associated with a specific dynamic. The score, however, does not specify how the timbres should be produced, leaving this choice for the percussionist, having as a guide six generic descriptions: *basse étouffé* (mf), *basse normale* (f), *basse claquée* (ff), *bord clair* (mf), *bord claqué sec* (f) and *bord claqué résonnant* (ff).

The score demands further timbrical choices from the percussionists in four places. On the *Éditions Salabert* digital edition of the score, bars 25-28, 31-32, 52-54 and 56-57, Xenakis requests 'three differentiated pitches in "*bord clair*"'; on bars 61-73, 'undulations (*glissandi*) with the fist'; on bars 74-79 'dense tremolo with sticks'; bars 80-110 'use sticks' for the three *bord* sounds. There is, however, a second version of the same score, an *Éditions Salabert* manuscript edition, with two discrepancies from de digital edition: on bars 74-79 the indication is 'dense tremolo with the nails' and on bars 80-110 the indication for the three *bord* sounds is to 'play with the nails' as well. The second step to learning *Okho* is then deciding not only how one will produce each sound, so that later on one can deal with the consequences of these choices, but also which instructions to take into consideration.

Considering the purposefully imprecise description of the timbres used in *Okho*, it is interesting to appreciate the fact that there are as many solutions to this as there are performances registered. By going through an array of versions, it was possible to determine that the diverseness in sound production of the six main timbres were more evident in the *basse claquée* and *bord claquée résonnant* sounds. The *basse claquée* sound is not a common sound in the traditional djembé playing and usually is done by performing the conga open slap tone in the center of the skin of the drum. This, however, can bring imbalance to the mixture of the six sounds, since the sound produced by this technique indeed activates the bass sound but has a lot more energy on the high partials of the slap: in short, it sounds more like a slap then a bass sound. Considering the sonic events typology of the piece, having a slap-like sound replacing a bass sound makes half of the total sounds slaps, which **drastically** alters the final rendering of the music. The version*5* of *Okho* we propose chooses to modify two of the bass sounds. The *basse normale* sound was done with the hands closed in a fist, hitting the carpal bones between the center and the rim, which in fact gives the roundest bass sound the instrument can produce, with the most drastic attenuation of high partials. The *bord claquée résonnant* sound was then differentiated by trying to enhance as much as possible the high partials of the bass sound without crossing the threshold of the slap sound; this was achieved by having the palm opened, the stretched fingers completely touching each other and hitting the metacarpophalangeal joint almost in the middle of the drum.

The *bord claquée résonant* sound is usually done in two different ways, by using either the conga open slap tone or the djembé slap tone. Using the same principles as above, it seems preferable to use the djembé slap tone, for this is the most pure and loud slap sound that can be produced by the instrument. In doing so, one can easily distinguish the three *bord* sounds types and dynamics. On the one hand, one could argue that if Xenakis really wanted specific techniques for the timbres, he should have made this very clear in the instructions of the piece; this could indicate a freedom of choice desired by the composer. On the other hand, one could conjecture if the percussionists indeed are making the choice of using the conga slap tone or just could not bother themselves to learn the djembé

[3] "Sonic events are the independent musical sounds which are found in an abstract musical space. Their attributes include: pitch, duration, and intensity, which are called dimensions. The positions of these musical sounds can be measured relatively to each other, for example: low, high, soft, loud, etc." (Soteriou, 2011,14)

[4] *'(...) Okho (1989), emploie uniquement des djembés africains. Seul souci, ici aussi, qui tient de la rationalisation la plus abstraite, la plus universalisante : la classification des instruments en fonction du registre.*'

[5] https://www.youtube.com/watch?v=JJyf5YrQE_Y

slap tone, which is harder to master and very different from any muscular memory built to play congas.

Xenakis wrote *Okho* for djembé and is expecting that the percussionist knows how to play the instrument. A composer is not required to describe every common technique for playing the instruments he/she composes to because that's on the performer's realm of action in the musical performance phenomenon. That being said, the percussionist is not necessarily nailed to the traditional technique of the djembé for playing *Okho*, but needs at least to acknowledge the secular tradition of the instrument, dating at least back to the XIII century. If the musical community is not careful, colonialist delegitimizing self-centered discourses may pass as libertarian propositions, a typical ideological mechanism of decadent bourgeois societies. Of all the family of instruments, the percussion is the one that suffers the most with the maintenance of it, by means of demeaning the technical aspect of its instruments either regarded as primitive or simple/incidental.

> I was talking about the formative elements that make percussion something always primitive. What would then be the concepts that sustain this whole structure of prejudice? There are two: the first is precisely the concept of generalization in relation to "primitive," which has always been related to the idea of origin, purity, and naturalness. This is where [Marianna] Torgovnick [in her 1990 book Gone Primitive: Savage Intellects, Modern Lives] demonstrates how so-called primitive societies are conceived as being outside of linear time. That is, the "primitives" are the same in any place and time. The second is the concept of Naturalization, that is, percussion already exists in nature itself, as well as in everyday actions. For example, because of its sound qualities, people establish an analogy between percussion and certain natural forces: thunder, the beating of the heart, breathing, the big bang6. (Stasi, 2011, 95)

The topic of threshold observation as a tool for timbre choosing will prove to be critical in the last section of *Okho*, bars 117 to 138. This is the hardest section of the piece to play, due to the two-voice polyrhythmic nature of the writing and the frequent division of the djembé into the two initial groups of timbre: *basse* and *bord*. This type of writing is very unusual to hand played drums and in fact comes from another piece by Xenakis that was being created simultaneously to *Okho*: *Rebonds A* (1987/89) for two bongos, three tom-toms and two bass drums7. The similarities between *Okho* and other percussion pieces by Xenakis (such as *Rebonds A*, *Rebonds B* and *Idmen B*) and a sort of common percussion set-up for most of his other pieces with percussion (usually a pair of bongs, one or two congas, two or more tom-toms, bass drums and a group of wooden instruments) have lead percussionists (mostly from the USA) to play *Okho* on this drums set-up.

> This is a comfortable option for musicians who are not willing to deal with the difficulties of hand percussion. However, Xenakis original intention for the work was that they be played with traditional technique, and this was only possible thanks to the collaboration with percussionists of the Trio Le Cercle (Willy Coquillat, Jean Pierre Drouet and Gaston Sylvestre), who had an interest and knowledge of the music of non-Western traditions. (Irlandini, 2020, 23)

It's hard to think of a more obvious example of the hazardous process of acculturation perpetuated by

[6] *Eu falava dos elementos formativos que fazem da percussão algo sempre primitivo. Quais seriam então os conceitos que sustentam toda essa estrutura de preconceito? São dois: o primeiro é justamente o conceito da generalização em relação ao "primitivo", que esteve sempre relacionado à ideia de origem, pureza e naturalidade. É aqui que [Marianna] Torgovnick [em seu livro Gone Primitive: Savage Intellects, Modern Lives de 1990] demonstra como as chamadas sociedades primitivas são concebidas como se estivessem fora do tempo linear. Ou seja, os "primitivos" são os mesmos em qualquer lugar e época. O segundo é o conceito de Naturalização, quer dizer, a percussão já existe na própria natureza, bem como em ações cotidianas. Por exemplo, devido às suas qualidades sonoras, as pessoas estabelecem uma analogia entre percussão e determinadas forças naturais: os trovões, a batida do coração, a respiração, o big bang.*

[7] The similarities of *Okho* and other percussion pieces by Xenakis (such as *Rebonds A, Rebonds B* and *Idmen B*) and a sort of common percussion set-up for most of his other pieces with percussion (usually a pair of bongs, one or two congas, two or more tom-toms, bass drums and a group of wooden instruments) have lead percussionists to play *Okho* on this drums set-up.

former colony owner nations on the traditional knowledge of the African and Latin American continent in the name of artistic poetic license and an unrestricted and inconsequential freedom of choice. *Okho* and *Psappha* are the only percussion pieces written by Xenakis that greatly diverges from the usual drum set-up presented is his other compositions (with occasional additions of timpani, flower pots and small instruments used in his pieces with voice), so coming to the decision of adapting the trio is an audacious move, to say the least.

Diving in the realm of technical mechanics of the djembé, let's consider player A on bar 117, the polyrhythmic group of the second half of the first beat (Figure 12). This transplant, coincidently, happens to fit quite well to the playing technique required to execute this sample. The first note, a *basse etoufféé*, is played in the center of the drum head and requires that the percussionist keeps the hand on the skin in order for it to sound muffled The next sound, *bord claqué sec*, is generally played with a conga dry slap technique, which also requires for the percussionist to keep the hand on the drum. Following this, the percussionist plays a *basse normale* and a *bord claqué*, both played with the hands allowing the head to vibrate. Another *basse etoufféé* at the end of the sample coincides with a *bord claqué sec*, making this an example of careful timbre craftmanship for the djembe. One has to consider also that playing drums with sticks is much more agile than playing the 6 timbres with bare hands. That being said the tempo of 56 BPM for the eighth note is in fact the maximum limit of feasibility for this section, with a few passages requiring either a laid-back tempo or playing the whole section lower than this (mostly when the groupings are distributed along the *bord* sounds).

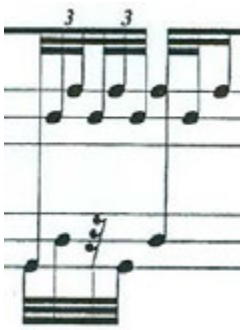

Figure 12: Okho (Xenakis, 1989) second half of bar 117, player A.

It is precisely the tension between the writing for drums played with sticks and the playing technique of the djembé that makes this last section of the piece such an interesting object of research. While playing *Rebonds A*, the percussionist has ready-made dimensions of the sonic events, mostly the timber, just triggered by hitting the drums with the sticks: the playing situation is mainly a matter of aim, height and physical transition between the large sized set-up of drums. While playing *Okho,* the percussionist deals with small sized striking spots that are extremely sensitive to small changes in the hands: the playing situation is more constrained to precise hand shapes/movements and all the timbres are produced in the same head of one single drum.

The next example is transplanted from bar 12 of *Rebonds A* to bat 19 from player B in *Okho.* This sample, completely feasible on *Rebonds A*'s set-up is, in itself, unfeasible to play due to the timbre composition chosen by Xenakis. As seen below (Figure 13), the composer writes simultaneously *bord claqué sec* and *basse normale,* the first requiring the hand to muffle the drum's head and the second a resonant sound. The whole passage presents this kind of 'wave destructive interference' relationship between the timbres and highly benefits from the alternative approach on impossible proposed by this article. One could choose to unsynchronized the strokes, giving space for the different skin configurations to vibrate/muffle (loosing rhythmic sharpness) or assume that this destructive interference will give birth to new hybrid sonic events.

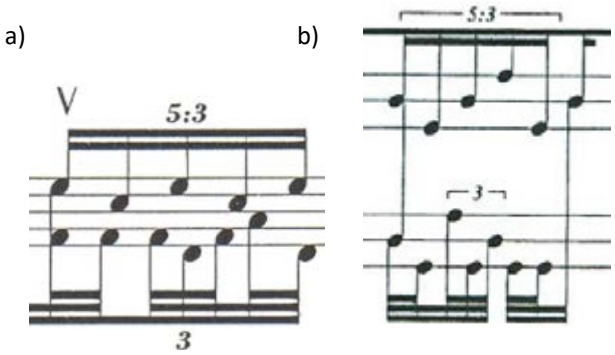

Figure 13: a): bar 21 of Rebonds A (Xenakis, 1987-1989) b): the transplant to bar 119 player B in Okho (Xenakis, 1989), with adaptations regarding timbre.

6 Afterthoughts

After all the considerations from this paper, it seems to us that trying to define or deal with the concept of 'the impossible' can be a contradiction in itself. How can the impossible be a poetic trait of a composer that has his pieces played massively nowadays? Such a transcendental value, echoing foundationists models of self and truth, may actually deviate performers from a path of proposing new approaches to canonic repertoire.

Let us take for a moment the words of Xenakis himself on one of his hardest pieces for piano, *Synaphaï*: 'The pianist plays all the lines, *if he can*.' (Xenakis *apud* HARLEY, 2004, 72) Xenakis undergoes through the hard work of writing a piece that handles the ten fingers of the pianist as individual performers having each finger its own stave, coordinates this with complex arborescence patterns and, in despite of all this multilayered complexity, counts with the performer's discernment of his own physical/intellectual limitations. With each of his compositions, Xenakis was laying the grounds for a radically distinct way of thinking music.

> All have been faced with the necessity of finding individual solutions, of engaging their responsibilities as performers. Performing Xenakis has led them radically to change their approach to the realization of a work from a score: the aim is no longer to perform indications of a prescriptive score as meticulously as possible, but rather to evaluate the musical and physical means to be applied in order to attain an aural ideal that the composer has set down on paper. This approach implies a new kind of interaction between the listening process and the production of the sound during the work itself and the performance: it is the ear that continually guides and controls the instrumental gesture (Calvet, 2011, 04).

When faced with unfeasible passages in Xenakis' music, the performer has to find new ways of dealing with the musical performance phenomenon and, in doing so, the impossible is conquered. Rather than preserving a system of beliefs based on the utopian and stale of the absolute execution of a musical text, we chose to ally ourselves with the restless attitude of the first performers of Xenakis' music: former pre-conceptions that forces the simplification of the musical text from the beginning of the learning process are left behind; the solutions should come from trying to play the text itself; there are a great amount of valid paths to take while learning his music, **so long those paths are taken with care, text observance and deep thinking.** The performers, then, can use their own expertise to give life to the composition and, to use the words of the Brazilian friar Frei Betto, go from the Utopia to the always renewing 'Topias' waiting to be made in existence.

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The enveloping spatial relationship : some perspectives relating to Xenakian architectural work

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Abstract

This paper proposes a reflection based on Xenakian architectural work relating to the idea of *enveloping spatial relationship* (Xenakis 1980). The unrealized Parisian Cité de la musique project is examined here through three important aspects of Xenakian thought : the idea of "integrating the arts of sight and hearing", reference to the Orient, and the "enveloping spatial relationship". It is linked to our various research projects on Xenakis and the question of the dialogue between architecture and music.

Xenakis' work responds to theoretical and scientific debates, heralding the multimedia era of the 21st century. It extends the idea of "*electronic gesture*" that he set out in 1958, at the time of the construction of the Philips Pavilion. With regard to a few texts and reflections such as "Music, Temporal Architecture" and "Art and the Arts" (Brelet 1941 and 1949), we will return to the idea of "integrating the arts of sight and hearing" (Xenakis 1958) and to Xenakian prospective experimental works — the films *Continu-Discontinu* (1959) and *Orient-Occident* (1960) made for the RTF under the direction of Pierre Schaeffer, as well as the musical pieces *Idole Amesha Spenta* and *Hibiki Hana Ma*, composed to be projected, both, in the Iran Pavilion and in that of the Japanese Steel Federation Pavilion at the 1970 Osaka exhibition.

We will then see how reference to the Orient, to Japanese art in particular, seems to have guided the designers of the "Cité de la Musique" project directed by Iannis Xenakis and Jean-Louis Véret, by focusing on the hidden part of the creative work (based on archival documents). What you canot see, what is in the shadows constitutes the essential parameters for the development of the Work.

Finally, we will see how the term *enveloping*, used by Xenakis in "spaces and sources of hearings and performances" (1980), is extended into the operating concept for the enveloping room, used in the initial program of the concert hall of the new Philharmonie de Paris, also located on the site of La Villette, designed by the architect Brigitte Métra in association with Jean Nouvel. We will then question the possibility of affiliation between the architectural work of Hans Scharoun (Berlin Philharmonic concert hall, 1956-1963), the unrealized prospective project of the team of Iannis Xenakis and Jean-Louis Véret (Cité de la musique, Paris, 1983-1984) and the one realized some thirty years later by Jean Nouvel & Métra+Associés (Philharmonie de Paris, 2007-2015).

1. Introduction

In January 1984, a national consultation was launched in two stages for the general outline of a future Cité de la Musique on the site of La Villette, in Paris, with a view in particular to moving the Conservatoire National Supérieur de Musique from rue de Madrid. At the end of the second stage, the architectural project of Christian de Portzamparc and his team was finally selected in January 1985. This project is designed "in a spirit of plurality, the two poles of the Cité de la Musique [responding] in counterpoint" (Christian de Portzamparc 1985, 112), according to a "singular geometry" (Christian de Portzamparc 1985, 106)[1]. In contrast, the (unsuccessful) proposal by Iannis Xenakis and Jean-Louis Véret appears as the result of thinking about the design of complex spaces, according to the principle of the *public-source relationship / enveloping spatial relationship* [2] (Xenakis [1980] 2001, 197-200) and of the *envelope* (Xenakis 1983), with the creation of an experimental concert hall sheltered by a *roof-veil* (Xenakis-Véret [1984] 2006). The Xenakian concert hall was conceived from the theorisation of an idea developed during the design of the Philips Pavilion in 1958, which was further developed until its investigations into the Cité de la Musique project in Paris in 1984-1985. Xenakis then proposed architectural systems that were free from the traditional models of concert halls. The particularity of Xenakis' work for this architectural project is that it is based on a theoretical reflection that is productive for the future. That is why it interests us here.

The uniqueness of this architectural project seems to me to stem from three important aspects of Xenakian thought :
- the idea of "integrating the arts of sight and hearing[3]" (Xenakis [1958] 1971, 143)
- reference to the Orient
- *enveloping spatial relationship* (Xenakis [1980] 2001)

2. "Integrating the arts of sight and hearing" : from *electronic gesture* to *immersion*

The idea of "Integrating the arts of sight and hearing" clearly stated by Iannis Xenakis at the end of the 1950s, in the text "Notes on an 'electronic gesture' " published in 1958 — year of the Philips Pavilion at Expo'58 in Brussels — is a particularly important point in Xenakis' work : the arts of sight and hearing find an extension in space, according to the three dimensions of space. Although this project is the beginning of the "enveloping spatial relationship" which is the subject of this paper, I will not return here to the case of the Philips Pavilion, which we have studied extensively in our previous work (Bridoux-Michel 2001, 2004, 2006, 2018). Let's just recall some of the background : at Expo'58, the aim was to work for "a more human world", to question the future of the world, in this period of technological innovation which saw the beginnings of cybernetics with the emergence of computers and everything that heralded the technological world we know today. Formulated at the time of the creation of the first multimedia space in the Pavilion (commissioned to Le Corbusier by the Philips company), the Xenakian *electronic gesture* responded to this idea of "integration of the arts of sight and hearing". It materialised a "new architectural conception", a "space with three real dimensions", as Xenakis put it in "Notes on an 'electronic gesture'".

2.1. a « new auditory sensitivity »

It was a time when young philosophers and musicians in Paris like Gisèle Brelet, in the wake of Etienne Souriau, participated in the renewal of the old debates concerning the question of the classification of the arts, which were still frozen in the Fine Arts system : Gisèle Brelet sought to define a critical

[1] Christian de Portzamparc states how his work is 'on the edges' of Euclidean geometry. inheriting the geometric experiments carried out in the studios of Candilis and Josic, he "sometimes tries to make several geometries play together" and confronts the drawing of the architectural project with "a-geometry".
[2] Adjective chose by Xenakis (*« relation spatiale enveloppante »*).
[3] See : Iannis Xenakis, "Notes sur un 'geste électronique'" (1958)

thinking of art by testing the comparison or correspondence of the arts, as well as the simple division of the arts into two categories : arts of space and arts of time. Brelet therefore proposed an analysis of musical thought by borrowing the tools of philosophy, psychology, but also those of the emerging phenomenology. A musician herself, she based her work on the musical and sound experiments of young avant-garde composers : Pierre Schaeffer, Pierre Boulez, Karlheinz Stockhausen, Henri Pousseur, Jean-Claude Risset, and also Iannis Xenakis[4]. The text "Musique et structure", broadcast for the French Radio-Télévision published in *Revue Internationale de Philosophie* (Brelet 1965), in this way provided an overview of "new music" by explicitly grasping the notion of *structure*. For her, the notion of structure is defined as a principle of "alliance between the arts". In her analysis of new music, Gisèle Brelet also takes into account the point of view of the listener and the question of listening, "new way of listening", a "new auditory sensitivity" (Brelet 1965, 391), a "total emancipation from the auditory sensitivity" (Brelet 1965, 392).

In this period of renewed debate on the classification of the arts, Xenakis' theoretical texts constitute important written traces concerning the renewal of the question of the relationship between the public, visual and sound sources and architectural space. His point of view as a theorist complements those of the composer and the architect. In his text "Notes on an 'electronic gesture' " (1958), Xenakis shows that the cinematic screen, usually flat and level, and defining the "space-time volume" of the work, should not be reduced to a "small window, even a panoramic one", but can become totally integrated with complex architectural surfaces. Similarly, the different sound sources must be able to define a three-dimensional space, consistent with the architectural space in which the audience finds itself. The history of the Philips Pavilion is well known. Unfortunately, the work was destroyed in 1959 at the end of the World Exhibition in Brussels. What is special here is that Philips had sought to collaborate with architects and artists (Le Corbusier, Edgard Varèse, Iannis Xenakis) not to present objects or works, but to offer a multimedia show combining visual and sound arts (le *Poème électronique*). Associated with the architectural project, the *Poème électronique* immersed visitors in a space integrating sound and light projections. After this remakable experience, Xenakis had to leave Le Corbusier's studio (in 1959) and continued his quest to "integrate the arts of sight and hearing" with a series of experimental works over the coming decades — and more precisely with the pieces of *musique concrète*, *Continu-discontinu* (1959) and *Orient-Occident* (1960), composed for experimental films directed by Pierre Schaeffer produced by Radio Télévision française. However, these "cinematic stereophonic" (Xenakis 1971, 148)[5] possibilities and "magnificent extensions of the art of vision and the art of hearing" (Xenakis 1971, 149), are not exploited as they could have been in a suitable space. Nevertheless, this series of pieces renews the question of the border between the arts around prospective experimental works, at the centre of the scientific and aesthetic concerns of the time[6], heralding the multimedia era of the 21st century. Indeed, the question of the relationship between space and time, between the arts of sight and hearing, seems to be posed here in relation to the question of *permanent values*[7] of art (Brelet 1946), which at the time infiltrated the fields of philosophy and aesthetics, but also that of architecture.

[4] Xenakis is quoted by Gisèle Brelet in "Musique et structure" (1965), p. 390 and p. 405.
[5] See : "Notes sur un 'geste électronique'" (1958).
[6] The study of the most archaic ancient societies also seemed to provide some answers to the questions. See Iannis Xenakis, interview by Jacques Bourgeois, October 1968 (Xenakis 1970, 50).
[7] Terms of Gisèle Brelet. It should be noted that Gisèle Brelet's research integrating the problem of formal perception in the West is a valuable contribution that could be further contrasted with the work of the new generation of artists and composers, notably those of Xenakis. The publication of his research work as "La Musique, architecture temporelle" (1940-1941), "L'art et les arts" (1949) already showed a shift in points of view defining the field of a new aesthetic. The notion of *form* was a central issue in his various critical essays on art. The boundary (and its dissolution) between the spatial and temporal arts was the subject of theoretical debates as early as 1946, and the publication of his text entitled « Musiques exotiques et valeurs permanentes de l'art musical » (1946) poses the problem of the modes of perception of the different musics (Eastern music, Western music) : "Ya-t-il en musique des valeurs permanentes […] ?".

2.2. Prospective experimental works : immerse the public

In *Continu-Discontinu*, a film directed by Piotr Kamler, the musical pieces of Luc Ferrari and Iannis Xenakis, musical pieces performed by Konstantin Simonovic's instrumental ensemble, respectively structure the two visual parts of the experimental film. In the second part of the film (music by Xenakis), the interplay between the continuous and the discontinuous is suggested by a succession of sound *spots* responding to abstract visual *spots :* the sound piece is an alternation of glissandi of string instruments, pizzicati and percussion of the orchestra, recalling in particular the writing of *Analogique A* (1958-59). Here we have the abstract expression of a mysterious visual and sound universe, a universe oscillating between telluric and cosmic energy. The authors of the film thus experiment with the possibilities of abstraction. As for *Orient-Occident*, this electroacoustic piece is part of Xenakis' series of *musique concrète* pieces. It celebrates the relationship between peoples, between East and West, it shifts the listening and viewing experience through the play of contrasts between different sound materials, evoking a kind of dialogue from one culture to another, transitions from an earlier time to a future time.

A few years later, performances combining laser beams and electroacoustics will form another type of extension of the idea of "integrating the visual and auditory arts", theorised by Xenakis in 1958 : the spatialization project proposed that the public were artistically and physically *immersed* (Delalande 1997, 137-140), , in all dimensions of the work, and — in the wake of the Philips Pavilion and its 1958 *Poème électronique* — to make sound and visual *gestures* coexist in the space in which the audience is standing. For *Idol Amesha Spenta* composed by Xenakis for the Iran-Turkey-Pakistan Pavilion, and *Hibiki Hana Ma* composed for the Japan Iron and Steel Federation Pavilion at the 1970 Osaka Exhibition, the spectators are not invited to see objects on display, but to experience projected sounds and lights, to be *immersed* in environments, to be in an *enveloping relationship*[8] (Xenakis, 1980), an " '*experiential' place"* (Nitschke 1966, 117), thanks to the principle of *sound routes*[9] and multiple spherical speakers arranged in the space[10].

2.3. Steel song, sound field and brutalist architecture

Let's take a look at this Pavilion of the Japan Iron and Steel Federation at Expo'70 : designed by the Japanese architect Kunio Maekawa[11], the Steel Pavilion had the particularity of hosting an auditorium with a circular, central, mobile stage, containing a system of some 800 loudspeakers arranged in the space above the audience. Specially produced according to the composer's intentions[12], this building structured on the basis of a parallelepiped of concrete, steel and glass[13], competed with other experimental pavilions at the exhibition, such as the origami faceted volume of the Pepsi Pavilion built by Takenaka Komuten's team to host active experiments, an environment of sound, tactile, visual and atmospheric immersions of the members of the E.A.T. group[14] ("living responsive environment" (Klüver 1970, 1)) or the German Spherical Pavilion designed by Fritz Bornemann to broadcast the music of Karlheinz Stockhausen[15], as an extension of its *Music in Space* (Stockhausen [1958-1959] 1988).

[8] To use the *enveloping* term used by Xenakis in "Espaces et sources d'auditions et de spectacles" (1980).

[9] *sound routes*, terms used by Xenakis and Philips technicians in the design of the Philips Pavilion (1958). See : Bridoux-Michel 2018, 139-141.

[10] See the graphic documents and photos published in *Révolutions Xenakis* (Solomos 2022, 134-139).

[11] Kunio Maekawa is one of those Japanese architects influenced by Le Corbusier's architectural modernity. He worked in Le Corbusier's studio in the 1920s as a young trainee. He collaborated with Le Corbusier on the National Museum of Western Art in Tokyo (1959). However, he later developed his own architectural style.

[12] "The score he [Xenakis] is completing will last seventeen minutes. It was commissioned for the Japanese pavilion at the Osaka exhibition, and will be performed in a hall built especially for it.", in "La prochaine symphonie de Xenakis sera jouée sous les fauteuils des mélomanes" (1969).

[13] And perhaps a bit of the Corbusean *miracle box* idea. See : Michel Richard 2012.

[14] E.A.T. : Experiments in Art and Technology, association of artists and engineers founded in 1966, based in New York, developing interdisciplinary projects developing interdisciplinary projects combining art and new technologies.

[15] This project is analysed in detail by Séverine Bridoux-Michel (Bridoux-Michel 2006).

Maekawa's work for the Steel Pavilion at Expo'70 is an extension of the spirit of the brutalist architecture of the Tokyo Metropolitan Festival Hall (Tokyo Bunka Kaikan) which he designed between 1957-1961, by transposing the Corbusian architectural style and in particular the Xenakian system of *undulating glass panels*. In this vein, it is a tool for the arts, an instrument of Japanese modernity, in which artists are invited to produce compositions around the theme of the "steel song" proposed by the Japanese Steel Federation. The brutalist materiality of the Pavilion is thus an essential element running through the whole project. Its relatively thick and massive walls contrast with the intangible atmospheres of the Pepsi Pavilion and the many bubbles, spheres and inflatable architectures in the exhibition. The public's immersion in the artistic works proposed in the various interior spaces of the Steel Pavilion goes as far as developing visual and sound experiments around tactility and the expression of the sensitive body : in the reception area, visitors can play the sound sculptures of the Baschet brothers. In the *Space Theatre*, central auditorium of the Pavilion, artists and composers are invited to produce new types of sound pieces immersing the audience in a series of electroacoustic works, recalling the spatialization work for Edgar Varèse's *Poème électronique* and Iannis Xenakis' *Concret PH* in the 1958 Philips Pavilion.

For the *Space Theatre* in Osaka, Xenakis composed *Hibiki Hana Ma*, an 18-minute sound piece produced in the Japanese NHK studio, created from various recordings, a collection of carefully prepared sounds including a thin sheet of steel, aircraft engines and some traditional Japanese instruments. This Xenakian "steel song" proposal is a collage of different types of mixed sound textures, fragments fixed on a support, diffused by a multitude of sources arranged in the space, extending the intrinsic effect of sound texture. The notion of *in-between* thus takes on a very particular meaning in time and space. Does the Japanese concept of *Ma* (間)[16], in the title of Xenakis' piece (*Hibiki Hana Ma*), lead us to understand that space and time are as an "'*experiential'* place, being nearer to [a] *mysterious atmosphere* caused by the external distribution of symbols" (Nitschke 1966) ? Japanese artist Keiji Usami collaborates on the project by creating a work of coloured laser beams responding to the *sound field* (音場) (Keiji Usami 1970) created by the Steel Pavilion. The program also includes works by Toru Takemitsu (*Crossing*) and Yuji Takahashi (*Yéguèn*, with the musical steel sculpture by François and Bernard Baschet). The Japanese Steel Pavilion also hosts a sinfonia concertante : *November Steps* (1967) by Toru Takemitsu including two soloists (Japanese flute and traditional plucked instruments). Still preserved, this Pavilion currently houses a permanent exhibition about Expo'70.

In parallel with this collective experience in Osaka, Xenakis continued with the well-known Polytopes series that he had initiated at the World Fair in Montreal (1967). He then concretized his idea of a "gesture of light and sound" (Xenakis 1978), notably with the creation of the *Diatope* at the Centre Georges Pompidou (1978). Following these experiences, Iannis Xenakis proposed the *Cité de la musique* project in 1984-1985 (unrealised). It thus renewed the debate on the distribution of music, proposing a new architectural model that responds to the different music styles of the world.

3. The Cité de la musique project (1984-1985), a setting for sounds that goes beyond *clichés*

The hidden part of the creative work, what is not seen, what is in the shadows, contains the essential parameters for the elaboration of Iannis Xenakis' work. Of course, for Xenakis, theoretical exploration is important; he made this clear in 1983, when he proposed "some ideas for the future building" at La Villette : "you have to [...] work in the theoretical field otherwise you are slaves, trapped by *clichés*" (Xenakis 1983, 41). He then invested in the architectural representation of the building to overcome *clichés* and *prejudices*. What do the study models and drawings of the complex canopies of the *Cité de la musique* project cover, in particular those kept at the *Cité de l'architecture et du patrimoine/Archives d'architecture du XXe siècle* ? How much novelty is proposed in this architectural project ?

[16] The character can be read as *ma* or *kan*, as Xenakis notes (handwritten document, Xenakis archives). The *ma*-concept was disseminated in France in 1978 with "Ma : espace-temps du Japon", an exhibition designed by Arata Isozaki as part of the 1978 Autumn Festival in Paris.

3.1 Cité de la musique competition

During the national consultation of architects for the future *Cité de la Musique de la Villette*[17], Xenakis responds as an "Architect-Composer ". Organised in two stages, this national consultation of architects first selected three projects (Marie Petit-Maxime Kétoff / Christian de Portzamparc / Alain Sarfati) from the sketches of 15 teams[18]. The jury then decided to invest in the Portzamparc team's proposal that proposes spaces in which several interrelated geometric figures play together, a system of "sequences of places and objects" linked to the spaces of the Parc de la Villette and of the gallery designed by Bernard Tschumi. Proposing in particular a "musical street" design, or a "spiral winding" (Christian de Portzamparc 1985, XXVI), the project appears to be designed according to compositional design principles. However, it is cautiously limited to the still relatively artisanal and traditional representational tools available at the time, computer tools and computer-generated images still being in their infancy in French architectural agencies. In contrast to Xenakis' proposal, he proposed a plastic composition by fragmentation of spaces, somewhat dispensing with the complex forms that would have required extensive collaborative work with a team of engineers. The June 1985 issue of the magazine *l'Architecture d'Aujourd'hui* presented all the proposals, with 15 photos of models, including the model of the "Iannis Xenakis - J. L. Véret" project. For this competition, Iannis Xenakis called on Jean-Louis Véret, an architect whom he had known at the Le Corbusier workshop in the early 1950s. The team formed around Xenakis and Véret included assistant architects and a structural engineer, Nicos Chatzidakis, of Greek origin, graduate of the Athens Polytechnic (like Xenakis). Chatzidakis had met Jean-Louis Véret and Iannis Xenakis at the Le Corbusier workshop, since 1946 when he was an engineer in the ATBAT design office.

3.2 Landscapes of *clouds, hills, valleys, islands*

The models produced for the Cité de la musique competition therefore presented a collaborative project respecting the elements of the competition program. The specificity of the Xenakis-Véret project was based on the design of two large umbrellas with autonomous and relatively complex volumes. Almost origami, these volumes are structured in self-supporting paraboloid veils, hosting the different spaces of the Cité de la Musique program, located on either side of the Place de la Fontaine aux lions. The project was then articulated with the urban space and the Parc de la Villette, according to the photomontage with inlay of a hand-drawn axonometry delivered in the competition file. This photomontage shows a concrete view of the southwestern area of the project, "from the roof of the auditorium[19]". The auditorium building, *patatoïde*[20] (Xenakis 1984), conceived in concrete covered with wood, is independent of the system of *hulls*, thin *veils*, *roof veils* (Kanach 2006)[21], covering and structuring the whole building. The experimental room is a kind of large *multimedia space* (Véret-Xenakis 1984)[22], free from traditional concert hall models, and, of course, totally free from the modern Corbusian language. Here we can see that Jean-Louis Véret collaborated in the project in harmony with the Xenakian

[17] In 1981, Jack Lang was asked to develop a « Mission de réflexion sur l'idée d'une cité de la musique » (Mission for reflection on the idea of a music city) following Jack Lang's proposals to François Mitterand : "Your presidency, even more than that of your predecessors, must be marked by a few exemplary achievements. You no doubt remember the great project that you presented to UNESCO concerning the establishment of a "Beaubourg of Music" at La Villette. If this project is to succeed, it is essential that the Minister of Culture has the upper hand in the entire la Villette operation." Note from Jack Lang to François Mitterrand, 26 May 1981. (Archives of Jack Lang, Institut Mémoires de l'Édition Contemporaine), see Thomas Hélie, "L'architecture des décisions. Un président-bâtisseur dans le tournant de la rigueur", in *Gouvernement et action publique*, vol. 6, pp. 7-35. https://doi.org/10.3917/gap.172.0007, Cairn.info, 29/06/2017.

[18] The 15 teams selected are as follows : 1. Archiplus (J. Bernard et F. Soler) 2. O. Baudry 3. H. Gaudin 4. E. et O. Girard 5. F. H. Jourda, G. Perraudin 6. M. Kagan 7. M. Petit, M. Kétoff 8. Maurios 9. G. Clapot 10. J. L. Pellerin 11. Ch. de Portzamparc 12. E. Robin 13. A. Sarfati 14. J. P. Viguier, J. F. Jodry 15. Iannis Xenakis, J. L. Veret. (*L'Architecture d'Aujourd'hui* 1985, XXI).

[19] Centre d'archives d'architecture du XXème siècle, Jean-Louis Véret Archives.

[20] According to the term noted in the axonometric competition drawing by Iannis Xenakis, March 1984.

[21] Terms of Xenakis and Véret (1984).

[22] Project, March 1984.

theoretical elements clearly stated in the 1983 text to reform traditional opera. Roof veils, complex canopies and undulating glass panels are used to reduce the frontal aspect of the stage.

This *patatoïd* concert hall, designed according to the well-known "box within a box" principle, is an *écrin de musique* for the designers (Xenakis 1980) or *écrin des sons* (Xenakis-Véret 1984). The hall can be transformed thanks to the numerous possibilities of scenic arrangements (hills, tiers, audience in the centre or on the periphery...) thus meeting the requirements of the music that Xenakis knew as a composer. While the formal complexity of the project makes it possible to regulate the acoustics of the spaces, it above all integrates the sensitive experience of the spectator, placed on *islands* (Xenakis-Véret 1984) and *clouds* (Xenakis 1983) : "The spectator, suspended in space like a spider at the end of its thread, should no longer have the feeling of living on a plan, but in three dimensions" (Xenakis 1983, 40).
The architectural proposal remains experimental, in the image of Xenakian musical thought ; it remains in the state of a "matrix of ideas" (Xenakis 1971, 16-19) [23]. The Cité de la musique project is an extension of this idea, unless it also evokes a reminder of the glissandi "waves" of the composer's first orchestral piece, *Metastasis* (1954), and the paraboloidal curves of the Philips Pavilion from which the spectator-listener "suffers the influence" (Xenakis 1957).

Landscapes of *clouds* (Xenakis 1983), *hills*, *valleys*, *islands* (Xenakis 1984). This vocabulary seems almost to echo the words of the architect of the Berlin Philharmonic, built some twenty years earlier (1956-1963), Hans Scharoun. This is how Scharoun describes the new Berlin Philharmonic, and in particular the so-called *vineyard hall* : "the shape of the hall is inspired by a landscape. It is conceived as a valley at the bottom of which is the orchestra surrounded by 'vineyards' on the hillside. This 'landscape' is matched by the 'firmament' of the ceiling. Its shape is reminiscent of a tent." (Scharoun 1963, 4) The Xenakian project echoes this: the idea of the *public-source relationship* is then translated into space by "hills or islands, valleys on which the listeners-spectators face each other or turn their backs", "variable arrangements", a "programmable and computerised" floor (Xenakis-Véret, 1984). Does this vocabulary allow designers to achieve a relatively immaterial architecture, inspired by undulating elements of a landscape ?

[23] Iannis Xenakis, « Les trois paraboles » (1958).

4. Xenakian project : the enigma of Japan

The reference to the *Orient*, to Japanese art in particular, we talked about in connection with *Hibiki Hana Ma* by Xenakis. But our hypothesis is that this experience seems to run through the Xenakian Cité de la Musique project, even if this is not clear. Certain documents held in the 20th century architecture archives of the Cité de l'architecture et du Patrimoine in Paris seem to support this view : Hiroshige's engraving, Naruto's whirlpools, reproducing the "noisy gate" of the Inland Sea in the Awa region, the eastern gateway to Japan, Japanese women sailing on the waves or walking on the edge of the reefs of a beach, playing the flute, the folds and undulations of dresses, all these images found in the Jean-Louis Véret archives alongside the models of the Cité de la musique project[24], are possible references for the design of the Cité de la musique project. Black-and-white photographs (Jean-Louis Véret archives) listing various models of the Cité de la musique project can be seen, alternating with representations of Japanese prints. We know that Xenakis appreciated the reproduction of Hokusai's wave, which figured prominently in his studio office. This is of course a reference to *La Mer* by Claude Debussy, who was himself fascinated by the Far East and Japanese prints. One might also wonder whether the project does not borrow some elements from the theatre No Japanese[25] that Xenakis had discovered in 1961. The reference to Japanese architecture, which Xenakis describes in a 1977 text, may have led Xenakis to sketch out some particular elements of this unrealized project : "simplicity of forms", "combination", "internal 'mobilit'" (Xenakis 1977). Does the Cité de la musique project outline a gesture towards the *Orient*, a sign of a shift in focus ? These photographs are an enigma, unless they are just an anecdote, without any relationship to the photographs of the models...

5. A future for the "enveloping spatial relationship"

Enveloping, this adjective is used by Xenakis, in « Espaces et sources d'auditions et de spectacles » (1980), to characterise the model of ancient Greek theatre : "the sources are in the centre, the audience around, on a plan, in a bowl or in a sphere [...]. The ancient Greek theatre is a first enveloping spatial relationship." However, the term seems to refer to the new paradigm of the 21st century concert hall. The unsuccessful architectural proposal by Iannis Xenakis and Jean-Louis Véret appears to be the bearer of a renewed reflection, centred on the design of an experimental, *non polyvalent* hall, but *enveloping* (Xenakis [1980] 2001). Thus, the notions of *envelope* and *enveloping* room were to become driving forces for other projects in the following decades. In the 1983 paper (Xenakis 1983, 40-41) , Xenakis explains what he means by *envelope*. According to him, the envelope is synonymous with the *elegance of the material* at the "limit of the unbuildable". "The envelope doesn't have to be unique because there are lots of things laid out on the periphery". Nevertheless, it was not until the beginning of the 21st century that the reflection was taken up again and concretized, particularly in France : "a model for the transmission of contemporary creation" (Bayle 2014) aimed at the "democratisation of musical life[26]" supported by Pierre Boulez and Laurent Bayle. Thus, the term *enveloping* is used today to describe the type of concert hall in the Philharmonie de Paris that the architect Brigitte Métra designed with her team on the La Villette site, as an associate architect at Ateliers Jean Nouvel (2007-2015)[27]. Jean Nouvel's project is a "calm relief" with "nuances of pearly tones", the "grey and silver folds of the building[28]" (Nouvel) develop a quasi-baroque architecture. At the same time, Brigitte Métra is setting up the project

[24] These documents were presented at the « Iannis Xenakis, entre les mondes » exhibition (Séverine Bridoux-Michel exhibition curator), Halle aux sucres / Learning center de Dunkerque, January - February 2019.

[25] Xenakis was "attracted by the sounds of the Japanese No' with their very intense contrast between the small flutes and the percussion". See : Iannis Xenakis interview by François Bernard-Mâche in *Revue Musicale*, n°383-385, p. 221. In 1961, Xenakis was invited to participate in the International East-West Congress in Tokyo at the Metropolitan Festival Hall (Tokyo East-West Music Encounter Conference). Iannis Xenakis, "The Riddle of Japan", in *This is Japan*, n°9, 1961, pp. 66-69.

[26] Official terms in rapport de la commission des finances n°3110 – annexe n°29 de l'Assemblée nationale, 8 October 2015 (https://www.assemblee-nationale.fr/14/budget/plf2016/b3110-tIII-a29.asp).

[27] She has collaborated with Ateliers Jean Nouvel as associate architect for the Philharmonie de Paris concert hall and the Théâtre de Perpignan, and as partner project manager for the Danish Radio concert hall in Copenhagen and the Culture and Congress Centre in Lucerne.

[28] Jean Nouvel, project presentation, http://www.jeannouvel.com/projets/philharmonie-de-paris/.

(a “box within a box”) according to the principle of “enveloping design” requested by Laurent Bayle[29], as President of the Philharmonie de Paris, the “*cyclorama volumétrique* envelope” (Nouvel 2007). The large 2 400 seat auditorium was then the subject of dialogue with all those involved in the project (acousticians, technicians, architects, but also composers, conductors, musicians, educators, etc.). The project complies with the various elements of the rules of the project management competition (2007) and in particular to the program requirement to propose an innovative architecture renewing the front room models : “It [the concert hall] differs from strictly frontal models and favours an envelopment of the stage by the audience in order to reinforce the feeling of intimacy between the performers and their audience[30]”. Brigitte Métra is able to play with the models in this way, to orchestrate the architectural work by drawing on her experience as a concert hall architect. Forming and meticulously deforming the interior volumes to optimise the acoustics of the hall, making the project flexible depending on its needs, altering the types of hall format, designing a new model resulting from the cross-fertilisation of different types of hall formats - starting with the one designed by Hans Scharoun for the Berlin Philharmonic. Creating a “modular enveloping room that we have enveloped”, “making the audience feel immersed in the music[31]”, this is the work in which Brigitte Métra actively participated for the Philharmonie de Paris. Thus, “the spirit that underlies the aesthetics of the building [...] is lightness, the impalpable side of music, just as the structure of the hall's balconies is light. There, nothing crushes... Everything is airy...” (Laurent Bayle 2014).

6. Conclusion

In conclusion, let us note that the case of the Xenakian Cité de la Musique project defined, before its time, the renewal of an architectural model that had become obsolete. The system proposed a tool based on theoretical reflection and several decades of experience, integrating the public, the performers, and the new means of sound diffusion experimented by Xenakis in Paris, Brussels, Montreal and Tokyo. If the 1984 La Villette project transposed more the baroque spirit of Scharoun's Berlin Philharmonic than the brutalist spirit of the Tokyo Metropolitan Festival Hall de Maekawa (1961), it heralded the concert hall of the 21st century, carried by the breath of a new paradigm : the enveloping space.

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[29] “To ask for a hall with an enveloping design that can be transformed with a really innovative and efficient modularity. I had many questions about the type of concerts that could be promoted.” (Bayle 2014).
[30] Extract from “règlement du concours de maîtrise d’œuvre. Construction d’une grande salle de concert de la Parc de la Villette, Paris, 19ème arrondissement”, competition notice 2006, “concours restreint international de maîtrise d’œuvre”, ordonnance n°2005-649, 6 June 2005.
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Space, Rhythm, and Architecture: Atmospheres in Works of Iannis Xenakis

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Abstract

The relationship between physical and musical space has been explored in the last few decades along with the interconnections between musical composition and architecture (see Böhme 2017; Griffero 2016). Not only genuine thought of Iannis Xenakis opened up new possibilities within the field of music but also defined the horizon for future feeling-based investigations in sound studies, environmental design, and architecture. Also, in the 1960s German philosopher Hermann Schmitz started developing his *System of Philosophy* with feelings and emotions perceived spatially as atmospheres. Schmitz noted that music is the "most telling and evident proof" that feelings (Gefühle) are atmospheres themselves (Schmitz 1978).

Along with such principles as stochasticism in the early works of Iannis Xenakis the first part of this article explores how an audiotactile imprinting is experienced felt-bodily (leib) and grasped through atmosphere considered as all-encompassing ambiguous feeling poured out into non-geometric space with a unique and immersive qualities charging the environment. This research employs mixed methodology and mainly focuses on the phenomenological perspective of the first-person experience apart. It undertakes the analysis of how the affective tone of the environment is being created and this is where a new look at perception emerges: there are several types of felt-bodily disposition and communication influencing the quality of the given space within a certain environmental register.

The second part is followed by the results of the first and is aimed at reconsidering Xenakis' works with a special focus on rhythms (Rhythmosphere), acoustic vibrations in his installations and musical compositions known as Polytopes. Phenomenological approach enriched by atmospheres appears as a prospective tool allowing to focus on affective scaffolding and to reveal the world of intangible architecture of affect. In this way a deeper understanding of Xenakis inheritance uncovers the perceptive register from the *inside*, not *outside*.

Introduction

The relationship between architecture and music may be easily captured within the field of history of art. The 'glue' that holds the layers of such intrinsic power lies in the field of mathematical proportions and harmonious spheres hidden in the taxonomy of spaces. Unfortunately, due to the variety of factors coming from different parts of history, politics, economics they were shadowed

and forgotten. More often such neglecting leads to narrowness of perspectives, blurred horizons of thought and blind spots in classic theories.

The harmonic proportions coming from Ancient Greece reach its peak in Renaissance thought embodied in architectural projects and grounded in the sorcery of numbers and shapes. The expressive quality of art became central in the late 18th century along with aesthetic relativism focused on the immersive qualities of architecture encoded in its aesthetic dimensions. Immersiveness is what unites both architecture and music: a deep submergence of diffusive qualities of the given space poured outside and affecting one's body. The works of Iannis Xenakis (1922–2001) could serve as the best example being the chips of this mosaic by assimilating all the named factors. Despite this fact the correlation as such was not yet articulated or conceptualized. Xenakis' influence on both fields is hard to overestimate. Known as an architect and a composer, he did not find interest in the phenomenological correlation between musical composition and construction but on structural connection of both. According to him, all the music could potentially be homogenized creating the new fabrics unified by the intangible tissue of architectural form. Even the titles of his works, however can easily open the new surface of meanings by revealing the profound lesson in passing: not yet learned and almost forgotten being buried under the pressure of massiveness of a brand-new investigations shaping blocks of actual theory responding to rational and quite materialistic requests within the fields of music, urbanism and architecture. Thus, clouds of hidden rays of rhythms and amalgams of affects remain unnoticed, not being so 'illusive' as they may seem initially. This work shows that a more powerful phenomenological perspective could be coined through the analysis and reconstructions of the methods Xenakis used as well as revision of his projects, vibrant, resonant and made with manifestations of his vital and incessant drive towards change and freedom of architectural and musical form without any point of return.

The analysis rooted in current research reveals the orchestra of immaterial components appearing as atmospheres, — invisible, immersive and always in-between, — masses of a certain affective qualities of the environment usually experienced corporeally and grasped in a chaotic rhythm of the events. The interdisciplinary methodology sitting at the core of this investigation, is followed by phenomenological analysis enriched by such concepts as contingency, stochastic (probabilistic) procedures as well as affective niches and scaffolding derived from the phenomenological psychology (Krueger and Colombetti, 2014). The concept of atmosphere, thus, is understood in a more dynamic perspective way than in sound or urban studies namely as set of intangible constellations of affect located externally and forming the flexible 'clots' of charged feelings spread in the environment and combining a set of affective niches. They are experienced felt-bodily through the qualities of architectural compositions and their rhythm is reverberating through the ocean of pulsating, fluid and constantly changing forms as refrain, a musical concept described by Deleuze and Guattari. Thus, the example of Xenakis' works and installations, makes it possible to revise already existing concepts as well as to refresh an ancient discussion about the registers of the intangible available through sound and feelings.

Between Stochastic and Audiotactile: Influence of of Iannis Xenakis

In the realm of music and architecture Xenaxis was highly influential by setting the frontline of the new-era of both fields: architecture and music. In the late 1950s, some composers were interested in synthesizing sound through the manipulation of individual digital samples. Such

interest comes along with the popularity of computers with digital and analog converters. Through this process, amplitude and duration values are obtained through musical procedures and do not stick to any acoustical model. A desire to explore the sound synthesis possibilities unique to computers was formed with the approach known as non-standard synthesis. In probability theory, the formal concept of a stochastic process is also interconnected with a random process. In 1954, Iannis Xenakis introduced the use of probability distributions in musical composition in order to manipulate the orchestral sound masses, he was experimenting with probability theories. As a pioneer in this field he defined microscopic aspects in his work Pithoprakta (1955–1956), translated from Greek as "actions by means of probability". It is divided into the four sections, classified by textural and timbral specificity (glissando and pizzicato). Getting to the macroscopic level, the sections are designed and controlled by the composer while the single aspects of sound are described through the mathematical theories.

The aim that unites all of most common non-standard synthesis strategies based on math theories and programming that appeared later, during the 1970s, was not only to unify the macrostructure and the microstructure of compositions, but to use synthesis techniques and to open an experimental field in sound synthesis. In 1972 Xenakis first used a computer for stochastic sound synthesis, he polished his experiments at the Centre d'Etudes de Mathématique et Automatique Musicales (CEMAMu) in Paris. After a short break, his works devoted to stochastic synthesis were published as Musiques formelles: «Nouveaux Principes Formels de Composition Musicale» and later in 1981 this edition was expanded.

Undoubtedly, indeterminacy and randomness are terms that are broadly applicable in a diverse spectrum of academic works and signify a lack of constancy or permanence in any given phenomenon or process. One of the most detailed researches made to the subject matter is a dissertation of G.M. Potter with the term "randomness" taken as the basis for the analysis of the "music of chance". In this thesis the concepts of "aleatoricism," "improvisation," "uncertainty," as well as "randomness" and "openness" are delicately differentiated (Potter 1971). He understands aleatorics synonymously with randomness, and, at the same time notes that any aspect of a piece of music can be considered as such. In relation to "disorder" in the sense of "randomness", Potter refers to Xenakis, who applied the term to a higher level of coherence, where a folding set of random events forms a unity of heterogeneity. Initially, the mathematical definition of "randomness" is brought together by Potter with "chance" as free choice without a definite goal, direction, principle, or method; but this choice is still determined by the statistical possibilities inherent in the physical situation or "state of affairs" (Potter 1971). Finally, he emphasizes that the composer refers to a situation with an unknown outcome as an "open" musical setting. He also gives a prominent role to the analysis of Xenakis' works and to the notion of randomness in physics (Potter 1971). Aleatoric music, that is the use of all kinds of random or improvised effects is not the same thing as the stochastic approach of Xenakis.

In chapter "Philosophy of Music" Xenakis introduces the phenomenon of sound as a correlation of sound characteristics and, thus, a combination of axes such as intensity, density, disorder etc. He treats elements mathematically aiming to approach them by the set of numbers (Xenakis 1992), and insistsing on limitations of traditional notation known from Ancient Greece. Xenakis, though, shows the new methods of sound representation, geometric and algebraic. Captured by the idea of the of sound emansipation, Xenakis worked uopn a diagonal dimension that negates the classical

construction of a musical composition with axes of vertical and horizontal. For Xenakis, it was important that the musical composition was encoded with a certain architectural form with its own coordinates and rhythm in contrary to classical methods. Remarkably, the notion of diagonal as a breakthrough trajectory in music (in space-time relation as well) was emphasized by Deleuze and Guattari in the second part of their famous work «Mille de Plateaux», describing the melodic horizon and referring to musician Pierre Boulez, a competitor and a colleague of Xenakis:

[…] And in each case it is a different diagonal, a different technique, a creation. Moving along this transversal line, which is really a line of deterritorialization, there is a sound block that no longer has a point of origin, since it is always and already in the middle of the line; and no longer has horizontal and vertical coordinates, since it creates its own coordinates; and no longer forms a localizable connection from one point to another, since it is in "nonpulsed time": a deterritorialized rhythmic block that has abandoned points, coordinates, and measure, like a drunken boat that melds with the line or draws a plane of consistency. Speeds and slownesses inject themselves into musical form, sometimes impelling it to proliferation, linear microproliferations, and sometimes to extinction, sonorous abolition, involution, or both at once (Deleuze and Guattari 1987).

That kind of non-intentional, revolutional at some point and more of random but, at the same time captivating feature illuminates the whole field of atmospheric investigations. Consequentely, it involves a particular way of bodily (leiblich) perception separated from the rational cognitive structure. It happens, for example, in the musical composition or in the processes of gesture-making aimed at a formalized production of sound. The audio-tactile ontology, developed in a couple of last decades, blurs the borders between *input* and *output*/ *inside* and *outside* (Caporaletti 2018). In this case, music not only allows to create atmosphere but evokes affective and corporeal responses, modulating moods and even influence the behaviour. German sociologist Hartmut Rosa, in his work devoted to Resonance, describes it as a key for the good life, world attunement and the environment. He casually develops his theory on the same dialectical orbit as German philosopher Hermann Schmitz with his elaborate notion of Leib as a felt-body (not physical) and atmospheres as feelings poured outside. Rosa claims the situational experience of resonance with the world as constitutive in the response to the dynamics of changes on a different levels of the space and environment (Rosa 2019). In his phenomenological research Schmitz shows that it is the atmospheric conditions, emotional impressions, and affective involvement that influence consciously regulated human actions. All of them can only be percieved felt-bodily and can barely be comprehended cognitively. Perception of the environment is shaped by impressions one receives through a variety of habitual processes, or spontaneously, as when one enters a room filled with luminous lightning — his or her mood changes drastically through a certain attunement. Atonality of the broken rhythm can be experienced as tense in terms of felt-body and captivating in atmospheric sense. The cities of affect and fluxes of the constant becoming or refrains that appear within in the form of a composition or sound event are more powerful than they initially seem.

On Atmospheres: Sound, Light and Architecture of Affect

After Schmitz' ambitious phenomenological project one of the brightest paths for Atmospheres comes from philosophy of architecture and was followed by works of such authors and architects as Juhani Pallasmaa, Peter Zumthor and Gernot Böhme. Generally, Atmosphere is a phenomenon

that undermines the common boundaries between the perciever and the percieved. The sound and light in atmosphere holds a transitive status between the subject and the object as well. German philosopher Gernot Böhme and french philosopher Jean-Paul Thibaud claim atmosphere to be “an objective sensation spilled into space and always diffuse” (Böhme and Thibaud 2016). Such statement matches the studies of space in architecture, in which its qualitative characteristics predominate over quantitative ones. In his famous work *Modulor II* Le Corbusier recognizes Xenakis prominent influence in both spheres, architecture and music and cites him quoting Goethe, noting that architecture is like a 'frozen music'. Xenakis, in turn, wonders how the sound space is organized or, in other words, how could one approach sound design through the built environment or architecture?

Ambitious artistic projects in contemporary sound studies in most cases are aimed at exploring the wide range of effects sound landscape (Schafer 1977), its sensory and affective qualities. On the other hand, affect understood in terms of Massumi settles a multiplicity of the new possibilities parallel to what we got used to see in acousmatic music or the situation. In Deleuzo-Guattarean terms, territorialization of the sonic event with potentiality of that situation transforms into sound object (l’objet sonore) (Schaeffer 2017) as there has also been a gap between the processes of perception and production with the reference to the ontological status of musical pieces, the objective characteristics of the latter and the qualities by means of which they radiate into space, atmospheres came to the fore again. Sound becomes the dimension of the space with a certain affective register of located in the environment.

Enviromental intensities are better to be approached with theoretical background of Deleuze and Guattari. They claimed affect could be a set of flows or fluxes moving through the bodies of human and other beings. Thus, the affective constitution of the atmospheric is quite material if understood in a more dynamic and continuous process of emergence (see Harvey 2013). According to this approach, we are at all times surrounded by fields of potential but not yet crystallized chances into possibilities (or actualities). Such radical empiricism is orbiting on the assumption of the experiental presence of the virtual recalling to the similar qualities atmospheres have with refrains extended through the fluxes. Massumi's theory of affect (Massumi 2015), reveals this event as a (trans)individual and (extra)psychological with a corporeal dimension belonging to both the natural and cultural spheres. After works of Deleuze and Guattari, Massumi assumes that affect (as opposed to emotion or feeling), is not merely a mental effect but an extra-mental intensity. As for atmospheres, they are what charges, energizes a pre-categorical realm of space, so they potentially have a capacity to forcefully engage the vital dynamics of the felt-body already mentioned in the previous section (Schmitz and Werhahn 2011). Often confused with the Merleau-Pontean lived body, Leib is more like a resonance board or sonar with the capacity of being spatially affected by atmospheres. Although the spatiality of the felt-body is non-geometric and surfaceless (flächenlose). In “Thousand Plateaus” Deleuze and Guattari employ the shift from possibility to actuality referring to the intensity and, finally, to the extended bodily placement. Their concept of *Body without organs* is a provocative dimension to be imbued with the intensities later distributed in a spatium that is intensive as well but lacks the extension and surface as such. In simple words, it is not merely a space or it is not something ‘located’ in space but it definitely occupies a spatial dimension to a certain extent. Thus, one perceives the environment as an interaction mediated by the same spatial sounds by reconsidering the status of architecture, music and a process of listening to a particular sonic atmosphere in a felt-bodily dimension being always

in communication with the environment. The work of Xenakis brings experimental spark with the extremely ecstatic and emergent qualities of his works combining the multiplicity of the possibilities of spatial for both fields music and architecture united by atmosphere. The sound space is no longer homogeneous, but is separated into different spatial areas. So, one perceives the music according to his or her location. Xenakis developed this concept of spatially differentiated music for the first time with his orchestral piece Terretektorh (1965–1966) and continued his experiments with the space.

From Topos to Spatium: Production of a Rhythmosphere and Affective Scaffolding in Polytopes

Determined by multiplicity of factors, we navigate space in everyday life finding ourselves in richly structured territories filled with a range of possibilities also defined by changes in our bodies and the environment. Space is often considered as a more abstract component grounded in mathematics and geometry, while place resists from being limited in the way in which it is imbued with memories, feelings and moods (Perez-Gomez 2016). Place, in turn, marks space through the experiential process. In other words, place is also "lived through" with the experience and space is understood as the homogeneity that is not place and does not have the peculiar characteristics of place. The affective states we face are external and thus, personally or collectively, we create affective niches to scaffold our experiences and navigate material environments. Sometimes people do it unconsciously, although that is why such bodily-affective style of living is often left unnoticed. We act upon the affective affordances expressed in the cities of affect urbanized by our habitual activities like working, wearing favorite pieces of clothing and working in specific places where the 'territory' we inhabit has a particular meaning for us as we explore the territory. In this game of the meaning, Le Corbusier citation couldn't serve better: "I am not building the Philips Pavilion, but an electronic poem. Everything will take place in the interior — sound, light, color, and rhythm. Scaffolding will form the exterior of the pavilion" (Le Corbusier 1958).

The close cooperation with Le Corbusier during the work on the Philips pavilion opened up a field of opportunities for Xenakis to further experiment with space. He implemented his ideas in his series of installations entitled Polytopes: these works included the experience of space not simply as present and real within a certain environment but corresponding to a sound, light and material charging "living" space understood by the visitors and condensed and reassembled as a career of moods. The term Polytopes originated from the two words poly (many) and topos (place). It mainly refers to the staging process in which architecture is a crossing point for sound, color and light. Here the concept of atmospheres also plays an important role in relation to space, allowing the dynamics to be grasped perceptually and bodily rather than through cognitive effort. In Xenakis' works, time also plays a spatial role and becomes the fourth dimension: because of the projection of different sounds in different places, many sound spaces collide. In this project, pliable colored plates of slide projectors changed the direction of light prints on the walls and dispersed with the help of mirrors, imitating natural phenomena and created illusory spaces. Since the installation assumed the simultaneity of what was happening, the space for fantasy was intensified, producing an illusory depth and blurring the images.

He applied this technique in his first light-and-sound installation, the Polytope de Montreal. In this piece, four orchestras transmitted by loudspeakers, projected music into the different layers of a

space. Thus, feelings and sound united by the volume and density are palpable spatially-hidden intensities unfolding in different forms. Sound flux patterned the rhythm of the vortex emergence creating a Rhythmosphere. Subsequently, the architecture of affect is sculpted through a steady maelstrom of sound fluxes and suggestive movements (Bewegungsuggestionen): a repetitive rhythmic turbulence driven by the concentrated and condensed energy of the forces is present at various layers of the musical performance and, again, turns to the environmental affectivity as a refrain along with atmospheric qualities within the certain constructions. However, it happens for the meantime only, until it acquires a new impetus with the change of light and highly emotional, intersubjective register. Another project, the church Couvent Sainte-Marie (1953–1960) also known as The Convent de la Tourette was built with reinforced concrete with undulating glass surfaces located on three of the four exterior faces. It was the first project Xenakis completed with Le Corbusier and one of the most prominent and unusual attempts to approach affectivity of the concrete and a form of a chapel with sculptural volumes of immaterial space. The general design of the building revolved a completeness in its spatial composition: the whole structure of the building evolves from the space, light, shape, shadows and half-tones of the darkness. Thus, intangible space and undefined darkness are to be the main components primarily interrelating with rhythms of the form, the textures of materials and the landscape.

Conclusion

Architecture and music after Xenakis was open to create hybrid and multiple spaces considered as constantly changing dynamic equilibrium where the opposition of the inside and outside was eliminated. Xenakis's rough electronic sounds, underestimated and marginalized have actually opened some trajectories to the most powerful electronic music to date. Most electroacoustic music of today, though, seems to consider clean and simple non dynamic sounds a goal avoiding its expressive potential. With the realization of Xenakis' architectural projects, the idea of the world-creation full of affective qualities becomes more real that ever imagined not only because these times pavilions served as a field of experiments but also the involvement they had on visitors with a certain atmosphere and specific sense of reality. In his architecture and music Xenakis managed to implement and develop abstract language of geometry with transparent volume: light and sound techniques fulfilled the space with music and sometimes occupied the whole historical sites (the examples of Mycenae (1978) or Persepolis (1971)), he actually built with sound and light, designing sound masses together with their qualities. Architecture and music created by Xenakis was an explicit manifestation of the Cartesian space disintegration with the blurred dichotomy between inside and outside, virtual and real, extending the latter towards the fluxes of sound and immaterial architecture of affect.

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Xenakis' journey to Indonesia: Influence on *Jonchaies* (1977) and *Pléïades* (1978)

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Abstract

Though Xenakis' interactions with Indonesian music began in the 1950s, it was after his 1972 journey to Bali and Java that some influence started to appear in compositions of the late 1970s. The analysis of materials directly collected in Indonesia by the composer, presented herein, will show how these changes resonate in pieces such as *Jonchaies* (1977) and *Pléïades* (1978). As will be discussed, this journey led to changes in his composition, influencing pitch collection, timbre, and structural aspects. To investigate how an orchestral piece and a percussion sextet of the second half of the 1970s have ties with Indonesian music and were influenced by aspects of gamelan repertoire, this study explored a large period of his career. For this purpose, documents were consulted in the Collection Famille Iannis Xenakis, Bibliothèque nationale de France (BnF), Bibliothèque musicale La Grange-Fleuret (BLGF), Institut national de l'audiovisuel (INA), and Archaeology of the Final Decade (AOTFD). Semi-structured interviews were also conducted with Betsy Jolas and François-Bernard Mâche. With scope for more material to be described and discussed, this paper highlights two specific aspects of the use of Indonesian materials by Xenakis: one tied to the choice of pitches and the other to formal structures. Thus, this study sought to build bridges to connect *Jonchaies* and *Pléïades* with elements of Indonesian music, based on the composer's personal experience, presenting data about him not discussed heretofore.

1. Introduction

Iannis Xenakis traveled to Indonesia in 1972, and mentions of this trip or the presence of aspects originally from Indonesian music in the composer's work was previously noted (e.g., Mâche 1981, Halbreich 1988, Solomos 1996, Lacroix 2001, Barthel-Calvet 2002, Solomos 2002a and 2002b, Harley 2004, Gibson 2011, Pires 2015). However, direct connections between the journey and his creative process are not frequent, and there are only a few studies discussing the way it influenced and impregnated some of his pieces. Viewing it from a historical perspective, it is possible to observe that the connections are not trivial and could explain ties associating different pieces and approaches toward the second half of the 1970s and beginning of the 1980s. This paper discusses two elements related to Xenakis and Indonesian music: *ex situ* interactions (summarized here, but covering at least two decades) and *in situ* experiences (a journey that occurred beginning the 1970s). After that, it focuses on how some aspects are reflected in structures and compositional choices in *Jonchaies* (1977) and *Pléïades* (1978).

2. Xenakis and Indonesian music: A summary of extensive *ex situ* interactions

Xenakis (1973), while discussing his interests in Indonesian music in a radio program for France Culture on March 29, 1973 (just after returning from Bali and Java), stated:

> I already knew the music of Bali [before traveling there]. The first time I got to know this music was from a Japanese record made during the war, when they had occupied Indonesia, and Mayuzumi[1] had that record, and I was in Paris at the time. There was a whole collection of music from Southeast Asia, including Bali, and it made a very big impression on me. In fact, one was one of the most beautiful pieces I've ever heard. And so, this time [with the trip, it] was to get a closer look and to hear it.[2]

The music made a great impression on him; as stated, it was until then "one of the most beautiful pieces" that he had heard, showing more than just some interest in sonorities or formal aspects of this music. However, the composer pointed to a different first hearing during an interview from December 1997. Even indicating the beginning of the 1950s, he pointed Schaeffner at the Musée de l'Homme as a primordial agent, mentioning: "I went to the Trocadero with André Schaeffner, who introduced me to the music of Bali, Java, Japan. That was in [illegible][3] (Xenakis 2003, 42).

A tape found in the Fonds Iannis Xenakis at the François Mitterrand site of the National Library of France (BnF), identified as DONAUD 0602 218 – Xenakis 223, and shown in Fig. 1a, could be one of the first recordings of gamelan music that Xenakis mentioned. It has a handwritten indication on its cover: "Folklore: Sion Java Sum. Bali. Viet. Thib Volta Gabon. [Date:] XII – [illegible]". It is a collection of 11 tracks, which mostly include Asian music from Thailand, Java, Sumatra, Bali, Vietnam, and Tibet, in addition to African music (Burkina Faso and Gabon). This could be one of the first gamelan recordings that the composer mentioned because the date indicated on the cover ("XII –[illegible]") coincides with his previous statements.

Figure 1: Different documents showing ex situ contacts with Indonesian music in Xenakis' life. a) Recording of traditional music in Xenakis personal archives (1951). Source: BnF, DONAUD 0602 218 – Xenakis 223. b) Program notes from International Music Symposium (Manilla, 1966). Source: © Collection Famille Iannis Xenakis. c) Poster of 3rd Festival of Arts (Shiraz-Persepolis, 1969), designed by Ghobad Shiva. Source: Archaeology of the Final Decade.

Another moment in which Indonesian music integrated references in Xenakis' life is tied to Messiaen's classes, with whom he studied from [illegible] to 1954. As Boivin (1995, 341) explained: "At the beginning of his teaching career, Messiaen's interventions on these 'other' musics seem to have been essentially aimed at introducing the students to an unheard world of sound. He made them listen to records, explained certain basic principles, and commented on the instrumentation. On a few occasions, he took his class to the Musée de l'Homme for a visit of the instrument collection." By

1 A reference to Toshiro Mayuzumi, Japanese composer who studied at the Conservatoire National de Paris (CNSM) from 1951 to 1952. Xenakis heard Gamelan with him probably around this period thus.

2 Je connaissais déjà la musique de Bali. La première fois que j'ai eu l'occasion de connaître cette musique c'était d'après un disque japonais fait pendant la guerre, quand ils avaient occupé l'Indonésie et c'était Mayuzumi qui avait ce disque et j'étais à ce moment à Paris. Il y avait toute une série de musique du Sud-Est asiatique, dont de Bali, et ça m'avait fait une très grosse impression. D'ailleurs, une était une des plus belles pièces que j'aie jamais entendue. Et donc cette fois-ci c'était pour voir de plus près et d'entendre. (Xenakis 1973).

3 [...] j'allais au Trocadéro chez André Schaeffner qui m'a fait découvrir les musiques de Bali, de Java, du Japon. C'était en 1950. (Xenakis 2003, 42).

visiting the Musée de l'Homme and André Schaeffner, Xenakis seems to have done exactly what Messiaen did at times with his classes and had recommended specifically to many students at the same period. Xenakis' notes do not indicate a complete class about Indonesian music by the master (as it repeatedly happened with Indian music). The few mentions are tied to the analysis of *Turangalîla* (specifically movements *V. Joie du sang des étoiles*, *IX. Turanglîla 3*, and *X. Final*), in which Messiaen used groups of instruments and timbres inspired by sonorities of the gamelan.[4]

From a passive hearing and observation in the 1950s, Xenakis passed to an active posture about it in the 1960s, participating in the Musics of Asia – International Music Symposium (April 1966, Manilla, Philippines – see Fig. 1b) and presenting a work that would later be a seminal text in his bibliography. The event was organized by the National Music Council of the Philippines and had Antonio Buenaventura as president and José Maceda as one of the vice presidents. In this event, various specialists from all around the world participated in different sessions organized by country (China, India, Indonesia, Japan, Korea, Philippines, Thailand, and Vietnam) and one exclusively related to avant-garde tendencies called Asian Elements in New Music, in which Xenakis presented his paper. A brief report about the event is available (Veneración 1967), and it documents the main topics, statements, and discussions. Concerning the session Javanese Music from Indonesia, Veneración (1967, 108) remarked that, "During the free discussion, Mr. Iannis Xenakis, composer, felt that there seemed to be a confusion in music which may be resolved by seeking for a universal structure which in turn can be separated into a time structure and a temporal structure." Xenakis also interacted in the session Classical Music of India, because "The discussion ended with a spirited debate between Mr. Xenakis and Dr. Powers regarding the scale system, the analysis of pitch and rhythm, the relationship between the pitches, and the totality of harmonic combinations." (Veneración 1967, 109).

Xenakis presented "Structures Hors-Temps" (Xenakis 1971) during the event.[5] According to Solomos (2008), this paper is based on an unpublished text from December 1965 entitled "Harmoniques (structures hors-temps)" which refers to Messiaen, but the paper Xenakis presented at the conference made no mention of him. The text still evolved, being published in different versions with a new introduction and conclusion. It turned into one of his fundamental texts called "Vers une métamusique" and, beside its publication as an article (Xenakis 1967), it was partially included in Musique Architecture (Xenakis 1976) and the revised edition of Formalized music (Xenakis 1992).

The Shiraz Arts Festival was decisive for the creation of two *chefs-d'œuvre* (*Persephassa* in 1969 and *Polytope de Persépolis* in 1971) and presented gamelan music two of the three times when Xenakis attended it. The 1969 Shiraz Festival (Fig. 1c) was specially dedicated to percussion, and it is almost certain that Xenakis saw the Balinese gamelan group performing in the ancient ruins of Persepolis as the official opening.[6] It is on the occasion of this festival that Xenakis stated: "We have a lot to learn from the percussion tradition of Asia, Africa, and the Far East in all areas. I am talking about percussion. There are three important families of percussion, it is the African, the Hindu, and the Far East. When I say Hindu, I mean the whole of the Near East. And the European percussion is very basic, it must be said..."[7] (Reichenbach 1969).

Xenakis premiered *Polytope de Persépolis* in 1971 Shiraz Festival (this time as the official opening), an event that hosted again a performance of gamelan music and traditional dance, this time with artists from Sunda (West Java). In both editions in which the composer was present, it is almost certain that

4 The best way to observe a possible parallel to this kind of approach is in the Messiaen's description of his own work in the booklet of the recording produced by Deutsche Grammophon (Messiaen, 1991).
5 The session Asian Elements in New Music had José Maceda as the moderator, Xenakis and Chou Wen-chung as the principal speakers, and Yuji Takahashi, Lucrecia R. Kasilag, Ton de Leeuw, and Harold Powers as commentators. Xenakis presented the conference in English but the proceedings were published with the original text in French (Xenakis 1971).
6 A deeper description about the official opening of the 1969 Shiraz Festival can be found in Charney (2020, 23).
7 Nous avons beaucoup à apprendre de la tradition des percussions de l'Asie, d'Afrique, d'Extrême Orient dans tous les domaines. Je parle de la percussion. Il y a trois familles importantes de percussion, c'est l'africaine, l'hindoue et l'extrême-orientale. Quand je dis hindoue c'est tout le proche orient compris. Et la percussion européenne est très élémentaire, il faut bien le dire... (Reichenbach 1969).

he had contact with Indonesian music, and before his 1972 journey to Indonesia, he certainly had many more opportunities than previously mentioned. In Paris, concerts, groups, artists, researchers, composers, and individuals interested in the subject were available.[8] François-Bernard Mâche, who traveled to Indonesia prior to Xenakis' departure to the country, presented the latter with elements of what he saw and recorded there. The former stated: "I had made a journey to Indonesia in 1972, and I brought back recordings that I published [later] in the collection of the Musée de l'Homme Gamelan Balinais.[9] And I made Xenakis listen to them, and maybe they made him want to go there."[10] (Mâche, personal communication, 2020).

3. Xenakis in Indonesia: Two weeks of *in situ* experiences

Xenakis traveled to Indonesia with a group of musician friends, including Betsy Jolas, Toru Takemitsu, Marie-Françoise Bucquet, Maurice Fleuret, and Henry-Louis de La Grange (Fig. 2a). This journey was stimulated by Fleuret[11] being a sort of family vacation because the travelers were each in the company of their respective spouses. As attested by his passport, Xenakis asked for a visa at the Indonesian embassy in Paris on December 15, 1972. He then entered the country on December 24, 1972, and after staying for two weeks in the country, exited on January 9.

a) b)

Figure 2: Xenakis' documenting aspects of the journey in Indonesia. a) Part of the group of friends that travelled to Indonesia in 1972. Seated from left to right in the foreground: Betsy Jolas, Iannis Xenakis (concerned about the recording of the cultural event), Marie-Françoise Bucquet, and Toru Takemitsu (who had a recorder on his legs). Source: © Collection Famille Iannis Xenakis. b) Drawings about gamelan instruments at the top and the performance place of a gamelan ensemble at the bottom. Source: © Collection Famille Iannis Xenakis, Notebook 38, page 2.

Xenakis produced two kinds of direct documentation about his journey: textual and drawn ("Carnet 38" in the Collection Famille Iannis Xenakis, herein referred to as "Notebook 38") and recorded (eight cassettes stored in the National Library of France – BnF). Notebook 38 contains drawings about different aspects of Indonesian culture and architecture. It does not include elaborated descriptions or large texts, something that was typical in his previous notebooks from the 1950s and 1960s, but he dedicated a page to some basic characteristics of gamelan instruments[12] (Fig. 2b).

8 Just to mention an example in the 1972 Festival d'Automne à Paris, when Xenakis was creating *Polytope de Cluny*, a traditional danse compagnie from Bali performed all day from November 6 to November 19 at the Champs Elisées Theater.

9 The disc called "Musiques anciennes de Bali. Semar Pegulingan – Gambuh" was released in 1983 by the label Le Chant du Monde (LDX-74802). It is thus certain that Mâche presented the original recordings to Xenakis.

10 Moi j'avais fait un voyage en Indonésie en 1972 et j'en ai ramené des enregistrements que j'ai publié au Musée de l'Homme, dans la collection du Musée de l'Homme Gamelan Balinais. Et j'avais fait entendre ça à Xenakis, ça lui a peut-être donné envie aussi d'y aller... (Mâche, personal communication, 2020).

11 Il y a six ans que je ne suis retourné à Bali. J'avais alors emmené là-bas Betsy Jolas, Xenakis, Takemitsu et Marie-Françoise Bucquet. Trois semaines durant, nous avions couru les villages, les hameaux, les rizières, à la recherche des merveilles musicales que signale et analyse Colin Mac Phee dans son monumental Music in Bali. (Fleuret, 1978).

12 Even with little information on this page, two different places and gamelans seem to be described. The upper part

The tapes demonstrate various aspects of his journey because Xenakis recorded not only the spectacles they witnessed (Fig. 2a) but also interviews and discussions with locals (in French or English). In fact, on some occasions, he left his recorder running as they drove around a town or village. He thus succeeded in preserving various moments of the trip and made it possible to understand part of what they visited and experienced. Thus, it is clear that they attended various ceremonies and festivities, including Barong Ket, Barong Landung, Barong Celeng, Legong, and Wayang kulit (shadow play), and they witnessed performances of Gambuh dance, Legong dance, Rejog (or Réyog), and Topeng (traditional masked dances). It is also possible to affirm that they met I Nyoman Kakul (1905–1982), a master of traditional dance in Batuan, and Gde Manik (1912–1984), a prominent figure in the development and diffusion of the gamelan gong kebyar style, in Jagaraga.

An important excerpt (in DONAUD 0602 753 – Xenakis 800) shows Xenakis and friends comparing bars of gamelan instruments, trying to understand the tuning system and the characteristic properties of the set of instruments. They compared different instruments and registers, perceiving the internal tuning differences between Polos and Sangsi (a small frequential difference between two instruments of the same kind that produces a beating effect) and their non-tempered qualities. This experience was so important that Xenakis tried to retain more information, the cassette thus has the scale heard transcribed on it (Fig. 3a) and shows by means of an arrow where it appears in the recording.

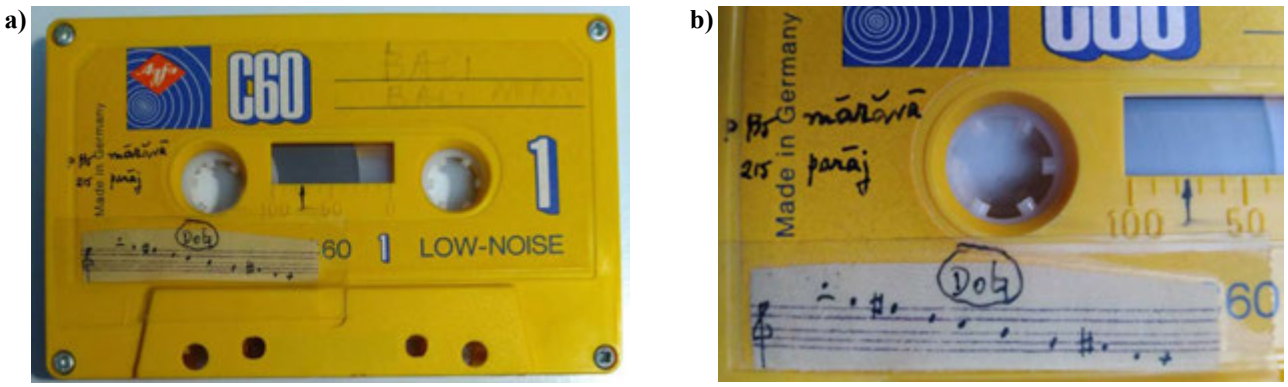

Figure 3: A tape produced by Xenakis during his journey to Indonesia. a) The tape produced in Bali showing additional information written and taped on it. b) Detail of the cassette showing an Indonesian scale and its presence on the record by an arrow handwritten by Xenakis. Source: BnF, DONAUD 0602 753 – Xenakis 800.

With the entire information recorded in the eight tapes and handwritten in Notebook 38, it is possible to indicate some of the locations that Xenakis visited in Indonesia (Fig. 4).

Figure 4: Cities and villages visited in Bali and Java mentioned in Xenakis' documents and directions of his journey.

could be a mention of Gong Lelambatan Kuno Geladag & Pinda from the village of Pindha, Bali (one of the most famous and traditional kebyar-style groups in the region). In the lower part, he indicates a group playing under a pendhapa (traditional structure in local architecture) that he called "Sekarsandat Gong at Sulanan [sic]", as a possible reference to the Sekar Sandat ensemble from Bangli village, which they saw in Sulahan.

The direction of the journey is clear, and it shows that they made an almost straight line from north to south of Bali (cities and villages mentioned by Xenakis: Singaraja, Jagaraga, Gondoral, Sulahan, Pujon, Kebisas, Batuan, and Sesetan), as well as a diagonal line passing through East to Central to West Java over much larger distances (Yogyakarta, Surakarta, Palimanan, Cirebon, and Sumedang), finally finishing in Jakarta and then returning to Europe.

4. Direct Indonesian influences

Many elements can be perceived in Xenakis' work as a consequence of contacts with Indonesian music, but only two will be here described showing a direct correlation with the previously exposed. *Jonchaies* and *Pléïades* are pieces of the second half of the 1970s chosen to enlighten some of these correlations.

4.1. Jonchaies (1977), Pléïades (1978), and resonances from Indonesia

Xenakis (1996, 164–65) directly mentioned an Indonesian scale while explaining the *Jonchaies*' sieve in a 1989 interview: "There's a scale at the beginning of *Jonchaies,* which is very close to the *pelog*. It's treated there in a way that is my invention: instead of having one line, there are many lines, but all in the same range using the same scales. It makes a kind of flux, or vapour, of music." Mâche (personal communication, 2020) also commented about that and stated: "This is very clear in *Jonchaies* where there is really a pelog mode, that is to say with five intervals in the octave but unequal intervals. So, some passages of *Jonchaies* sound abruptly Indonesian indeed."[13] This was also very perceptible for Betsy Jolas, who traveled with Xenakis to Indonesia, and both had even commented together the connection between the orchestral piece and the 1972 journey. She explained:

> With Iannis, when I heard *Jonchaies*, I said to myself: well, this is what he got out of there [from that trip to Indonesia]. You know Iannis and I have known each other since 1951 [...] I have always followed his work [...] You can hear [in *Jonchaies*] from the beginning a melody that is Balinese, I think he must have notated it from there, in fact, it is almost a quotation. It appears and sneaks into the orchestra, it's a magnificent effect. [...] I must say that, when I heard *Jonchaies*, I said to him: 'it seems to me that I have already heard that...' There was this side of 'I know where it comes from' and he said to me: 'you are not wrong!'[14] (Jolas, personal communication, 2021)

It is perceptible in Xenakis' sketches (Fig. 5) that this aspect is really not trivial. At the origin of the sieve constitution, when he was still trying some sequencies of pitches, choosing intervals, and establishing initial materials (Fig. 5a), he intrinsically incorporated the exact same scale that he had heard in Indonesia and noted on the tape DONAUD 0602 753 – Xenakis 800 (Fig. 3). With the specific mention "Bali nord" (Fig. 5b) – the same name that he gave to the tape – he used the exact notes previously transcribed, making clear that he was literally returning to previous documents and consulting old recordings to produce new materials. This specific structure thus introduced a complete hemitonic pentatonic scale that is recurrently present in the different periods of the sieve.

13 C'est très net ça dans *Jonchaies* où il y a vraiment un mode pelog, c'est à dire avec cinq intervalles dans l'octave mais des intervalles inégaux. Donc ça sonne brusquement Indonésien en effet certains passages de *Jonchaies*. (Mâche, personal communication, 2020).

14 Chez Iannis, quand j'ai entendu *Jonchaies*, je me suis dit : ben voilà ce qu'il a sortie de là [de ce voyage en Indonésie.] Vous savez Iannis et moi on se connait depuis 1951 […] J'ai toujours suivi son œuvre […] On entend [en *Jonchaies*] dès le début se former une mélodie qui est balinaise, je pense qu'il a dû la notée de là-bas, en fait c'est presque une citation. Elle apparaît et elle se faufile dans l'orchestre, c'est magnifique comme effet ça. [...] Moi je dois dire que, quand j'ai entendu *Jonchaies*, je lui ai dit : 'il me semble que j'ai entendu ça déjà…' Il y avait ce côté de 'je sais d'où ça vient' et il m'a dit : 't'as pas tort !'" (Jolas, personal communication, 2021).

a) b)

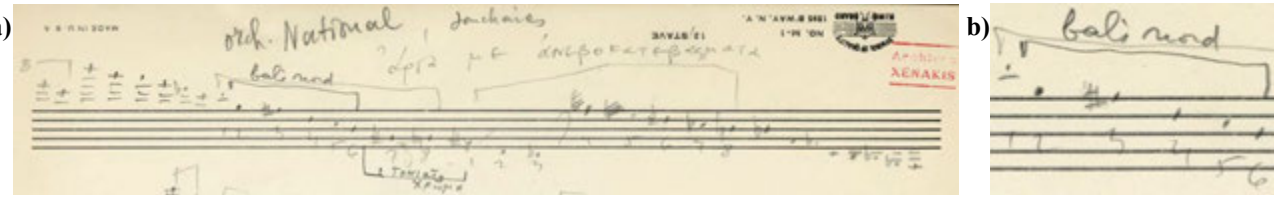

Figure 5: Excerpt of Xenakis' sketches about Jonchaies (1977). a) Upper part of a page with elaboration of scales and groups of notes that would be the base for the sieve created initially for Jonchaies. b) Detail of the previous image indicating the specific mention "Bali nord" in reference to a recording made in Indonesia in 1972. Source: © Collection Famille Iannis Xenakis.

The material initially experimented is a little different than the final one, but the excerpt from Bali nord was important at the origin of the sieve that finally established the beginning of *Jonchaies* (Fig. 6). The same sieve was expanded and used once again in *Pléïades* (considering *Claviers* and *Mélanges*), showing a certain continuity and homogeneity with regard to pitch collection in both pieces.

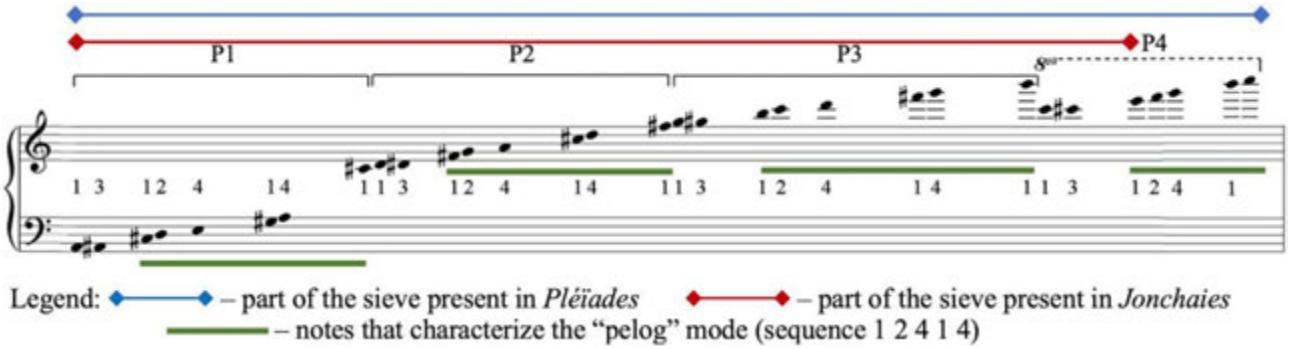

Figure 6: Sieve used at the beginning of Jonchaies (1977) and once again in Pléïades (1978).

Xenakis again expressed ties with extra-European traditions in the introduction of *Pléïades*, and this could also better explain the sieve material created. As affirmed: "After a long trial, I constructed a series[15] (scale) which, surprise !, was similar to the scales of ancient Greece, of the Near East, or of Indonesia" (Xenakis 1978, 1). While making this statement, he was focusing on three clear aspects of this pitch collection. First, there is a quasi-complete double harmonic scale (also called Byzantine scale) that could indicate the "Near East" reference. Second, there is a complete hemitonic pentatonic scale present that explains the "Indonesia" reference, and because this pentatonic has an intervallic structure characterized by a minor second, that could also indirectly be a reference to the third aspect, a Phrygian mode (though modern in its constitution, it could explain the "ancient Greek" mention).

The sieve common to both pieces is characterized by a sequence of semitone intervals 1 3 1 2 4 1 continuously repeated from bottom to top, being thus expressed by a periodicity of 17 semitones (or period P = 17) and characterized by a lower period that could be called P1, an intermediary P2, and so on (Fig. 6). This kind of structure, when continuously repeated through the higher registers, presents new pitches, and for this reason, it is called non-octaviating. With this sieve, the quasi-complete double harmonic part is formed by the semitone sequence 1 3 1 2 4 1, which creates – in terms of intervallic disposition – a minor second, a major third, a perfect fourth, a perfect fifth, a major seventh, and a perfect octave from the first note. It is clear that, to have a complete double harmonic scale, it is missing the minor sixth. However, at the same time that this sixth degree is missing, its absence allows the emergence of the hemitonic pentatonic scale (Fig. 6). This "pelog"[16]

15 In the French text, he used the term "crible" (sieve), but in English he adopted the term "series".

16 The term is used in quotation marks to do a reference to Xenakis' terminology about a specific variation of this kind of structure with which he had contact in Bali. Considering the Indonesian music, the term "pelog" could refer to numerous scales and tuning possibilities that it is hardly associate with one and exclusive kind of interval collection. This term originally referred to a seven-note structure, being after adopted by many groups in a disposition of five notes as some intervals of the heptatonic were discarded. As better specified by McPhee (1966, 37): "*Pélog* may be defined as a

aspect of the sieve emerges from the semitone sequence 1 2 4 1 4 characterizing a pentatonic scale with minor second, minor third, perfect fifth, minor sixth, and perfect eight. The Phrygian mode (in terms of a modern concept about Greek modes) could also be characterized by the sequence 1 2 4 1 4, but it is clear that the perfect fourth and minor seventh are missing, being 1 2 2 2 1 2 2 the complete sequence of semitones to achieve it. This material, a consequence of the interaction with *in situ* aspects of the Indonesian music, returned in other opportunities as Xenakis himself mentioned: "In *Aïs* I modified this scale slightly in order to make it less recognizable, to be different and yet retain a kind of specific tension" (Xenakis 1996, 56).

2.C laviers and the resonances of "one of the most beautiful pieces I've ever heard"

As initially discussed, Xenakis affirmed in 1973 (just after his return from Indonesia) that "one of the most beautiful pieces" he had ever heard was a gamelan piece that he would have heard at least 20 years before. As presented, the record saved at the BnF as DONAUD 0602 218 – Xenakis 223 coincides with the period mentioned and is likely to be related to the music he mentioned. Hearing it at the BnF, a direct correlation with the movement *Claviers* emerged. A parallel could be traced between both materials, showing that Xenakis would have again consulted previous Indonesian materials to creatively stimulate his compositions. A link is indicated (Fig. 7) to access the excerpts from the original Balinese gamelan piece present in the tape DONAUD 0602 218 – Xenakis 223 and a recording of *Pléiades*.

Figure 7: Link to access excerpts of a gamelan piece from Bali present in a Xenakis' tape dated from 1951 and a conclusive section in Claviers movement. Please use the QR code to access ronangil.com/xenakisbaliclaviers.

The correlation emerges from rhythmic patterns, pitches, and a sound globality that are perceptibly and demonstrably similar. The concluding section in *Claviers* (from measure 111) presents the only unison that occurs between metallic (three vibraphones) and wooden instruments (marimba, xylophone, and xylomarimba), characterizing a tremendous change in the general texture. This passage even presents a different use of the original sieve, with the break of the specific octave of the intervallic succession P1. This means that Xenakis used the pitches that would be characteristic of P1, but one octave higher, where others should be characteristic (as specific pitches of the intervallic succession P2). The change in the logical sequence determined by the sieve and the abrupt modifications of the texture breaks a previous expectation and brings the section into focus by a surprising ending.[17] For us, more than just changing expectations, Xenakis is directly mentioning the gamelan recording he acquired in 1951 and kept in his collection for nearly three decades, using it in 1978 specifically in this percussion piece.

3. Final considerations

Xenakis had contact with Indonesian music from a vast specter of experiences and exchanges, which,

seven-tone quasi-diatonic scale which is less of an actual scale than an instrumental system for the forming of different five-tone modal scales within the seven-tone scale." The term is extremely variable region by region and could address a large spectrum of possibilities. As Tenzer (2011, 36) complements: "Rather than think of Balinese tunings as scales, it is perhaps helpful to conceive of them as a set of guidelines for intervals (distance relationship between tones). This idea is flexibly interpreted by tuners, giving rise to the variety of tunings found in actual practice."

17 A complete analysis of *Pléiades* and a broader discussion on it will be better elaborate in future articles.

as shown herein, started at the beginning of 1950 and culminated in a journey to Indonesia in 1972. The conditions of this trip, albeit for a rather short stay, provided him access to numerous local artistic manifestations in Bali and Java. The composer gave great importance to this journey as he tried to record as many experiences as possible. Thus, this trip and his previous experiences, directly influenced his compositional practice (in terms of pitch collection, timbre, and textures) from around the mid-1970s.

Xenakis' relationship with Indonesian gamelan music cannot be described as appropriation but rather more of an influence. It was, in part, a consequence of deep reverence and interest in traditions that rest on millennia of experience.[18] Many artistic aspects of Indonesian music resonate in different pieces that he composed in the 1970s and the 1980s. This paper presented only a few elements that directly correlate Xenakis' compositions to his experience in Indonesia, the Sixxen, for example, a very interesting percussion instrument specifically conceived by him for *Pléïades*, is not even mentioned here, but it would certainly deserve a whole specific part in the current discussion. This project will continue to present different aspects that the Indonesian music would have influenced Xenakis' work.

Acknowledgments

I would like to gratefully thank all the individuals who made this research possible, sharing rich and very precious knowledge, memories, and documents. First, I would like to send my gratitude to Betsy Jolas and François-Bernard Mâche for their immense contribution. I would like to thank Mâkhi Xenakis, who provided me with the access to the Collection Famille Iannis Xenakis and a number of precious personal contributions, the staff of the Bibliothèque nationale de France (BnF), Bibliothèque musicale La Grange-Fleuret (BLGF), Institut national de l'audiovisuel (INA) and Archaeology of the Final Decade (AOTFD) that offered the opportunity to visit and consult important collections, and Sarah Brabo-Durand who worked on the 1951 recording to allow for a better hearing. Finally, I would like to thank Anne-Sylvie Barthel-Calvet, with whom exchanges were fundamental and irreplaceable in many moments, and Georges Starobinski, Christian Dierstein, and Matthias Schmidt, who did not measure efforts to incentivize this approach.

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18 An argument and a sort of reverence perceptible in different interviews – Reichenbach (1969) or Xenakis (1990, 1996, and 1997).

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The score of *Rythmes sur Tabla*, a "key document" in the work of Iannis Xenakis?

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Abstract

With the publication of a revised and expanded edition of *Iannis Xenakis, un père bouleversant* (Xenakis [2015] 2022), Mâkhi Xenakis has brought to light several previously unknown documents related to her father's work. Her work as an artist is based on a study of the creative process and on what is revealed as a piece evolves, giving rise to a very interesting reading of the appearance of *glissandi* and sound clouds in I. Xenakis's work in 1953–54.

Two challenging documents were specifically identified as important triggers. One, found in Xenakis's engineering thesis, is an image in pencil on graph paper (Xenakis [2015] 2022, 234-1); the other is the score for *Rythmes sur Tabla* dated January 1953 (Xenakis [2015] 2022, 239–1&2). The first is understood to be at the origin of the *glissandi* in *Metastasis* (1953–1954) and the hyperbolic paraboloids in the Philips Pavilion (1956–1958),[1] while the score is understood as a study leading to the graphic writing of the sound clouds in *Metastasis*, and later the undulating glass panes (1954–1955). M. Xenakis finds in these two documents the foundation for some of her father's creations, an influence that runs throughout his œuvre...

This article intends scientifically to mine this vein using first-hand archival documents, with reference to works listed in the composer's personal library.

The article will first identify elements behind a new consideration of the score for *Rythmes sur Tabla*, and will complete the analysis carried out by F-B Mâche (Mâche 2009).

A graphic score, the partial graphic representation of *Rythmes sur Tabla* found in 2020, will be presented. This discovery makes it possible to examine the document anew, and to consider it Xenakis's very first graphic expression of a polyrhythm, created between January and December 1953.

Lastly, the article will discuss the latest archival studies, which seem to confirm the importance of Indian musical theory to the young Iannis Xenakis.

1. Introduction

With the publication of a revised and expanded edition of *Iannis Xenakis, un père bouleversant* (Xenakis [2015] 2022), Mâkhi Xenakis brought to light several previously unknown documents related to her father's work. Her work, the result of a long journey both as the composer's daughter

1 E. Kiourtsoglou also mentions this relationship in her doctoral thesis (Kiourtsoglou 2016).

but also as an artist interested in the creative process,[2] attempts in particular to trace the genesis, in 1953–54, of *glissandi* and clouds of sounds in I. Xenakis's work. Two challenging documents were specifically identified as important triggers. The score of *Rythmes sur Tabla*, the subject of this contribution, was one of them. It led, according to the author, to the development of the graphic representation of the sound clouds in *Metastasis*, and later to the undulating glass panes (1954–1955).

We will present here what is known concerning the score, and investigate how this helps illuminate the genesis of the composer's work. These advances are the result of a collaboration with Mâkhi Xenakis, and are more broadly part of the idea of exploring the importance role Hindu music may have played for Iannis Xenakis in opening new avenues of exploration.

2. Reconsideration and analysis of the *Rythmes sur Tabla* score

2.1. Discovery of new materials in 2020

Our meeting with Mâkhi Xenakis, the beginning of our "investigation" into *Rythmes sur Tabla*, dates back to March 2021. At that time, she shared her thoughts on Iannis Xenakis's work, and noted that graphic writings seem to link, by analogy, the earliest scores for *Pyrovasia-Metastasis* (1953–1954) to later works such as the stereophony of the interlude *Concret PH* (1958), the *Protocole à l'équilibre* (1959), or *Psappha* (1975). Made from a succession of vertical lines at irregular intervals, the artist brings these writings closer to the architectural work carried out on the undulating glass panes (1954–1955).

When, in 2020, she discovered an old and at that time unplayable recording entitled *Rythmes sur tabla. Tala ruapka, tala ata, tala gumpa*, in the archives, Mâkhi Xenakis looked at a score of the same name previously attributed to her father. Although written in traditional notation, the latter adds "barlines accompanied by numbers" (Xenakis [2015] 2022, 238), which reminded the artist of the graphic scores she had already mentioned.[3]

Research unearthed a recording corresponding to the transcription in the BNF's online archives.[4] This confirms the work is not by I. Xenakis, and leads us to put forward an additional hypothesis as to how it came, via Olivier Messiaen,[5] be in the composer's possession.[6]

Just as interesting as a work by Iannis Xenakis, the score offers a transcription and rhythmic analysis of a piece of Indian music the composer made at a key moment of his musical training, and on the eve of the creation of the major work that is *Metastasis*…

2 Mâkhi Xenakis' consideration of the composer's work is part of an approach parallel to that which she took to the work of the artist Louise Bourgeois (Xenakis [1998] 2008 and Xenakis 2018). More generally, her official website provides information about her research into the creative processes – in the work of both Louise Bourgeaois and Iannis Xenakis – and its importance for understanding and developing her own artistic work. https://makhi-xenakis.com/

3 Statements made on the basis of conversations with Mâkhi Xenakis.

4 The piece is by Narayan Das, E., solo sitar, accompanied by tablas. *Tala ruapka, Tala ata, et Tala gumpa*, sound recording, disc 1, side A, British East Indies (India), 1931, BNF, Gallica, Musée de la parole et du geste, https://gallica.bnf.fr/ark:/12148/bpt6k128548t.media

5 F-B Mâche suggests two other possibilities: on the one hand, Indian music concerts organised by the Association des amis de l'Orient at the Musée Guimet; and on the other, listening to recordings of Indian music acquired by André Schaeffner for the Musée de l'homme du Trocadéro (Mâche 2009, 21).

6 The music relating to the recording is a piece of Indian music played and recorded at the 1931 Colonial Exhibition. O. Messiaen recalls being present at the event and portrays it as a real revelation (Messiaen 2002, 59). Moreover, the date on the score is just subsequent to the study of Greek and Hindu rhythms that took place in his December 1952 course, about which Xenakis took detailed notes (Barthel-Calvet 2013, 184).

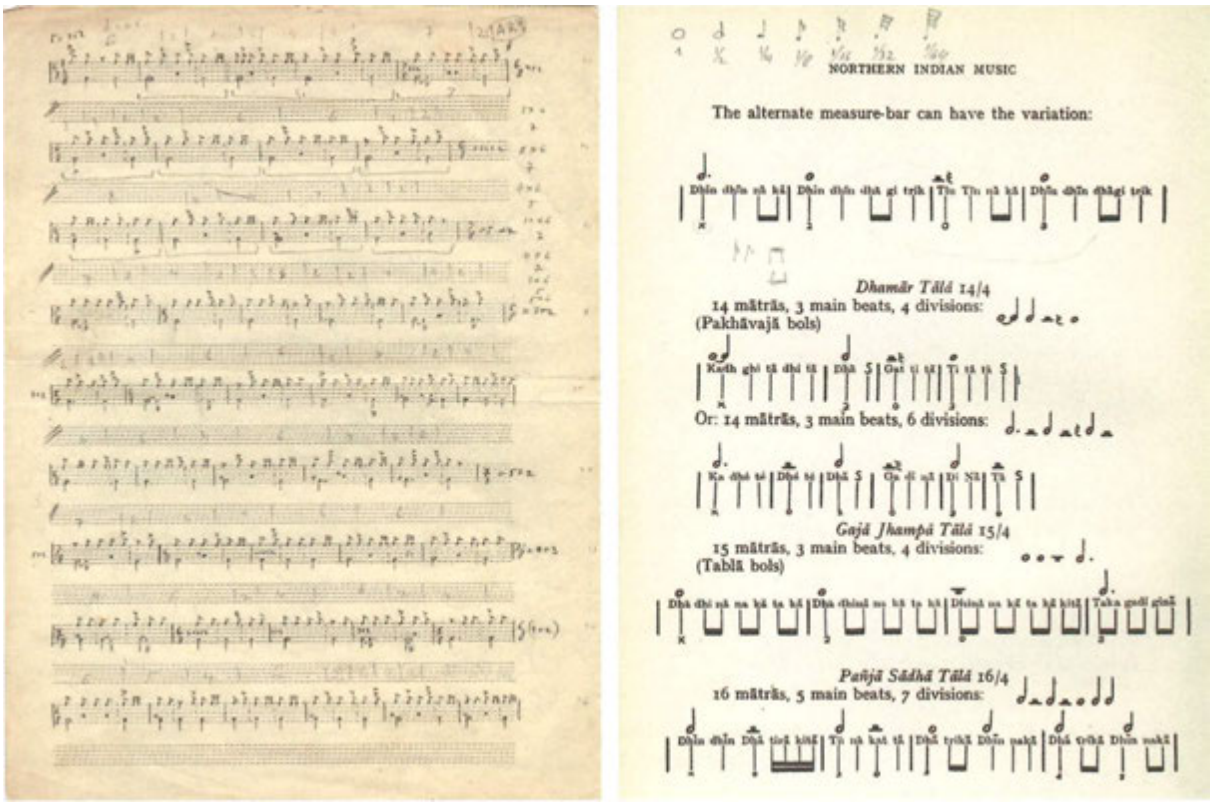

Figure 1: Bringing closer of an extract from the score of Rythmes sur Tabla, and a page dealing with Hindu rhythm in Northern Indian Music (Daniélou [1049] 1954, 96) by Mākhi Xenakis (Xenakis [2015] 2022, 239-2&3)

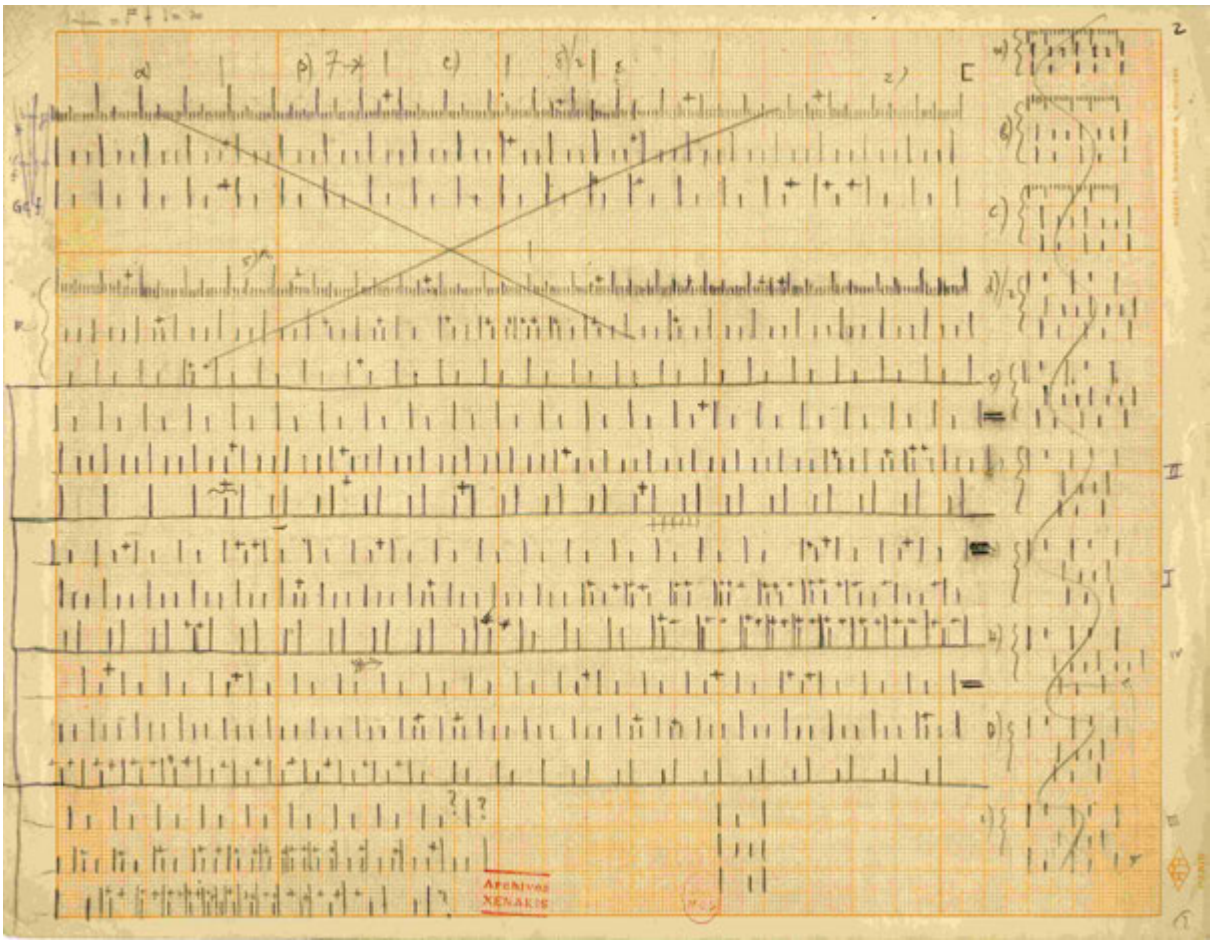

Figure 2: Earliest graphic writings for Pyrovasia-Metastasis (1953-1954) (Xenakis [2015] 2022, 96)

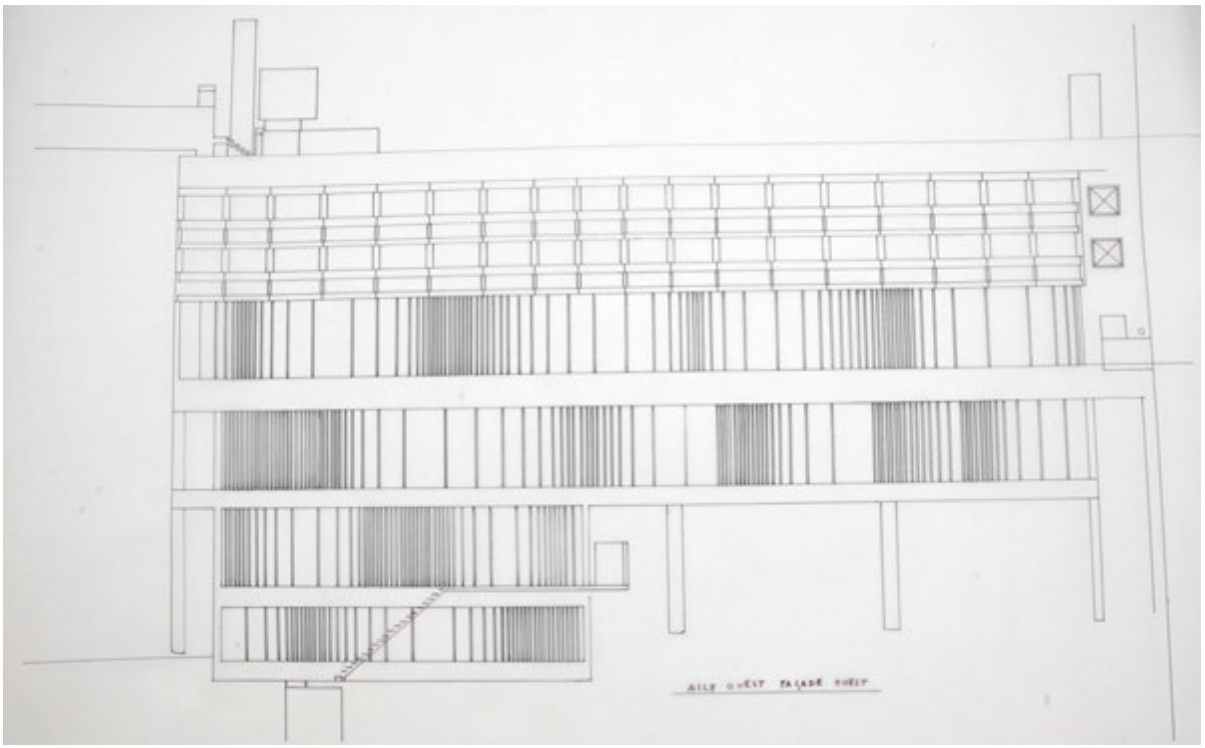

Figure 3 : Undulating glass panes, Western façade of the Covent of the Tourette (1954), ink on tracing paper (Xenakis [2015] 2022, 58-2)

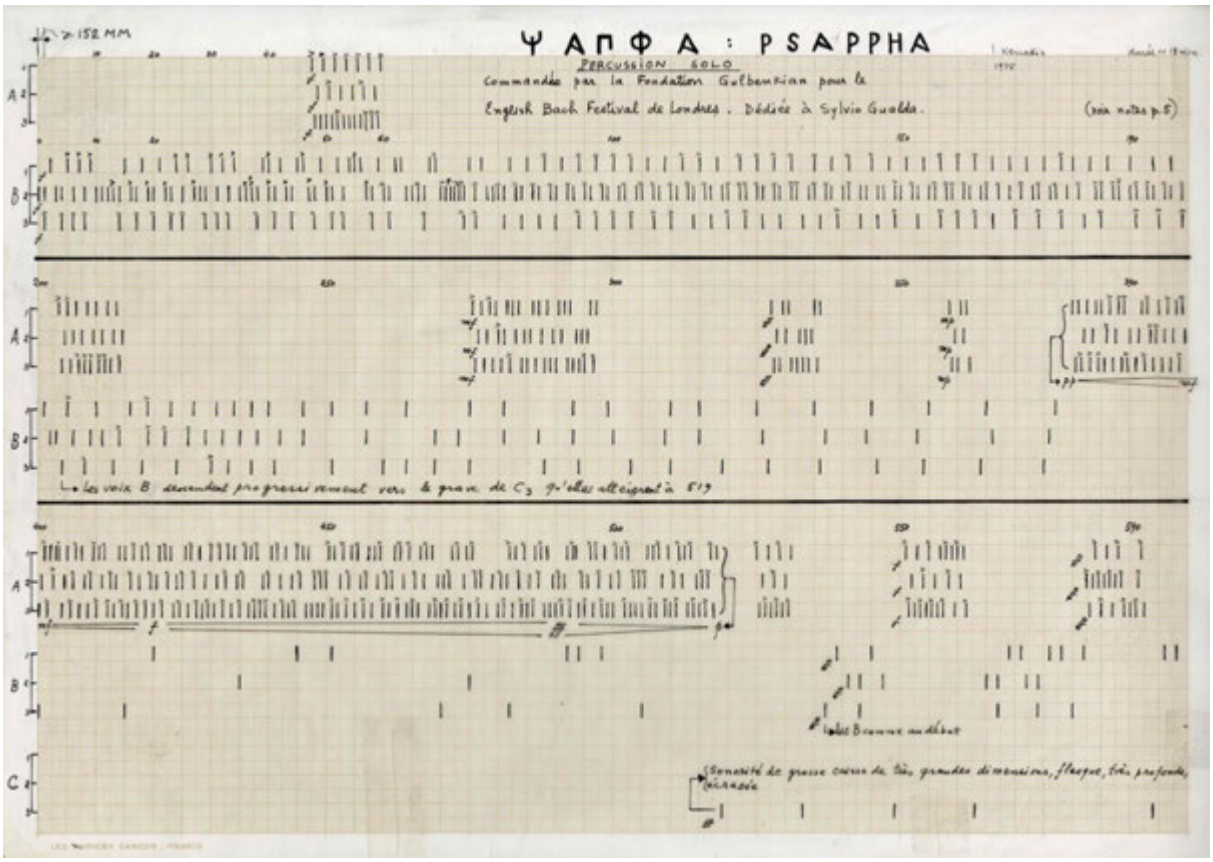

Figure 4 : Graphic score for Psappha (1975) (Xenakis [2015] 2022, 241-4)

2.2. Investigating an early attempt at graphic writing

The description of the score and its analysis having already been the subject of scientific study (Mâche 2009), we are content here to emphasise the features that seem important to us, or, as it were, to complete the reading. It is still necessary to specify how our approach differs from that of

F-B Mâche. It is no longer a question of studying a work by I. Xenakis by trying to relate its analysis to the principles of Hindu rhythm, but rather of trying to understand what the composer acquired through his performance of transcription and analysis.

Thus we note that Xenakis superimposes three "rhythmic flows" (Mâche 2009, 24), choosing – counter-intuitively – to express the tabla's different sonorities as three distinct voices. The bottom line corresponds to the beat as announced by the basic measure, maintaining a strong sound. The barlines are placed here in the traditional way. The middle voice corresponds to a weak sound, resembling, according to I. Xenakis, that of the timpani. The related barlines are expressed as dotted lines and are perhaps based on the striking of the instrument.[7] Finally, the upper voice corresponds to the "monnayage" of the rhythm. It is expressed as a clear sound produced by a plucked string. Xenakis restores the strong beats from accents which intervene in counterpoint to the bottom voice based on the basic measure, thus superimposing several rhythmic systems in an offbeat way. A note appearing on the cover page reading, "The barlines have been placed according to the preponderant rhythm found either in clear sound, or in the sound of the congo",[8] seems to confirm this. The subdivision of the *tâlas* (rhythms) is repeated through the counting of the *mâtras* (common measure).[9] Xenakis accounts for this in several ways: either with a "frame" referring to figures on the margins of the staff, between the "barlines" of the upper voice, or, when in doubt, between occasional brackets that can appear between barlines. The superposition of flows, which is organised according to simple mathematics, makes it possible to reveal breaks in the *tâlas*' cyclical regularity (Mâche 2009, 25).

I. Xenakis mentioned his search for polyrhythm in Hindu rhythmics in October 1951, when he wrote: "Hindu music. The most civilised and perfect rhythmic organisation. I did not find any polyrhythm there." (Mache 2009, 22).[10] Anne-Sylvie Barthel-Calvet further emphasises the young composer's earliest, inconclusive attempts at polyrhythms with the superimposition of cyclically repeated odd rhythms.[11] The result, according to him, is "very poor" and fails to achieve the unanticipated[12] (Barthel-Calvet 2012, 58–59). Xenakis' contemplation of Hindu rhythms' transformation and the "shocks" provoked by their "oppositions" or their "oscillations" (Mâche 2009, 22)[13] therefore certainly demonstrates what interests him in the context of a polyrhythm which should, to his mind, be livelier.

Moreover, looking to polyrhythm to account for a certain auditory complexity seems to come from the teachings of Olivier Messiaen.[14] Indeed, in a chapter devoted to polyrhythm, the latter suggests "entering" all the rhythms in a measure, and multiplying "the indications of links, accents" where they are necessary to produce the desired effect (Messiaen 1966, 17–26). We also note the use of "frames" indicating the major rhythmic divisions, as well as the added values expressed by the "+" sign (Messiaen 1966, 10), which I. Xenakis adopted for the same purpose in the polyrhythms of *Pyrovasia-Metastasis*. We note, however, that the latter's writing differs with respect to these teachings, sometimes superimposing in an offbeat way, replacing "frames" with vertical bars containing the different voices' rhythmic division. We identify this graphic gesture as a first step towards the elaboration of his own writing.

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7 This principle seems to have been inherited from Olivier Messiaen, who uses a dotted barline between instrumental attacks (Messiaen 2002, 257).

8 F-B Mâche corrects the name of the instrument, and specifies a conga instead (Mâche 2009, 24).

9 In his notebook referring to Messiaen's course, Xenakis notes: "Matra = 1 short unit which also changes" (Notebook 9, p. 7). We suggest comparing this with Messiaen: "The unit of value is called *Mâtrâ*. It sometimes represents times, sometimes the mean value common to all rhythms. According to the slowness or rapidity of the tempo (*laya*), according to the *accelerando* or *rallentando* affecting the established tempo (paces of execution or *yatis*), the *mâtrâ* is, of course, longer or shorter (…)" (Messiaen 2002, 259). This work is in I. Xenakis's library.

10 This connection between Hindu music and polyrhythm can be found in Xenakis's Notebook 1 (Notebook 1, 3). We again point to the joint presence of Hindu music and polyrhythm in the text appearing at the end of Notebook 9 (Notebook 9, 161–163). The latter evokes the scenario of *Pyrovasia*, which is itself compared to the notes appearing on the first page of the graphic scores for *Pyrovasia* dated 26 December 1953 (Barthel-Calvet 2012, 74).

11 We note that such attempts at polyrhythm are also mentioned by Olivier Messiaen in *Technique de mon langue musical*: "Superimposition of rhythms of unequal lengths. Our first attempt at polyrhythm, the simplest, the most childish, will be the superposition of two rhythms of unequal length, repeated until they return to their starting combination." (Messiaen 1966, 17).

12 Xenakis writes this in Notebook 1, p. 1.

13 We find these statements by Iannis Xenakis in Notebook 1, p. 4.

14 This could enrich the list of "convergences" between the two men, in which Hindu rhythm already seemed to play a specific role. (Barthel-Calvet 2013, 191–193).

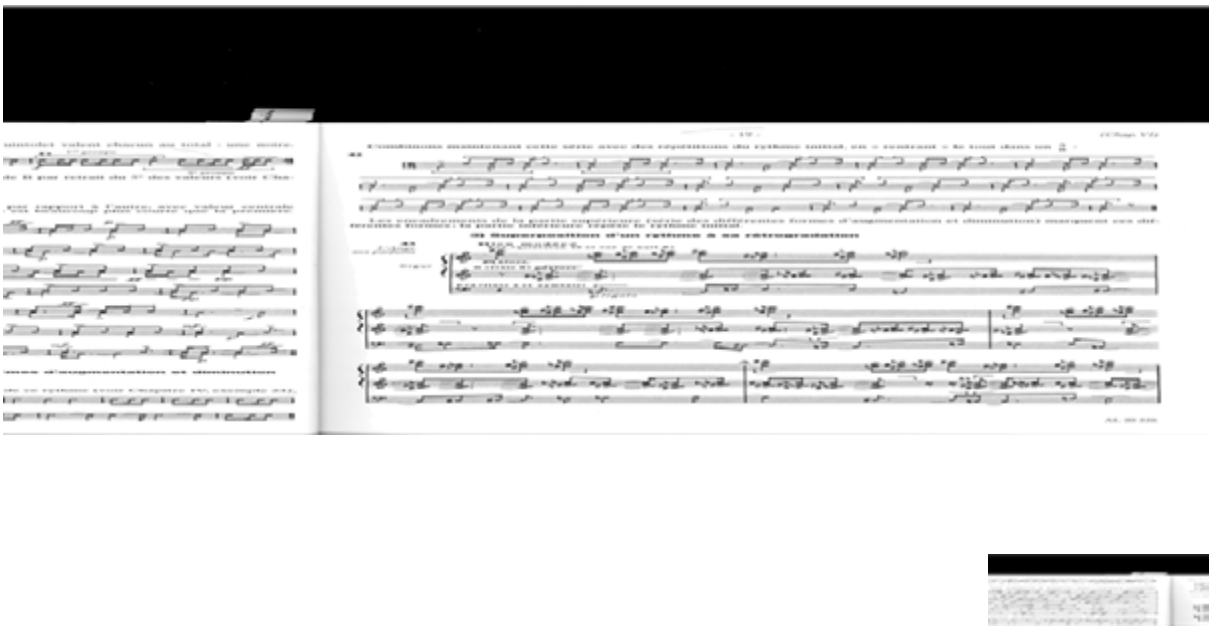


Figure 5: Polyrhythm analysis from O. Messiaen (Messiaen 1966, 19)

According to F-B Mâche, the piece consists of three distinct parts, probably corresponding to the *tâlas Rupaka*, *Ata*, and *Jhampa* (Mâche 2009, 25).[15] The musicologist nevertheless seems to encounter difficulties in precisely identifying one or the other *tâla* (Mâche 2009, 24). This could be linked to the distortions implied by Xenakis's transcription, which, if our experience listening to the piece is an indication, is based on a poor-quality recording. In addition, the *tâlas* he performs may not correspond to the actual structure of Hindu rhythms. This is what F-B Mâche's questioning of the *tâla* "*gumpa*"[16] (Mâche 2009, 25), in which we can clearly read the rhythmic division 4-1-2 in the upper voice, seems to indicate, disregarding the accents introduced by Xenakis. If we assume the counting the latter performs is based on accents – perhaps corresponding to a particular sound of the tabla – then the poor quality of the recording can explain the alternation of the 3 and the 4 noted by the composer. Moreover, by carrying out the 4-1-2 count corresponding to the *tâla jhumpa* according to the *jâthi chaturashra* – already mentioned by F-B Mâche for the part devoted to the *Rupaktâla* (Mâche 2009, 25) – the even and odd oppositions Xenakis reproduces based on the principle of added value are no longer necessary!

In light of the above, asking exactly which *tâla* interested the composer no longer seems to make sense. It is rather a matter of understanding the interpretation and the formalisation that the latter brought to the pieces he listens to. In this respect, F-B Mâche's analysis underlines the specificity of an approach which he distinguishes from that of a tabla player: "[Xenakis] combined several *tâlas*, he varied the *ostinati* by adding or retracting rhythmic values, by unpredictable accentuations, and, a little in the Pythagorean tradition, by classifying the families of durations into even or odd to make this opposition the main source of interest within a relatively monotonous continuum." (Mache 2009, 25). Perhaps Xenakis was already looking for these different principles when

15 Concerning the title, we note the questions F-B Mâche asks about the incorrect spelling of *talas* (Mâche 2009, 23) can probably be explained by transcription error by the person in charge of indexing the recording.

16 The musicologist believes that I. Xenakis permuted the three *angas* (giving 2-4-1 instead of 4-1-2) in the *tâla karnatique jhampa*, which has a value of 4-1-2 *mâtras* in its *madhura* form (Mâche 2009, 25).

transcribing the score? Be that as it may, by highlighting these elements within the precise framework of what he considers to be a polyrhythm and by setting himself apart slightly from Messiaen's writing, the composer seems to appropriate the *Rythmes sur Tabla* for the purpose of giving it his own interpretation. As such, we insist on the fact that the score, despite its "traditional" appearance, is not a simple transcription coupled with an analysis. It is already an early attempt at a graphic formalisation which will truly materialise with the development of his following score...

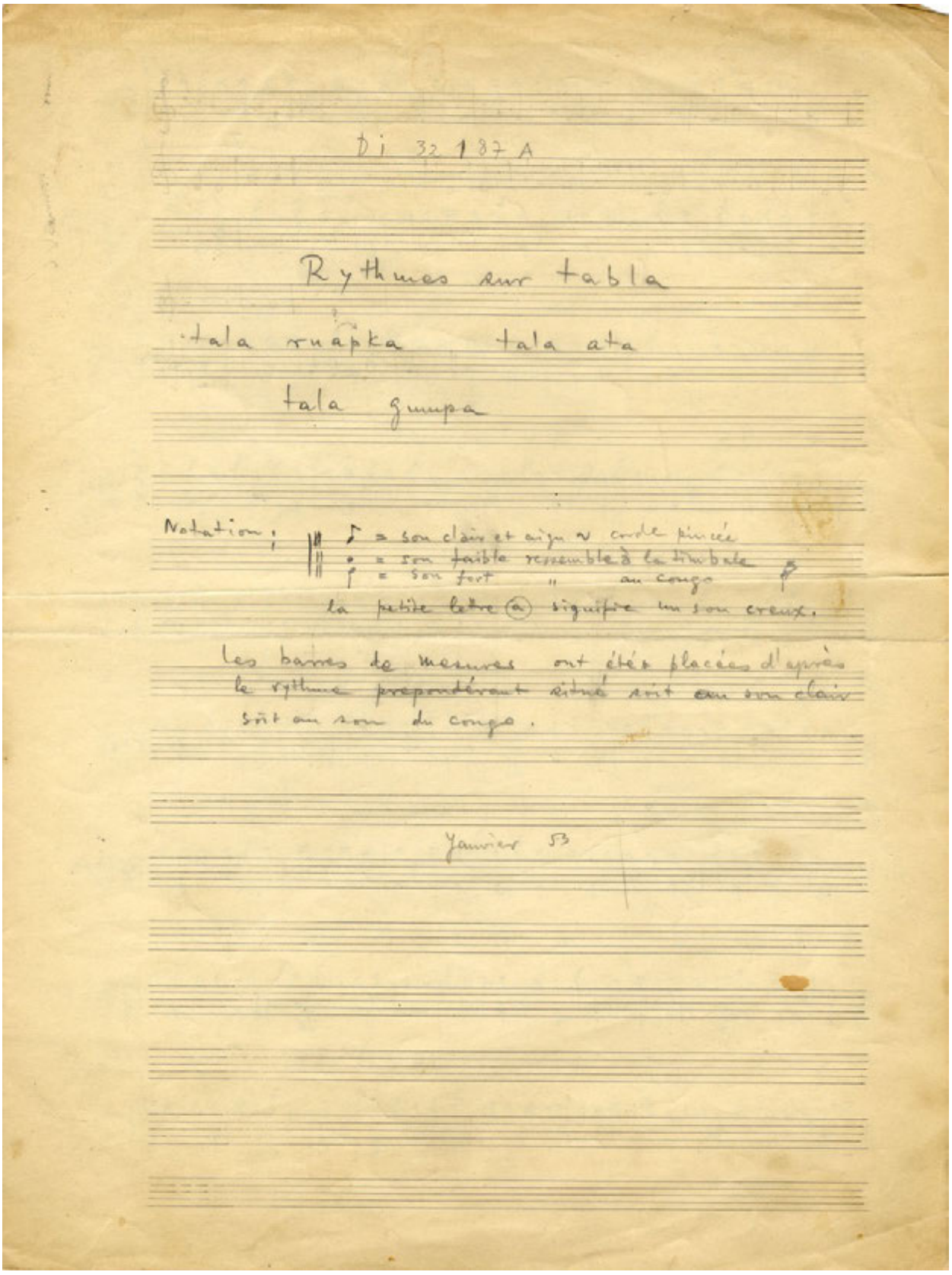


Figure 6: Score of Rythmes sur Tabla, p. 1.

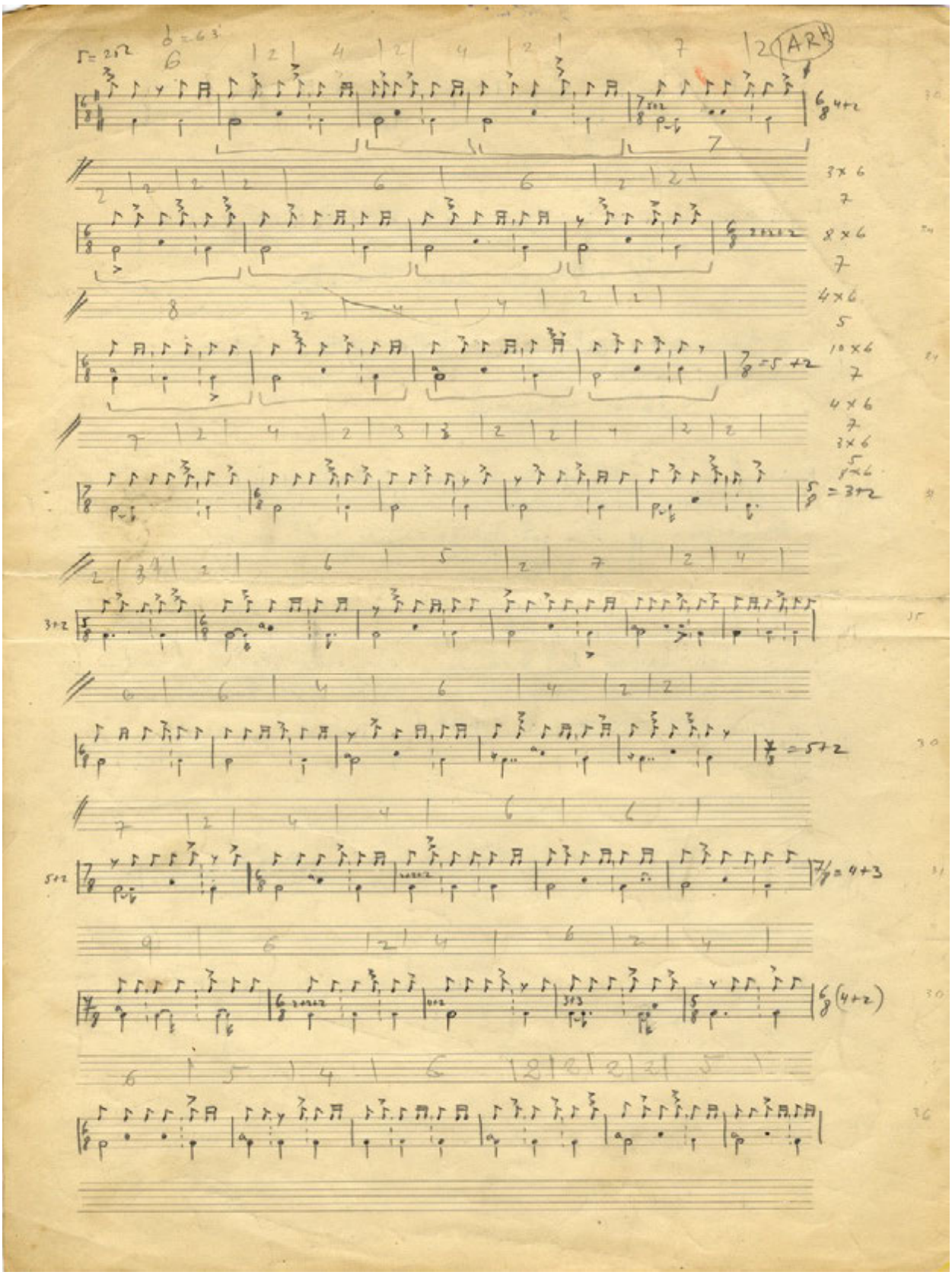


Figure 7: Score of Rythmes sur Tabla, p. 2.

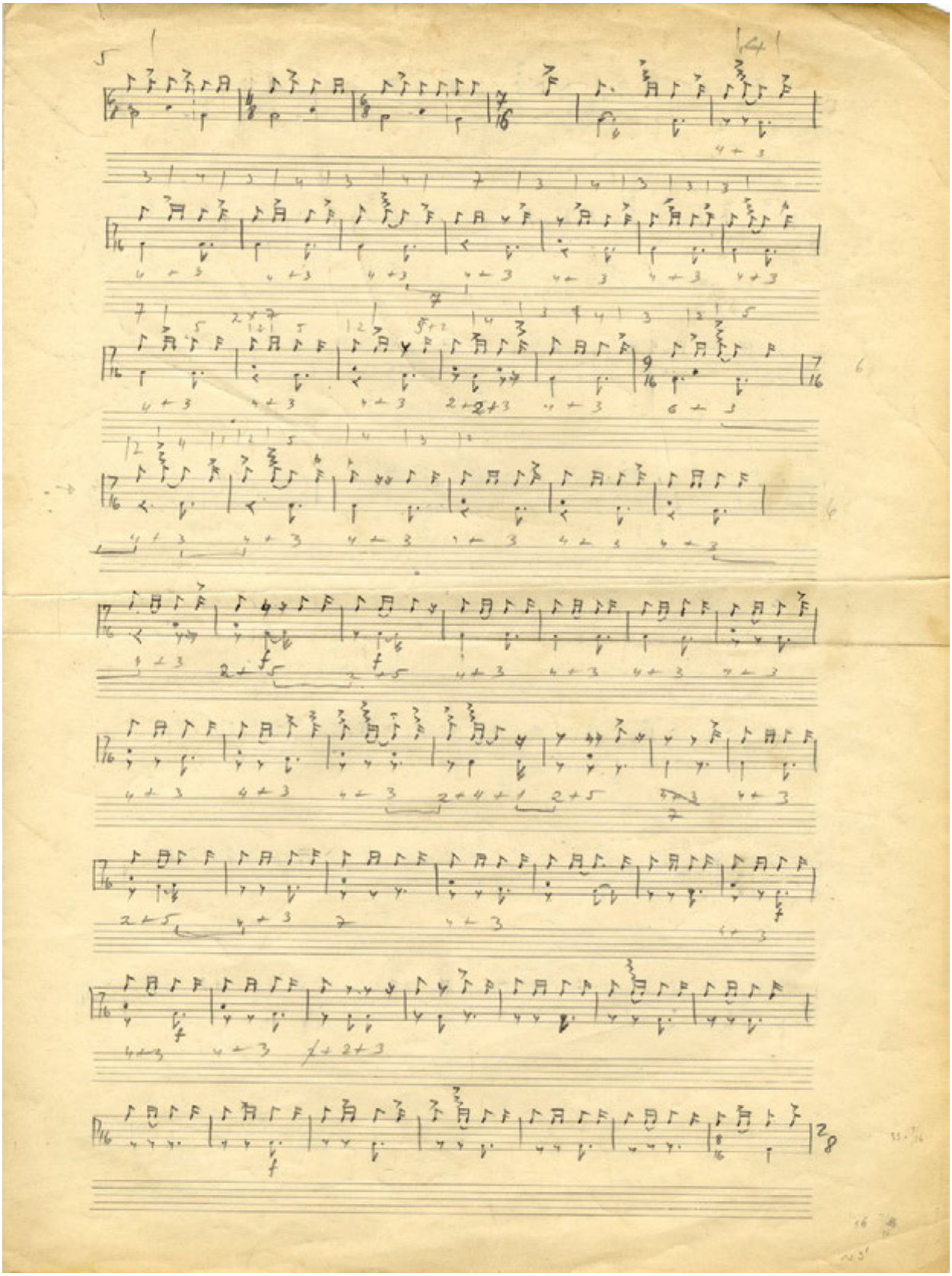


Figure 8: Score of Rythmes sur Tabla, p. 3.

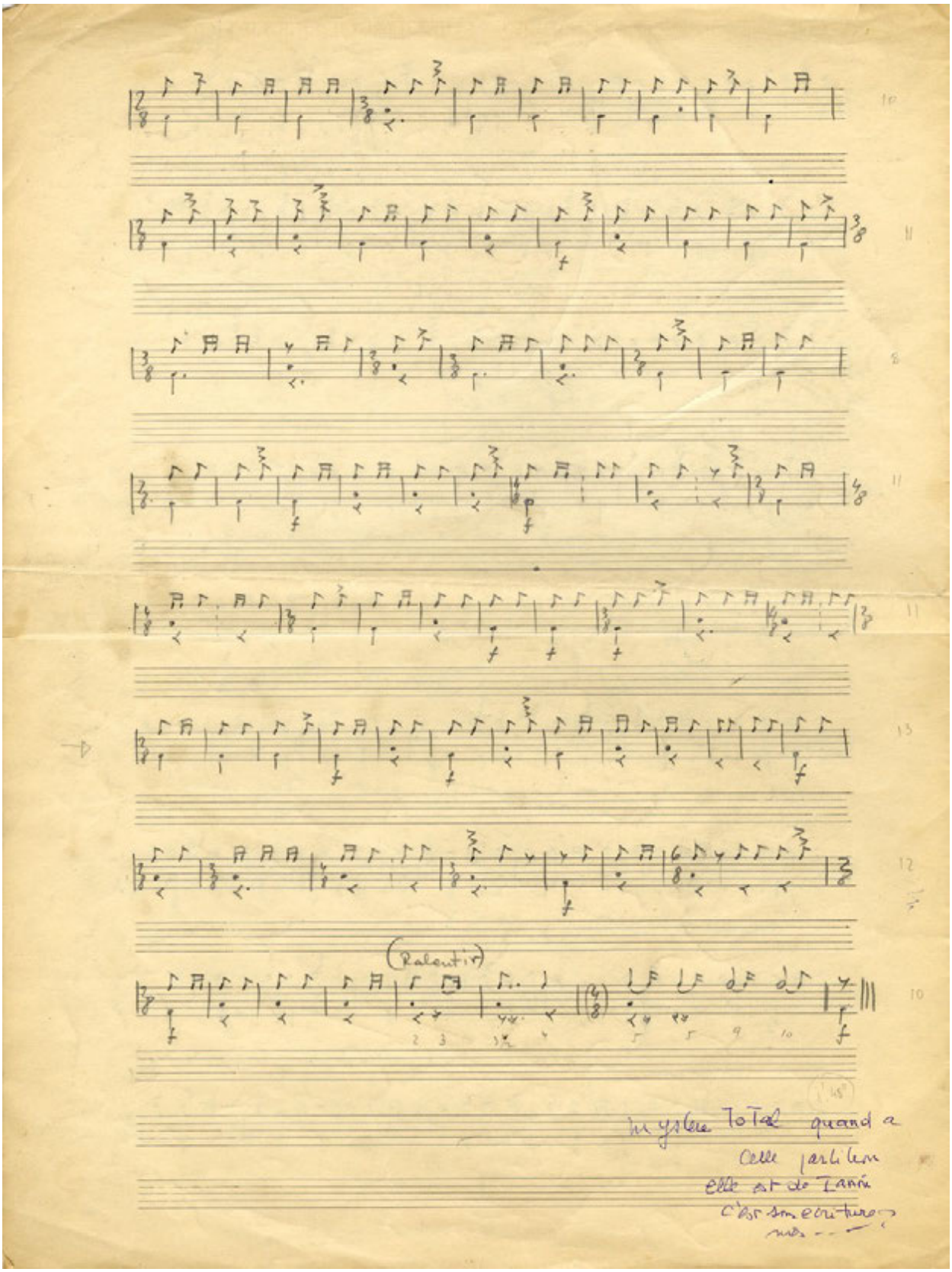


Figure 9: Score of Rythmes sur Tabla, p. 4.

3. What the graphic score of *Rythmes sur Tabla* can teach us

3.1. Identification of a partial graphic partition of the piece

Our research into *Rythmes sur Tabla* led us to study a score found in the archives in 2020. The document was compared at first to *Pyrovasia* (Xenakis [2015] 2022, 240-1). However, the graphic writing – less elaborate than that of the polyrhythms dating from 26 December 1953 (Xenakis [2015] 2022, 95–96) – led Mâkhi Xenakis and me to believe the score predates them, and was probably made between January and December 1953.[17] Also, the search for common elements between this score and the *Rythmes sur Tabla* pushed us to investigate more closely the particular writings that constitute it.

The first element that drew our attention was the representation of a rhythmic passage appearing twice in traditional notation on the graphic score. It seems to take up the rhythm of the beginning of the low voice of *Rythmes sur Tabla*, with the difference that it is doubled.[18] Another important element, the numerical analysis indicating the general count of changes of measure – even and odd – at the beginning of the score of *Rythmes sur Tabla*, seems to correspond to the graphic score. Finally, we must consider that the drawings Xenakis made prevented him from representing the beginning of the score graphically, and made us rely solely on the figures repeated in the low voice to recognise this as a work "in progress" and understand that the document is a partial graphical representation of *Rythmes sur Tabla*.

This revelation allows us to place the period of creation sometime between January 1953 – after the preliminary and obligatory traditional transcription of the score – and 26 December of the same year, which appears on the first polyrhythmic writings of *Pyrovasia*. This allows us to identify the document as being the very first polyrhythmic graphic score Xenakis produced. Lastly, it confirms the essential role of the more traditional score of *Rythmes sur Tabla*, which brings together all the elements necessary for its graphic transcription. It is moreover with a certain emotion that we realise that the difficulty deciphering the beginning of the graphic score testifies almost literally to the passage from traditional musical writing to graphic writing.

3.2. Analysis of the graphic writing of Rythmes sur Tabla

The graphic score of *Rythmes sur Tabla* consists of two sections. The upper part corresponds to bars 1 to 49 of the basic score, and the lower part to the deployment of the second *tâla*, whose unit of time is reduced to a sixteenth note.[19] The middle stream has disappeared, leaving two main voices.

As discussed above, the graphic writing of the first section refers to the end of measure 3 of the traditional score, even if the count of the low voice appears as figures starting with the first measure. At the top left of the document are small sketches of instruments as well as a ternary rhythm corresponding to the rhythmic pedal of the lower voice, which appears twice in traditional notation.[20] Xenakis indicates a tempo: "two mm = approximately 252". There follows a series of numbers: "4=2, 6=3, 8=4, 10=5" indicate the conversion of a measurement in millimetres (the left-hand digits) into units of time or *mâtras* (the right-hand digits). These elements make it possible to decode the lines of digits "floating" above the first section. The first on the left relates to the beginning of the low voice, and the second to the passage mentioning the repeated appearance of the value "6".

The second section takes up the passage to the dominant 7/8 of the traditional score. Xenakis insists

17 The score was initially linked to *Pyrovasia* because it was among the graphic scores dated 1954, when that piece was being written. It was only later, with the musicological expertise of Makis Solomos, that we came to believe this score antedated the writings dated 26 December 1953.

18 The rhythm is represented by quarter notes in the traditional notation, but eighth notes on the graphic score.

19 We cannot refer the reader to corresponding bar numbers in the traditional score, as Xenakis modified the placement of the barlines for the section in 7/8.

20 We note that this same basic rhythm appears on one of the pages corresponding to a note taken during Messiaen's course (Notebook 9, p. 6), accompanied by observations written in Greek, probably dated 4 or 6 December 1952. It was on this same page that Xenakis drew the picture of the deçi-tâlas. Perhaps the composer saw in the *Rhythms on tabla* the opportunity to study a simple rhythm which appears in both the Hindu and Greek rhythmic systems?

on an alternating superposition of the two voices, however, choosing to modify the strong beats of the bass from the measures indicated in the first score. The monnayage of the tenor voice, "1-3-2-2-1-2-2-2-1-2 etc.," is repeated below in the form of an alternation of 3-4, and certainly allows the composer to make a visual comparison of the shifts established on the basis of similar numbers between the two voices.

The graphic system used expresses a certain rhythmic hierarchy. The downbeats are indicated by arrows – head down for the tenor voice, head up for the bass voice. The size of these is proportional to the accentuations to the upper flow in the traditional score. The lines not marked with an arrow establish the "monnayage" of the rhythm (in the upper flow), or refer to weak beats. The arrows superimposed with a circle correspond to the hollow sounds marked with an "a" on the more traditional score, and suggest that Xenakis ultimately chose to integrate the middle flow into the bass.

The numbers at the bottom of the first section repeat the count of measures that appear in the margins of the score analysed by F-B Mâche. The graphic score, on the other hand, explicitly informs us about I. Xenakis's search for added or subtracted values. This search can be seen in each of the "strata" included in the document. It can be seen in the planes of the interior lines marked with arrows implying an initial numerical count, but also at the more general stage of the "bar measurements", when a horizontal line joins two vertical bars or when a circle is placed between two vertical lines.[21] Added or subtracted values appear as a last resort, with the numerical indications furthest from the graphic writing, indicating +1 or -1.

It also seems to us that we can identify the origins of what would become the principle of "differential duration" (Barthel-Calvet 2003, 131). Indeed, the pointed shifts between the different rhythmic flows, expressed by the distances between the bars "framing" the sound events, appear here visually, and in an obvious way.[22]

Certain textual indications are related to the effects obtained by the values added or subtracted: the insertion of the 5 in the flow constituted by the 4-2s makes it "advance", while the sequence of several 3s gives the feeling of a "stop".

Finally, Xenakis offers a series of observations to the right of the score:

"1. Time first eighth note = 252 = 2 mm. 2. The rhythm is composed of two elements a) The rigorous rhythmic pedal provided by the tenor voice b) The action of the low voice which first establishes an order [4, 2] (2, 1) and then disturbs that order by introducing larger or smaller values [5 2] or [3, 2] or [4, 3] or [3, 3] = [4, 2] The last equation is not systematic. Impression of slowing down or speeding up. Impression of positive (anticipates) and generalised negative syncopation 3. The rhythmic pedal (tenor sound), as a rule, is accentuated offbeat in the low attack. 4. Irregular variations of the tenor accent add an appearance of complexity to the rhythm and its counterpoint which is fundamentally simple and regular."

These comments confirm F-B Mâche's remark about the composer's interest in the psychological effect rhythmic changes can produce in the listener (Mâche 2009, 25–26). The observation and mathematical recording of the "oppositions" and "oscillations" that for Xenakis characterise Hindu rhythms still refer to what was to become a "major axis" of his poietics, with the use of stochastics and sieves. (Barthel-Calvet 2012, 59).

If we go beyond the strict technical aspects and "toggle" to a more visual and global reading of the graphic score, a certain number of characteristics are revealed. Indeed, the composer crossed into the "spatialisation of time" (Solomos 2001, 7) and "abstraction" which would distinguish him from

21 The horizontal bar means +1, the circle -1.

22 Furthermore, we observe that Xenakis "lowers" the "monnayage" of the upper voice to the lower rhythmic flow to emphasise the *tâla*'s augmentation. This specificity appears particularly at the moments corresponding to the rhythmic augmentations of the first section. We also note that it is through the graphic medium – which allows a geometric and metric intermediary – that Xenakis institutes the establishment of irrational numbers in music, notably within *Metastasis*.

Messiaen (Solomos 2006, 4). And the choices he made intuitively already prefigured the more complex polyrhythms he implemented later.[23]

At this stage Xenakis had already superimposed the two sections of the *Rythmes sur Tabla* on a single sheet of paper, even if for him this didn't yet imply any sound reality. This effect invites us to apprehend visually a form of globality referring to the notions of "mass" (Solomos 2001, 9) and "density" (Solomos 2001, 3), which Xenakis would later formalise more consciously with the sound clouds.

Finally, we note that the repetition of certain constituent features of the analysis throughout the pages graphically induces a "parallelism" which is also found in certain Xenakian polyrhythms (Solomos 2001, 10), even if, in the case of *Rythmes sur Tabla*, the vertical dimension of the graph paper doesn't yet relate to the precise pitch of the sounds...

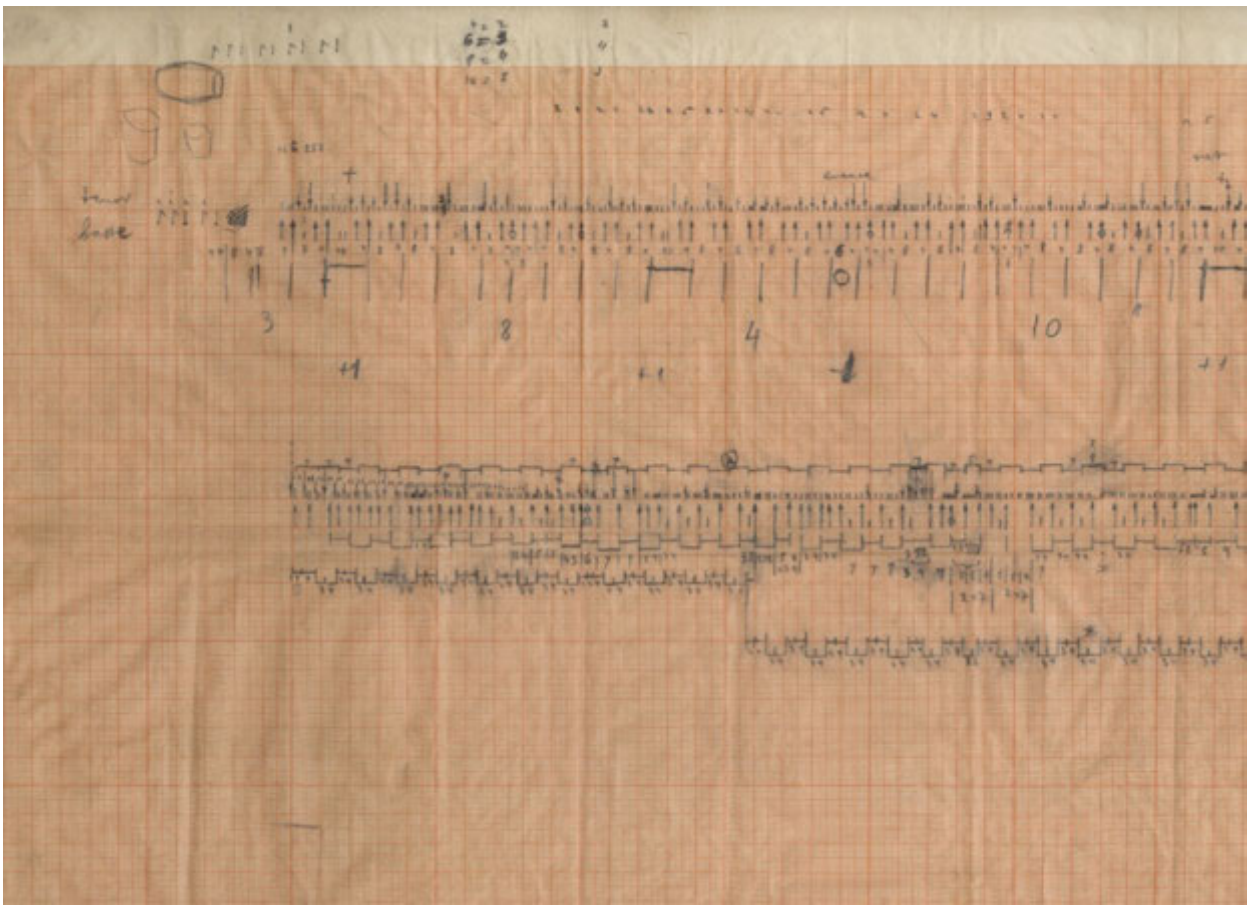
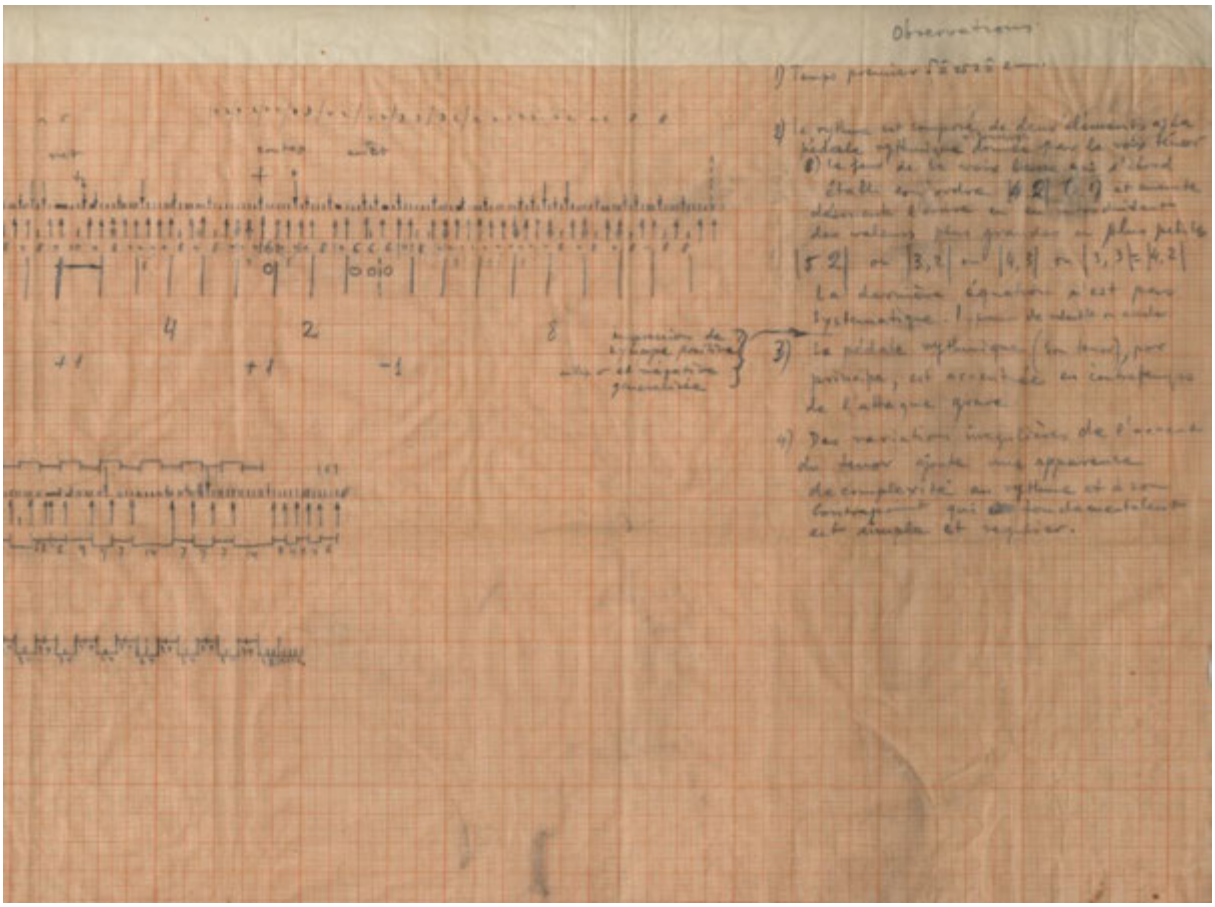


Figure 10 : Graphical sore of Rythmes sur Tabla (1953)

23 We refer the reader to their detailed analysis in (Barthel-Calvet 2000, 153–296).


Observations
1) Temps premier
2)
3)
4)
4
2
8
+1
+1
-1

4. Other issues raised in the context of this study

The research we carried out in cooperation with Mâkhi Xenakis led us to consider the question of Hindu music within the composer's work more broadly. Also, we have attempted to identify all the works on the subject in the latter's personal library. Among them, the two volumes of *Northern Indian Music* by Alain Daniélou particularly caught our attention, because of the correspondence of their publication with creations such as *Metastasis* or undulating glass panes.

In addition to the striking analogy between the representation of the *tâlas* and the graphic scores of the sound clouds which had been noted by Mâkhi Xenakis (Xenakis [2015] 2022, 239-241), reading the work indicates I. Xenakis's interest in certain passages, which he annotated extensively.[24]

The composer was particularly interested in the question of pitch as conceptualised in India in intervals called *shrutis* – which means "audible" (Daniélou [1949] 1954, 45). The 81/80 interval, related to the *comma*, is, it seems, the smallest perceptible difference and constitutes the unit of division of the scale of sounds of modal music.[25]

In I. Xenakis's Notebook 8 dated 1952,[26] prior to a text mentioning the notion of interference,[27] a series of calculations report ratios identical to those mentioned by Daniélou, and seem to indicate that I. Xenakis was looking for the ratio corresponding to the *comma*.[28] The concept of interference[29] also appears in the composer's writings dated 31 August 1953 in Notebook 1.[30] The calculations in this notebook seem to be related to the papers Xenakis left in Daniélou's book, referring specifically to pages 71–73 and to the scale mentioned: *Shadja grama*.[31]

According to Daniélou, a note (*svara*), as implied by its name, always depends on a relationship with a basic sound – the tonic, the definition of which can apparently vary. It is therefore, by nature, intervallic. This leads to a "theory of classes of intervals" or *shruti-jâtis* (Daniélou [1949] 1954, 61–67), making it possible to establish "series" of sounds (Daniélou [1949] 1954, 65). The principle is still organised according to a cycle whose representation strongly evokes the system Xenakis established for calculating the serial diastemic for *Metastasis*;[32] Mâkhi Xenakis has published one of the plates (Xenakis [2015] 2022, 98). The design of the "brushes" used for *Metastasis* seems to refer to the establishment of the "differential duration" for pitches of sound,[33] and could invoke the notion of "interference"[34] by superimposing series on one another. This hypothesis is further supported by the relationship between the diagrams illustrating the Hindu series (Daniélou [1949] 1954, 62) and page 17 of Xenakis's Notebook 13.

These discoveries, while still at an early stage of analysis, seem nevertheless to highlight the composer's real interest in Hindu musical theory, and specifically in Alain Daniélou's exposition of it. Also, it would seem that exploring the content of *Northern Indian Music* could offer insights into the genesis of *Metastasis* and into musical concepts Xenakis developed later, such as stochastics or sieve theory.

24 The latter annotated pages 47, 70, 71, and 73 in particular.

25 The choice of *shrutis* to compose a "basic scale" of sounds (Daniélou [1949] 1954, 72) is made by choosing the simplest ratios in relation to the tonic, from ascending or descending fifths (Daniélou [1949] 1954, 61). The accumulation of all the intervals of the series is taken up to form the general scale of 66 shrutis.

26 We remain cautious about this, because Xenakis does not mention an exact date.

27 This text seems to refer to the creation of a work (Notebook 8, p. 43).

28 We refer to the notes in Notebook 8, p. 30–35.

29 We refer the reader to the development of this notion in (Xenakis [2015] 2022, 79–84).

30 This discussion is repeated on pages 43-49 of the notebook.

31 The latter refers, according to Daniélou, to the Pythagorean scale.

32 We refer the reader to the analysis proposed by A-S Barthel-Calvet (Barthel-Calvet 2003, 151).

33 We refer to page 14 of Notebook 13.

34 This can be found on page 8 of Notebook 13.

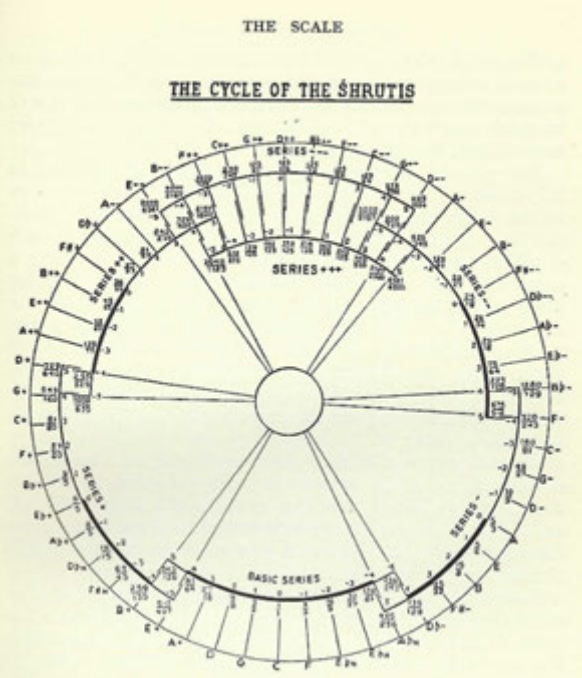


Figure 11 : The cycle of the shrutis (Daniélou [1949] 1954, 67)

Figure 12 : Metastasis brushes (probably february1954), Notebook 13, p. 14

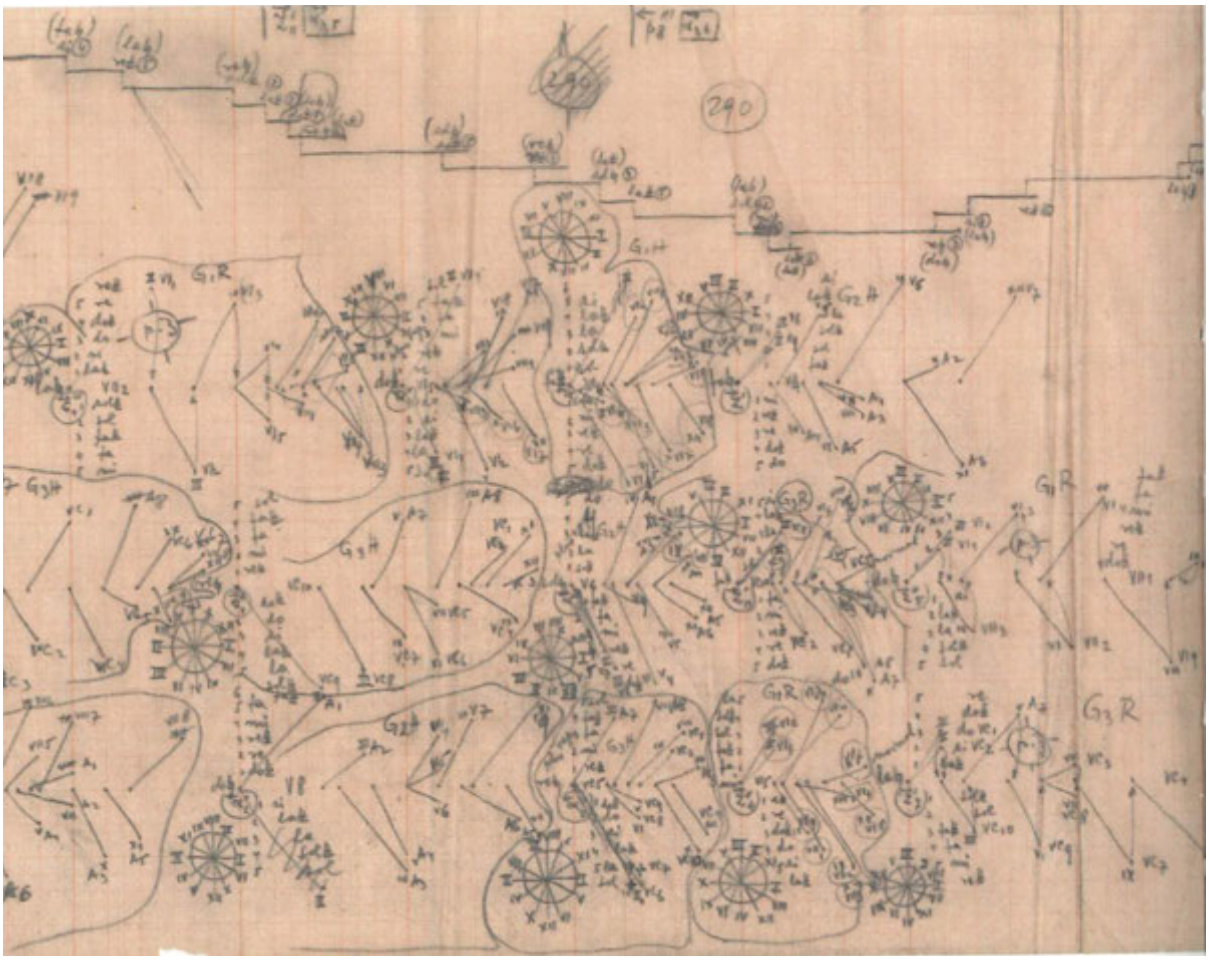


Figure 13 : Diastemic calculs for Metastasis's serial part (1954) (Xenakis [2015] 2022, 98)

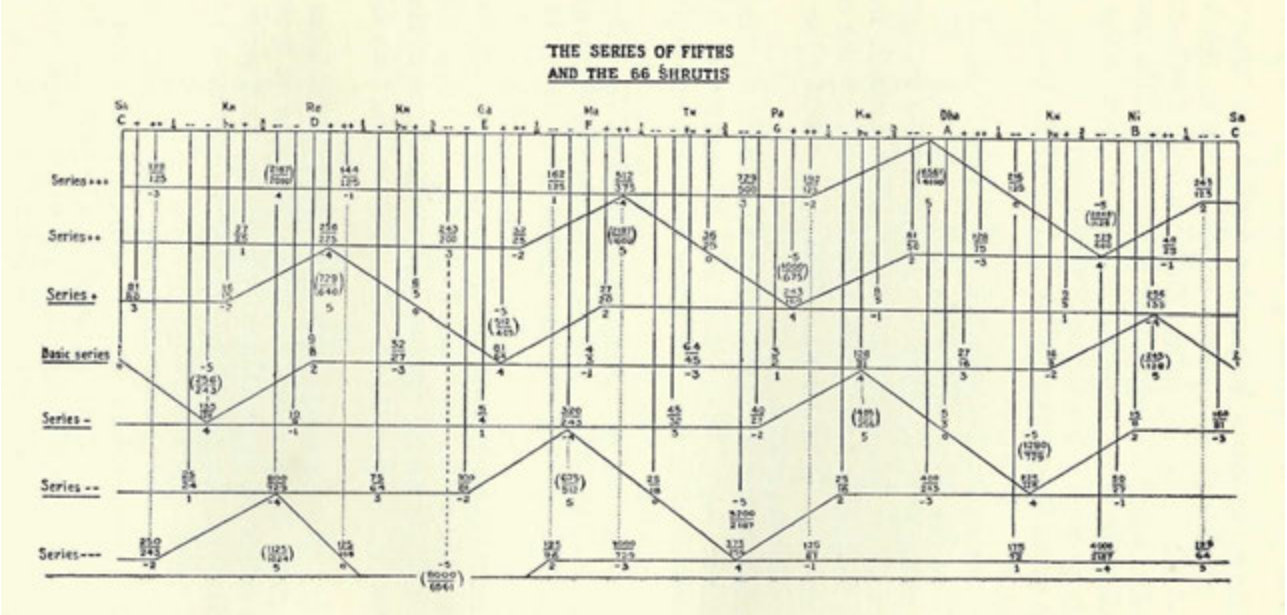


Figure 14 : The series of fifths and the 66 shrutis (Daniélou [1949] 1954, 62)

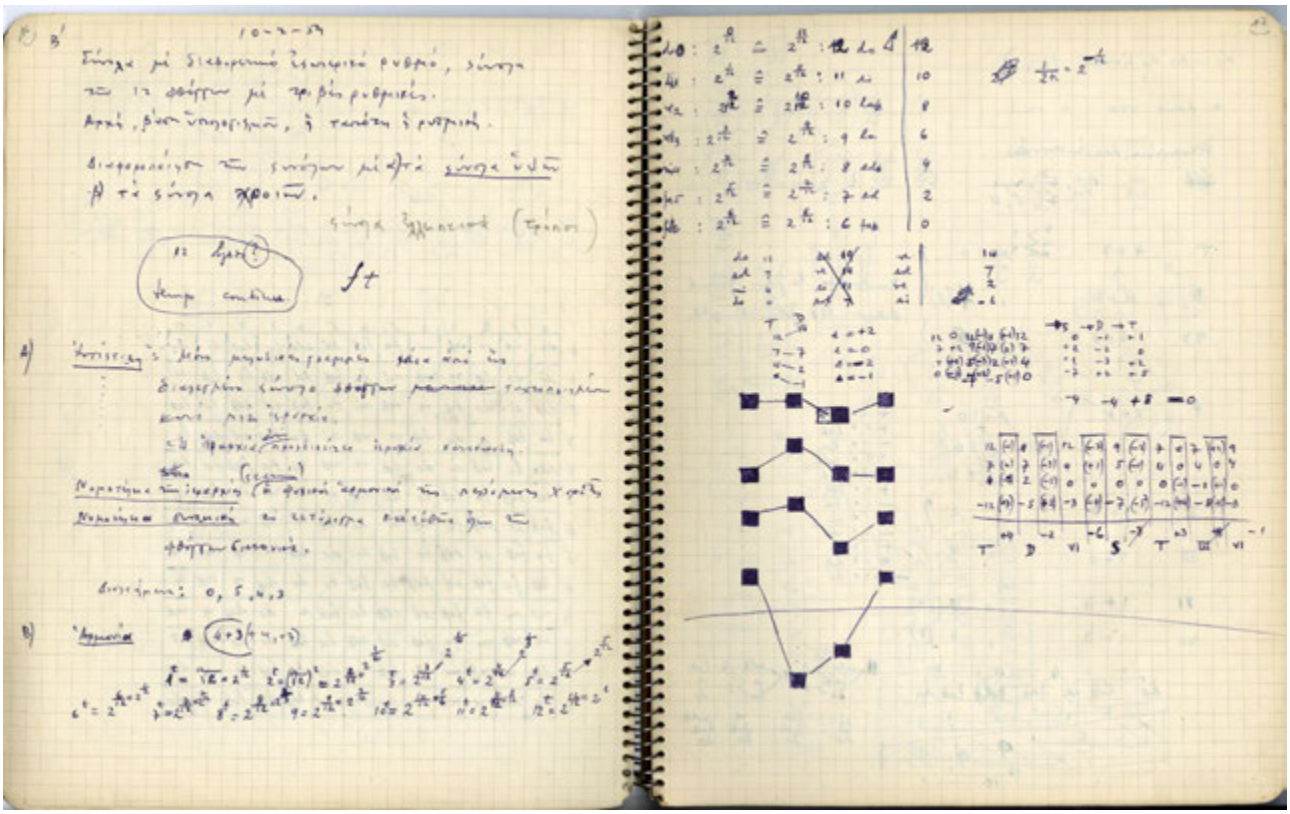


Figure 15: Diagram of superimposing series (10-02-1954), Notebook 13, p. 16-17

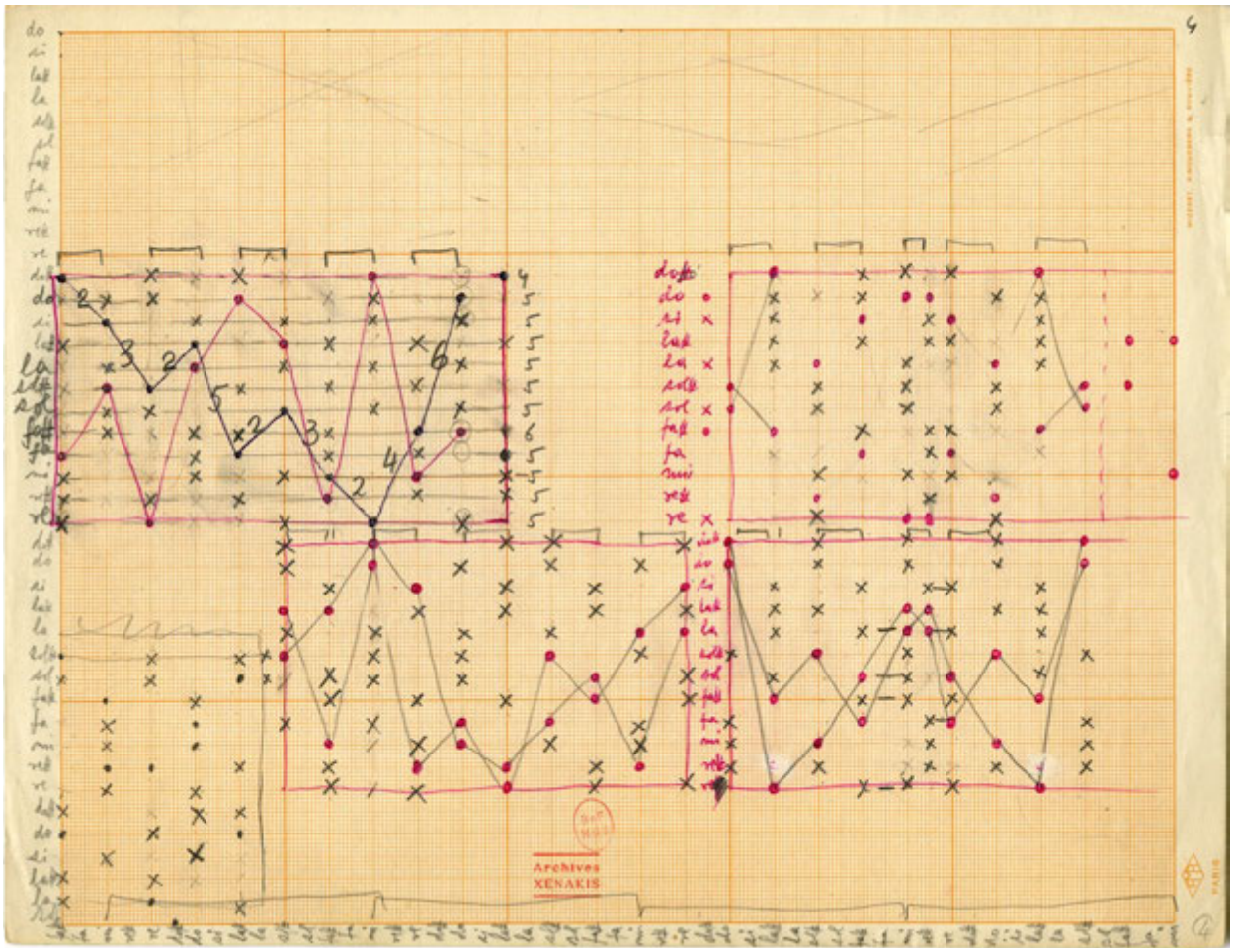


Figure 16: Probably calculations of the trajectories of the string glissandi for Metastasis (1954) (Xenakis [2015] 2022, 97)

5. Conclusions

It seems the decisive role of the "traditional" score of *Rythmes sur Tabla* within Iannis Xenakis's more general work, in particular through the emergence of a particular musical writing, can be established here.

In addition, the beginnings of compositional mechanisms contained in the piece's graphic transcription have also been highlighted. The specific method of inscription that the young composer employs seems to prefigure the appearance of masses of occasional sounds, as well as the emergence of certain principles leading to their musical mastery.

We hope we have stressed the importance to Iannis Xenakis of Indian music, and the way in which he drew on the principles inherent in it. This observation should perhaps give rise to an investigation of his work from yet another angle.

Finally, the possibility of a relationship between the undulating glass panes and the *Rythmes sur Tabla* and whether the principles underlying the two scores could govern the musical polyrhythms as well as the architectural principles of the glass panes remain unexplored.[35] This work is still to be done. It seems in any case that the question is worth asking.

Acknowledgments

I sincerely thank Mâkhi Xenakis for her confidence, and for inviting me to join her in this

35 Sven Sterken evokes for the latter the principle of a polyrhythm on the plans for the facade (Sterken 2007, 37), while Elsa Kiourtsoglou highlights a linear juxtaposition of elements evoking continuity but also density, and the use to principles of musical composition (Kiourtsoglou 2015, 75–118).

fascinating investigation in the heart of the archives. I would also like to express my gratitude to her for the richness of our exchanges, and for agreeing to publish here the complete versions of the two scores of *Rythmes sur Tabla* as well as for other archival documents. Thanks also to Makis Solomos and Elsa Kiourtsoglou for their encouragement and insights at an important moment in this research. Finally, I am grateful to Pr. Renaud Pleitinx, Pr. Jean Stillemans, Ghita Barkouch and Brigitte de Terwangne for their support in the translation process ; the Louvain research institute for Landscape, Architecture, Built environment » (LAB) and the Fonds de la Recherche Scientifique (FNRS) for their financial supports.

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Archives

Copyright I. Xenakis Archives : Carnet 1. / Carnet 9. / Carnet 13. / *Rythmes sur tabla. Tala ruapka, tala ata, tala gumpa* score. Pencil on musical score, January 1953. / Graphic score OM 1/1 document 1. Pencil on graph paper, undated. / Graphic writings of musical rhythms for *Pyrovasia-Metastasis*. OM 1-4 p. 002. Pencil on graph paper, 1953-1954. / Probably calculations of the trajectories of the string glissandi for *Metastasis*. OM 1-4 p. 004. Pencil and ink on graph paper, 1954. / Diastemic calculs for *Metastasis*'s serial part. OM 1/5 document 4. Pencil and ink on graph paper, 1954. / Graphic score *Psappha*, percussion. Ink on graph paper, 1975 / Undulating glass panes, Western façade of the Covent of the Tourette. Ink on tracing paper, 1954.

Expanding the rhythmic writing of Iannis Xenakis in my works of the 2010's

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Abstract

Iannis Xenakis' approach to rhythm has been one of his many innovative contributions that helped shape contemporary music since the 1950s. From his early works and the notion of "differential duration", to his works that introduced non-polymetrical polyrhythms or the generalized homorhythms of his later works, rhythm had always been an important parameter that went hand-in-hand with the musical and mathematical ideas the music was the vector of. In this paper I will explain how many of my works of the 2010s, most notably "*Incompatible(s) V*", find inspiration in and also expand Xenakis' rhythmic writing, focusing mainly on his works from the 1970s, aiming at a result that is even more free-flowing, based on the idea of a "self-regulated" music. Both Xenakis' and my own approach are closely related to the ideas of Ivan Wyschnegradsky on rhythm, as expressed in his book "*The law of pansonority*", something this paper will also examine. Finally, my personal approach to rhythm functions also as a way to clarify and comment on the new complexity school, with the intention to shed some new light on the rhythmic aspect of Xenakis' work.

1. Rhythm in the works of Iannis Xenakis

In her thesis that deals with the various rhythmic structures in the work of Xenakis, Anne-Sylvie Barthel-Calvet claims that one can divide them into three major categories:
a. Polymetries, mostly in the early works of the composer,
b. Non-polymetric polyrhythms, mostly in the works of the 1970s and 1980s,
c. Homorhythms, mostly in the composer's later works.
We will now shortly present the first two categories, explaining the context in which they operate, how they are constructed and how they function musically.

1.1 Phased Polymetries

Usually, by the use of the word "polymetry", one thinks about the coexistence of different time signatures for the various layers of musical activity. In the work of Xenakis, this is never the case, but the use of the term is still valid, as Barthel-Calvet points out: "[…] On the other hand, with regard to the phased polymetries that present a cyclic convergence of the different strata, let us recall that the first attestation of the "3/4/5" type polymetry in Metastasis presented the superposition of three measures of different time signatures: 3/16; 5/16 and 3/8. Finally, as we shall show, the measure is no longer a relevant metric unit in Xenakis. For all these reasons, we believe that the use of the term polymetry is justified and relevant in the context we have defined (Barthel-Calvet 2000, 156)".
In the case of Xenakis' early works, it was common that each individual line was assigned a specific regular rhythm or density, for instance 8th notes, quarter-note triplets or 8th note quintuplets, as was the case for "*Pithoprakta*" or "*Syrmos*". The rhythms were mostly subdivisions either of the half note or of the entire measure, in most cases a 2/2 time signature. As a variation of this logic, each regular

rhythm was later not assigned to one specific individual line or instrument, but moved around the ensemble or the orchestra, thus creating more varied lines and densities that, even if globally stable, were not internally regular in nature, as far as the musical result was concerned. In this specific case of polymetry, Xenakis was mostly interested in what he called "differential duration", i.e. the time interval between two sounds, and not the individual rhythmic lines themselves.
The rhythmically stable individual lines, along with the fact that sometimes each line is assigned a specific repeated pitch, create the sense that each line is playing at a different tempo, thus amplifying the notion of polymetry, if not even a virtual poly-temporality.

1.2 Un-phased Polymetries

In the 1970s, Xenakis started introducing a more elaborate rhythmic language, the one I will focus on for the remainder of this paper, since it was this kind of writing that influenced me the most and inspired me greatly on my personal compositional research. This new approach to rhythm sees Xenakis write rhythmic subdivisions whose denominator is no longer 2 or 4, meaning tuplets that no longer completely fit inside his usual 2/2 time signature, but rather move freely inside a bar and over bar lines, starting at different points of each measure, as if completely unrelated to the written time signature. The density of each line is thus even more varied, accelerating and decelerating at ease, at speeds that bridge the gap between the more common tuplets of 3:2 and 5:4, creating the possibility for a smoother transition between different "tempi". One can safely say that, in this particular logic, every line is a succession of ever-changing time signatures that rarely coincide with each other, hence the term "un-phased polymetries".
This rhythmic writing sees the emergence of tuplets the likes of 4:3, 5:3, 6:5, 7:5, 9:7, 10:9, 11:9, to name but a few. These groups, combined with the more traditional triplets and quintuplets whose denominator is a multiple of 2, create a rhythmic palette that allows the music to sound free-flowing, abolishing at times the notion of the bar and the bar line, that by now have become simple reference points for mostly practical reasons. This writing is found in some of Xenakis' most important works, notably *Jonchaies*, *Mists*, *Komboï, Tetras* and *Jalons*, to name but a few.
In this particular way of thinking about rhythm, what I found extremely interesting was the notion that a rhythmic group could start and finish at any point within a measure, regardless of bar lines and time signatures, allowing individual lines to evolve independently, as if completely liberated from any notion of hierarchy. This, along with the fact that every line was basically a succession of different tempi and a very efficient way to notate poly-temporality, made me want to explore it and see where the extension of this logic could take me.

2. Ivan Wyschnegradsky's theory on rhythm and the temporal continuum

I believe it is now necessary to write about Ivan Wyschnegradsky's writings on rhythm, since one could assume that they had had an influence on the thinking of Xenakis and, consequently, on my own later compositions, even if I was completely unaware of their existence at the time. In his book "The law of pansonority", Wyschnegradsky explains in great detail his theory on rhythm and how his ideas on micro intervallic harmony and the "total continuum" could be also applied to time and, evidently, rhythm.
Wyschnegradsky argues that the most commonly used tuplets, notably triplets and quintuplets, do not offer but a limited amount of possibilities and do not allow the composer the degree of continuity and subtlety one could wish for. It is for this reason, meaning in order to obtain a more continuous passage from one sense of tempo to the other, that he suggests the use of tuplets whose denominator is not a multiple of 2, with a nominator ranging from 1 to 13 (Wyschnegradsky 1996, 234). In his mind, a rhythmic group can be made up of any number of units within the space of any other number of units (Wyschnegradsky 1996, 218), something that closely resembles Xenakis' attitude in his works form the mid-1970s onwards.

Wyschnegradsky then gives a series of examples of rhythmic modulations, mostly accelerations and decelerations that use a wide range of uncommon tuplets to achieve greater continuity and fluidity (Wyschnegradsky 1990 233-273). Along with that, he pushes his logic even further, giving several examples using nested tuplets, almost prophesizing the *new complexity* school and the writing of Brian Ferneyhough.

In his article "*Enfin de l'espace*", composer Philippe Leroux mentions that Olivier Messiaen, Pierre Boulez and Iannis Xenakis had all of them solicited Wyschnegradsky in order to better apprehend his theoretical positions, although "[…] they had always remained very discreet on this issue […]" (Leroux 2019, 11-18). The truth is that it is striking how the examples of Wyschnegradsky bare a resemblance to some of Xenakis' rhythmic scores, especially the ones of the mid seventies, so it would be safe to assume that Xenakis was well aware of the writings and the theory of his colleague.

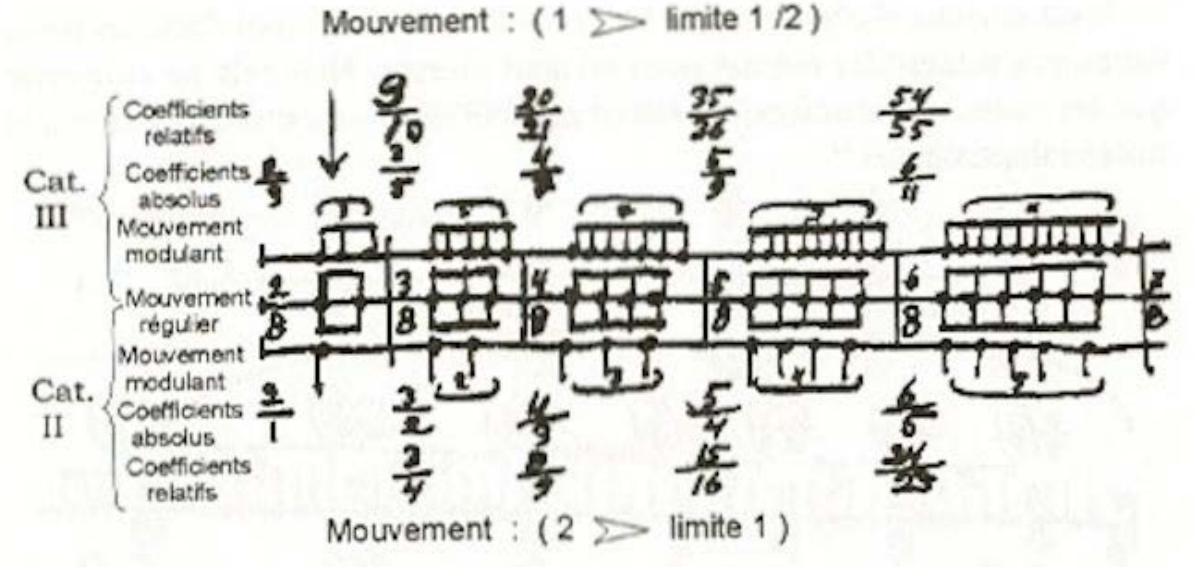

Figure 1 Wyschnegradsky, Ex.66 p. 258

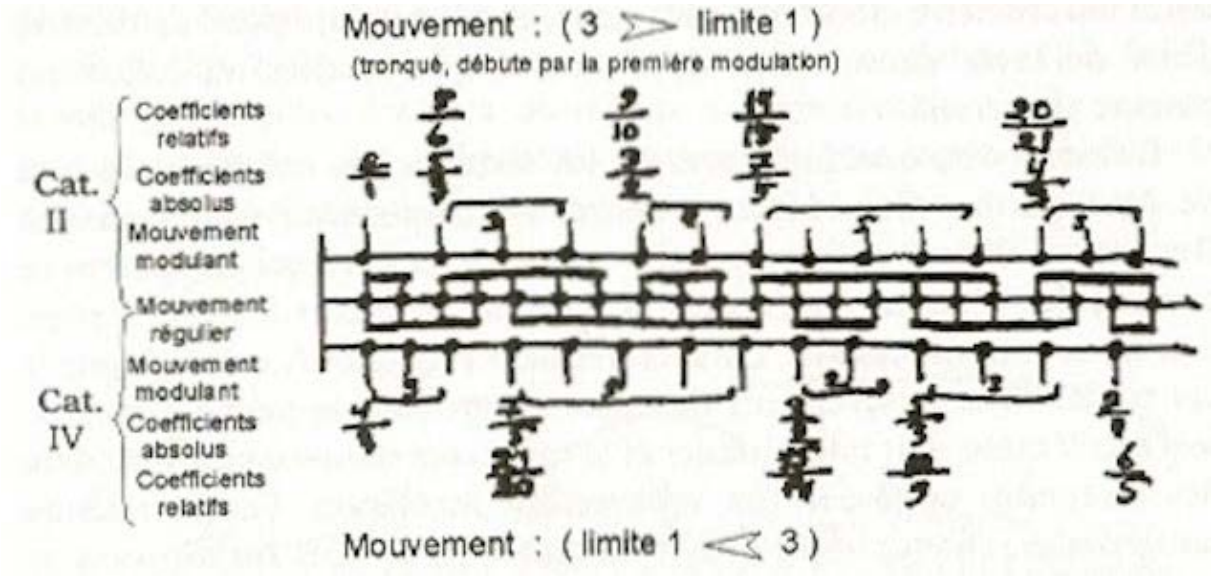

Figure 2 Wyschnegradsky, Ex. 67, p. 258

3. Expanding Xenakis' rhythmic writing in my "*Incompatib e(s) V*"

3.1 The starting point

"*Incompatible(s) V*" is a work for silent piano and live electronics, but we are not going to talk about the technological aspect of the work, focusing solely on the instrumental part, that is the one closely

related to Xenakis' approach. It is the first work that saw me experiment with this kind of rhythmic language, a kind of laboratory on how to approach density, speed, rhythm and notation.
As mentioned before, what I found particularly interesting in Xenakis' rhythmic writing from the mid 1970s and on, was the idea that a tuplet could start and finish at any given point in time. But after a certain point I started to realize that his logic, like any logic, had its limits, and that this idea could be taken a lot further, especially given the fact that musicians today, and especially pianists, were much more used to performing complex scores than they were forty years ago.
What made me start thinking about developing his idea was the fact that, throughout Xenakis' works where this writing is applied, there is always a 16th note grid that every rhythm is attached to. This meant that the idea of "any given point in time" was only partially true, and that there was plenty of room within this logic for one to further explore, taking also into account the findings of later composers, like the ones of the new complexity school that had largely been influenced by the music and the ideas of Xenakis (Ferneyhough 1998, 425).

3.2 Theoretical and poetic background

When I started composing "*Incompatible(s) V*", I was in the process of reading what turned out to be a fundamental book for me and my music, "*The imaginary institution of society*" by Cornelius Castoriadis. In this book, the Greek philosopher writes a lot about the notions of autonomy and heteronomy, emphasizing on the notion of a self-regulated society, that legislates as it evolves, making it up as it goes along, without any a priori ideas imposed from the outside. This idea appealed greatly to me and it was through the rhythmic writing that I was able to apply it to the fullest. My goal was to write a music that would allow each line an even greater freedom, while, at the same time, creating stronger ties between them, as if everything that happened in one line could (or would) potentially serve as a reference to the other. I wanted to give myself the choice between independence and interdependence as a way to put the notions of autonomy and self-regulation into music, being able to navigate between the two at any given moment, and even combining them at different layers.
At the time, I did not use any formal plan for my works, nor any other pre-determined guide for the music, apart from some basic pitch material, in the form of non-octaviantic scales, mostly for convenience reasons. My basic consideration was to write music that "wrote itself", not in the form of an automated procedure, but as the exact opposite, meaning an ensemble of free cerebral and musical associations, simulating the way the human brain works and basing my decisions solely on my musical instinct after a great number of hearings, either internally or externally, with the help of the notation software's playback. For this reason, and also in order to create the score follower script for the electronics part, I had to figure out exactly how to notate every rhythm so that it is played back exactly how it should be, something that was one of the biggest challenges I had to face. This aspect will not be featured in this paper, since it largely surpasses the purpose of the present text.

3.3 Developing Xenakis' approach

In Xenakis, the different rhythmic groups that begin at different places in the bar are always wedged to a virtual grid of 16th notes. The point of junction of two rhythmic groups is always their common beginning, whereas, in the abstract logic of the arborescence, a branch could arise from the middle or from any other point in time.
Here is an example from the work "*Mists*", for solo piano:

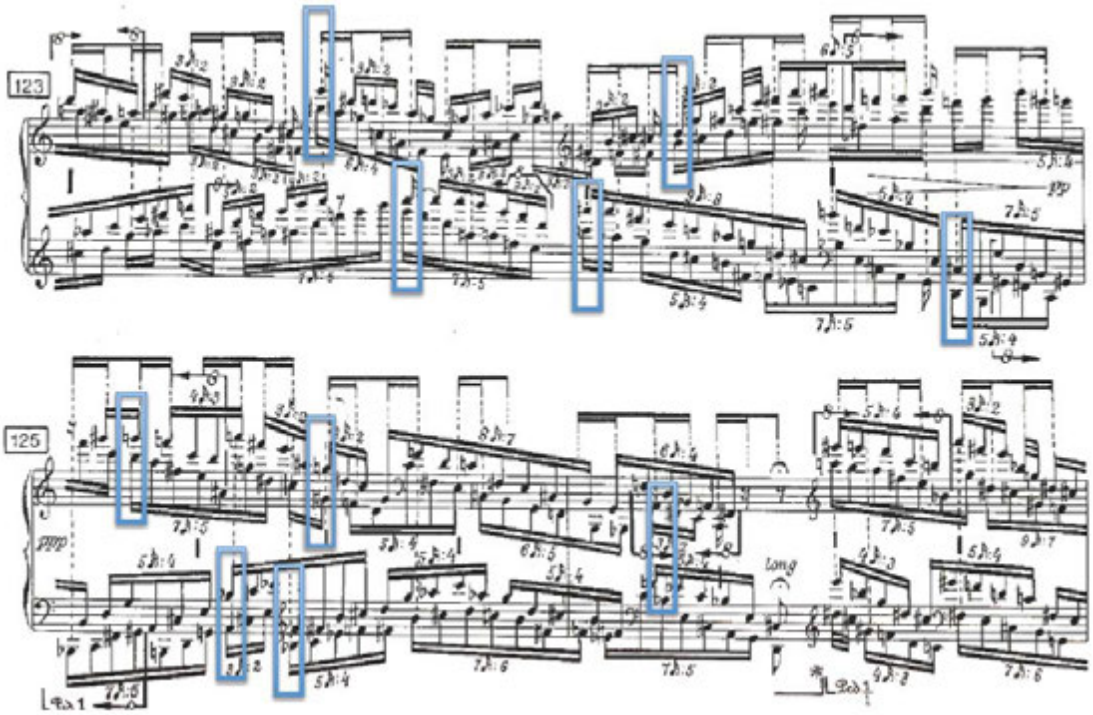

Figure 3 Iannis Xenakis, Mists, mes. 123-126

To make this phenomenon even clearer, and also for practical reasons, Xenakis even notates this 16th note grid in a way that is easier for the pianist to place each group.
Another example, this time from "*Komboï*", for harpsichord and percussion.
Everything is still wedged to the 16th note grid and the common notes between two layers are always the beginnings of each group:

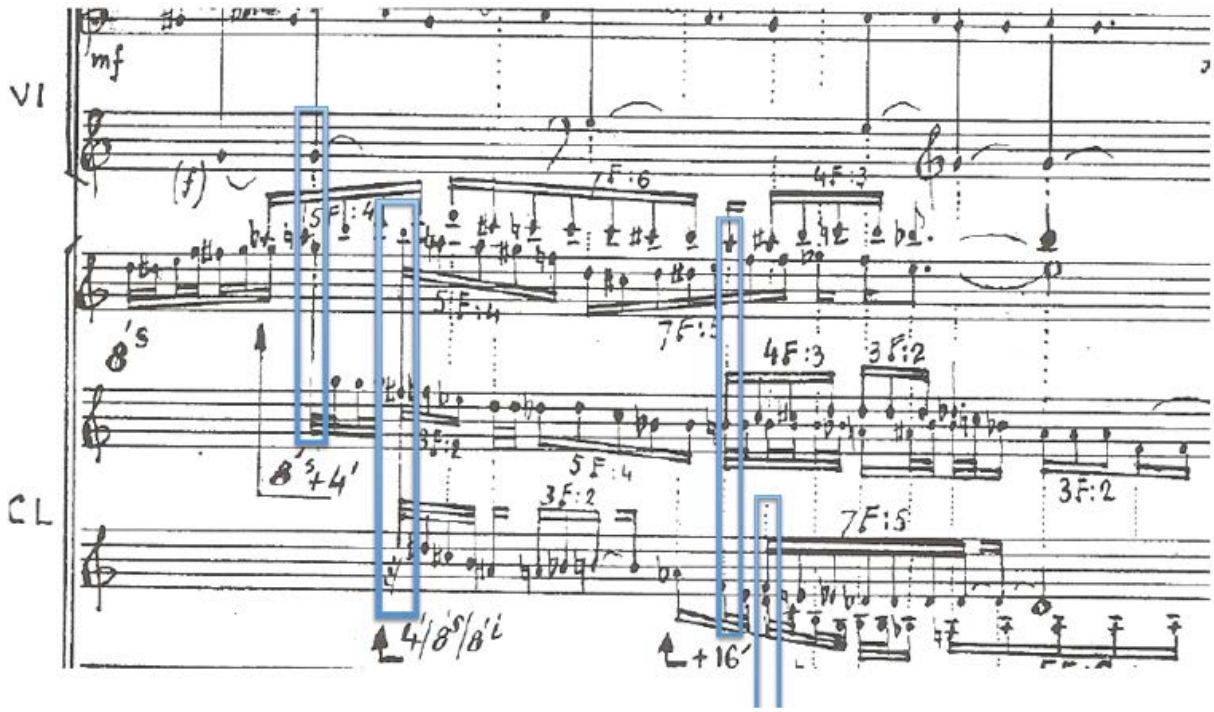

Figure 4 Xenakis, Komboï, p.4, ex1

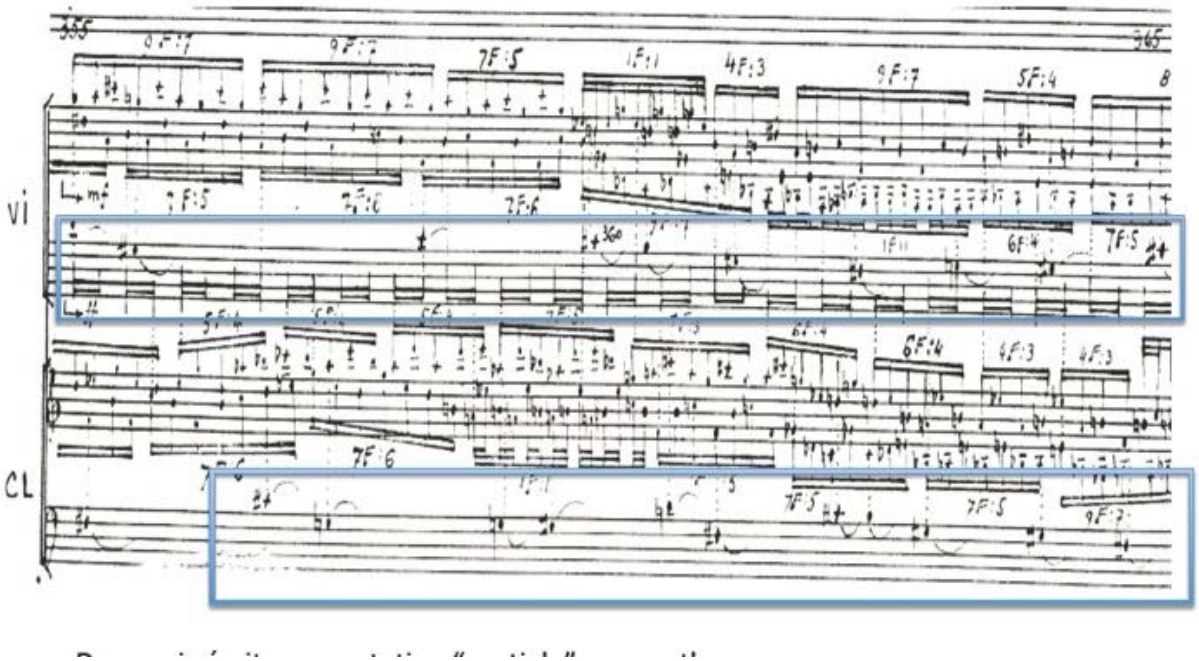

Figure 5 Xenakis, Komboï, p.4, ex2

However, we can also see in "*Komboi*" that there are layers that are created with notes belonging to different groups, that Xenakis feels the need to notate on a separate staff, probably in order to clarify the polyphony.

These layers are not precisely notated, contrary to Xenakis' usual logic. One can thus see the logic of rhythms that are independent from the 16th note grid, except that they are written in a kind of spatial notation. It is impossible to know why Xenakis did not write these notes as a separate voice (in this particular context, perhaps it would not make sense, since each note belongs to an already existing layer), with precise rhythms, but one can see a logic that was not developed all the way, even if it came directly out of the applied technique. Throughout his work, Xenakis remains faithful to the 16th note grid, while his music has a clear tendency to break free of it. In a private conversation with composer and long-time Xenakis associate, François-Bernard Mâche, it was pointed out to me that musicians at the time had already great difficulty executing Xenakis' rhythms, so it would not make sense to push the envelope even further.

But in 2011 that was no longer the case, so I decided to try out this logic and see what kind of musical ideas it would bring up. I was fortunate enough to be writing this piece for Pavlos Antoniadis, a specialist in complex scores, who encouraged me to pursue my ideas to the fullest. So, following Xenakis' logic and taking it several steps further, in "*Incompatible(s) V*", any note of any group can be the beginning of another independent line, as can be seen in the following example:

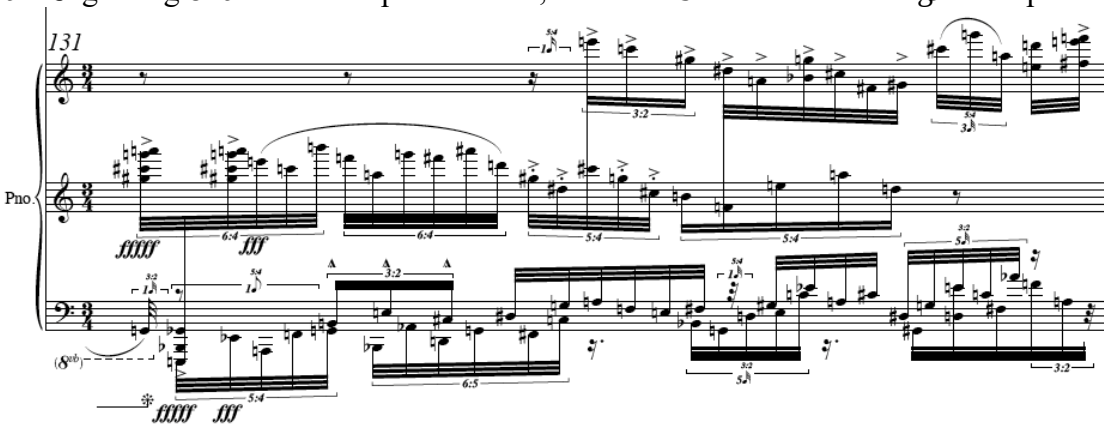

Figure 6 Nicolas Tzortzis, Incompatible(s) V, version 1.1, mes. 131

Or here:

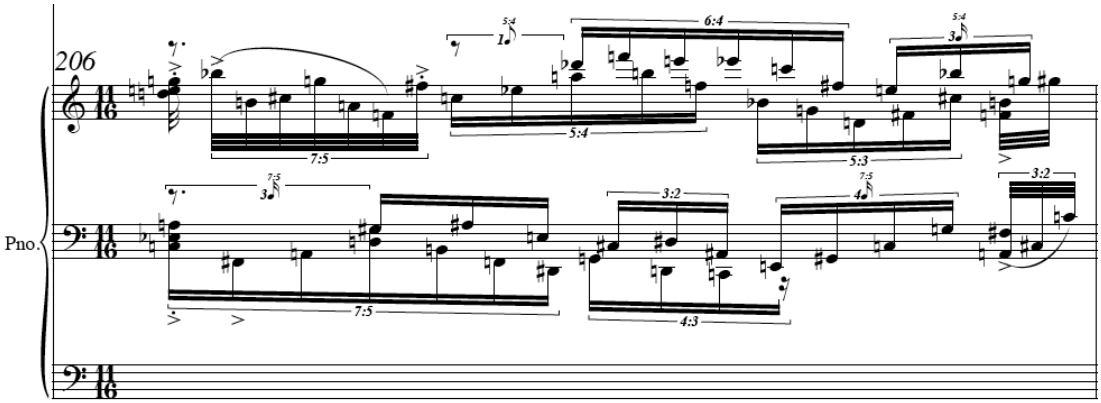

Figure 7 Tzortzis, Incompatible(s) V, version 1.1, mes. 206

This writing creates polyphonic networks whose lines can be both independent of the metric logic of each bar, but also closely linked to each other, each line creating possible resting points for the other lines. This is a form of what I call "self-regulating" (Tzortzis 2014) music, since the possible junctions between the voices are not subject to pre-existing or pre-determined grids, but emerge as the piece is composed, the form of a whole sequence depending on the order the different voices were composed in. Each new element, each rhythmic group influences the next, each bar reveals its own history which would have been quite different if there had been even a small change along the way.
Time signatures function as "time boxes" the different sequences can fit in, even if at times one or several voices do not fully correspond to what is shown at the beginning of the bar and overlap into the next bar. In most cases, time signatures were written after the bar was completed, acting also as indications for the structural clarity of the work. Furthermore, the different bars had also a lot to do with how things needed to be notated in order for the software to play them back correctly. Once again, the music "gives birth to itself", not following any pre-existing rule, but rather creating or applying the tools necessary for it to fully unfold.
In the following example, we can see how the different voices can go beyond the bar lines, have a rhythmic logic completely different from each other, while maintaining close links between them, since they eventually meet:

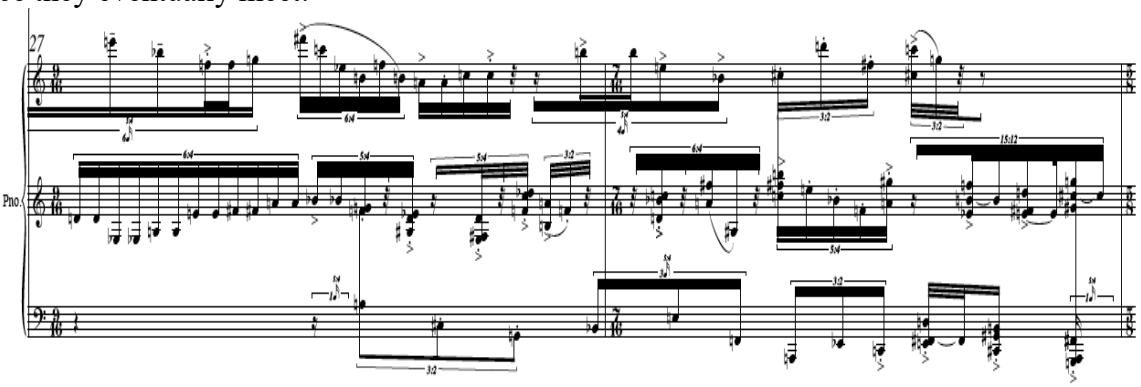

Figure 8 Tzortzis, Incompatible(s) V, version 1.1 mes. 27-28

In my work "*Digression*", for six percussionists, written right after "*Incompatible(s) V*", I use this new logic to simulate the delay effect, shedding a new light on Xenakis' phased polymetries. In the following example, the 2nd percussionist on vibraphone plays an 8th note quintuplet whose pitches are all taken up by the other instruments whose role is to simulate the motor effect of the vibraphone, thus creating a virtual delay. The repeated notes are all in 8th note triplets, following the motor speed of the vibraphone at that particular moment. It is thus not the difference of speed that creates the difference between each line, but their point of departure:

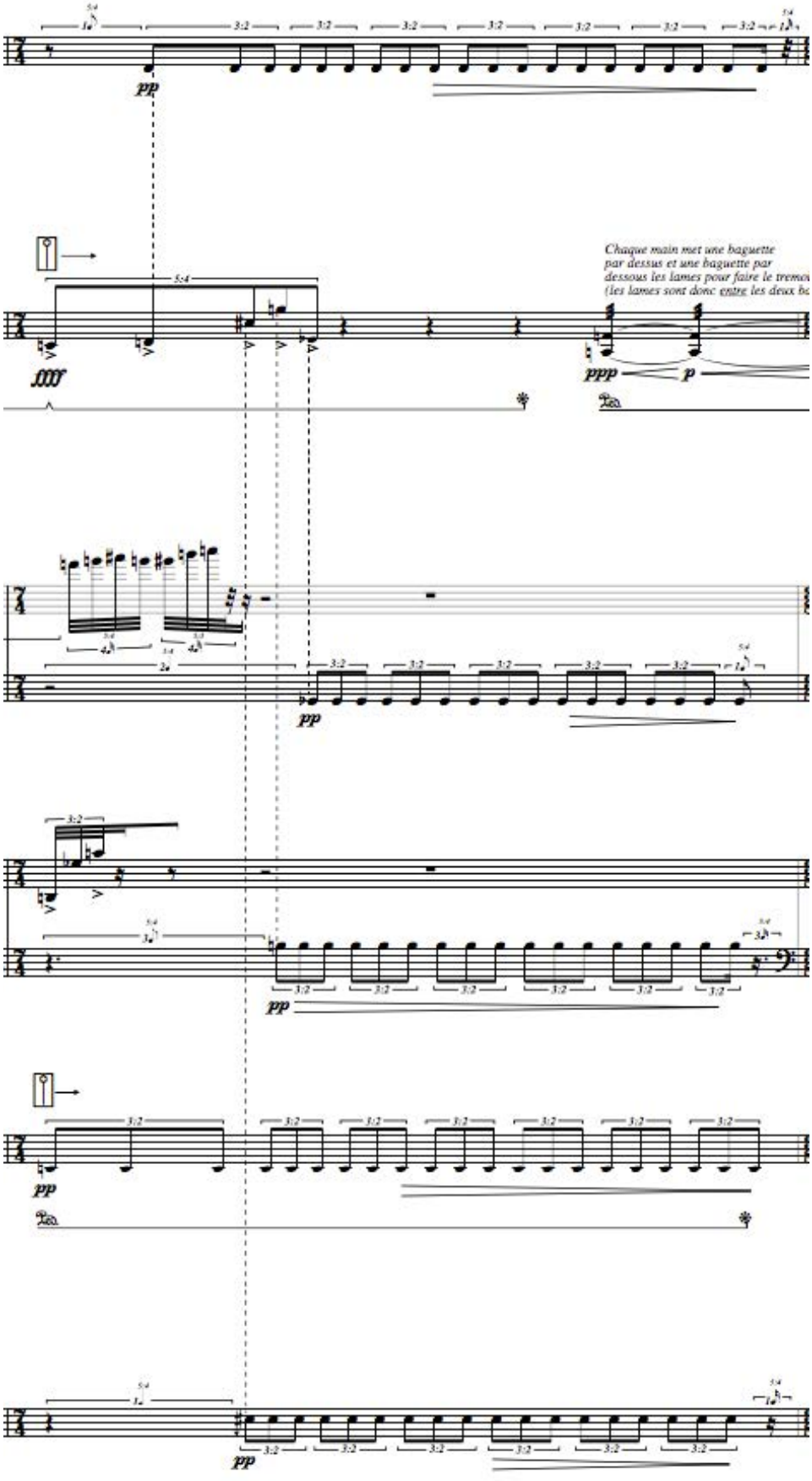

Figure 9 Tzortzis, Digression, mes. 33

In the bars that follow this idea is repeated, with the initial group changing speed going from a 5:4 to an incomplete septuplet of five notes, an acceleration of the previous five-note shape without the need to change the tempo, since the "delay" part is still in 8th note triplets. Then the main shape changes speed again and moves to a 5:3 ratio while the responding lines remain faithful to the triplets, before going back to the initial 5:4 ratio that is now an incomplete quintuplet.

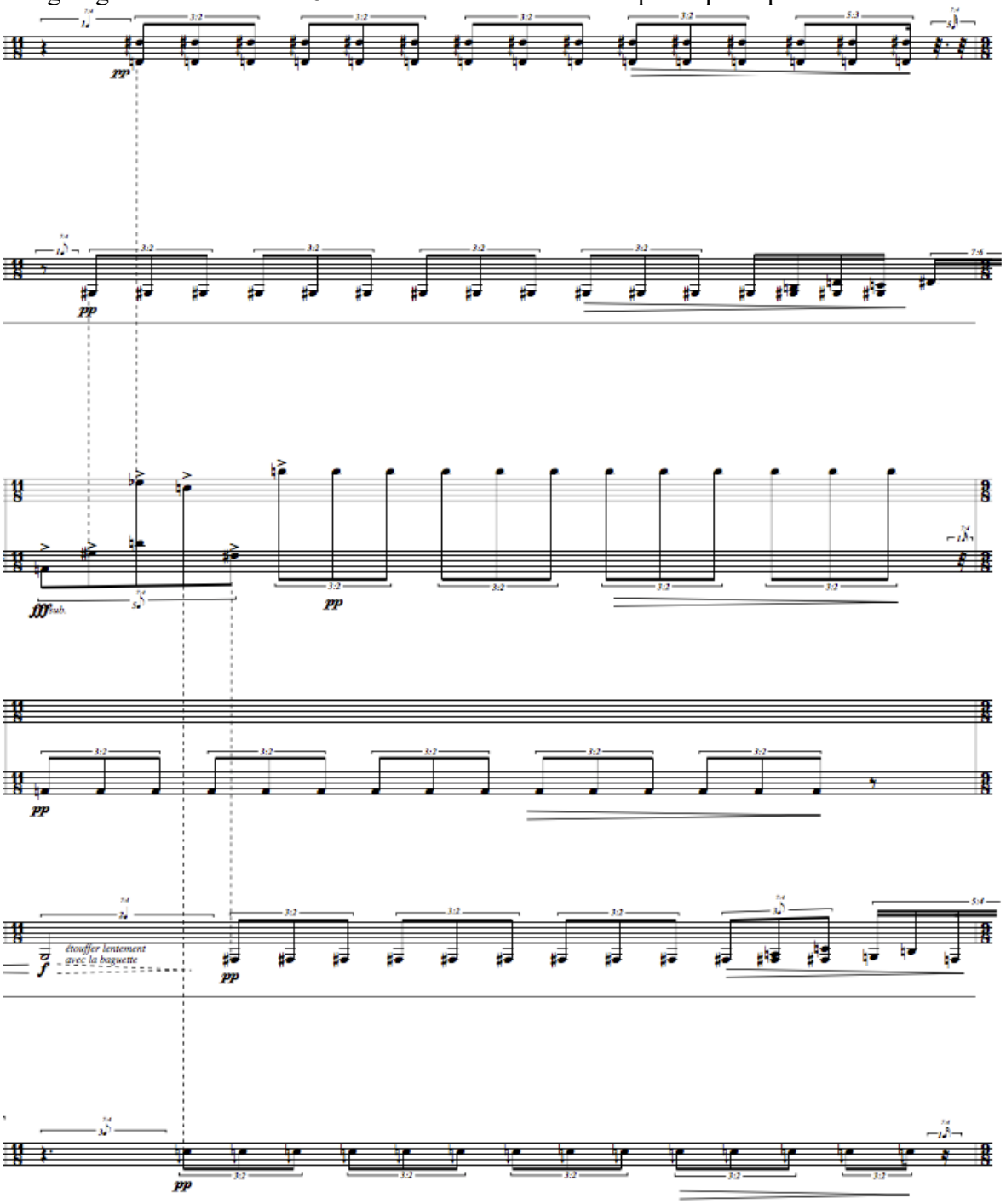

Figure 10 Digression, mes. 36

Throughout the first two parts of this work one can also see examples of un-phased polymetries like the ones in "*Incompatible(s) V*", with lines made up of broken tuplets and constantly evolving densities, mostly in the two marimba parts.

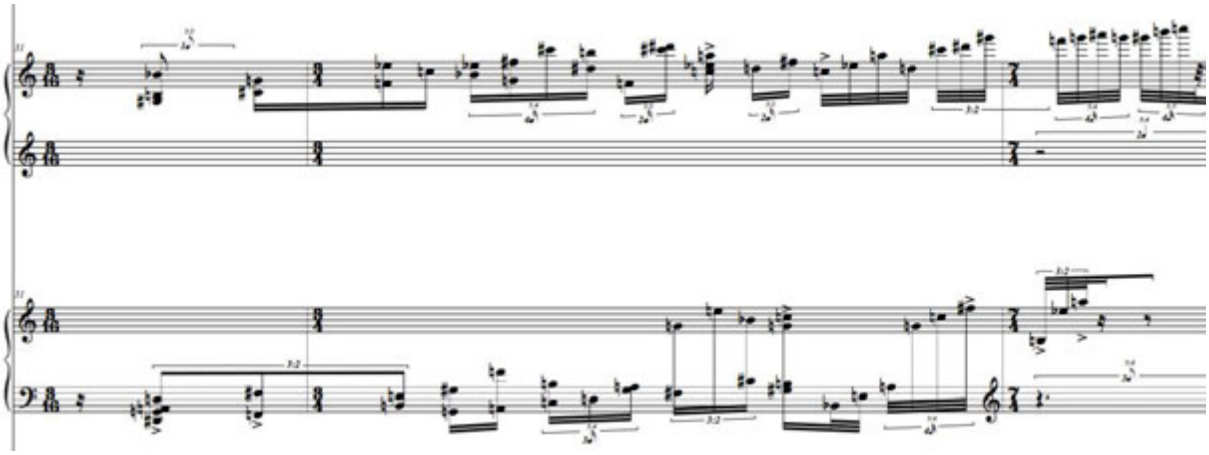

Figure 11 Digression, mes. 31 marimbas

A similar example is to be fd in my 8 quintet "*Emak Bakia*", only this time the "echoing" instruments d not keep the same speed after every new phase, varying their reactin time. In the three consecutive phases, the initiating figure is a quintuplet, a triplet and a septuplet respectively, with the delay following an opposite, deceleratig path goig from triplet to quintuplet ad finally to simple 8th nes.

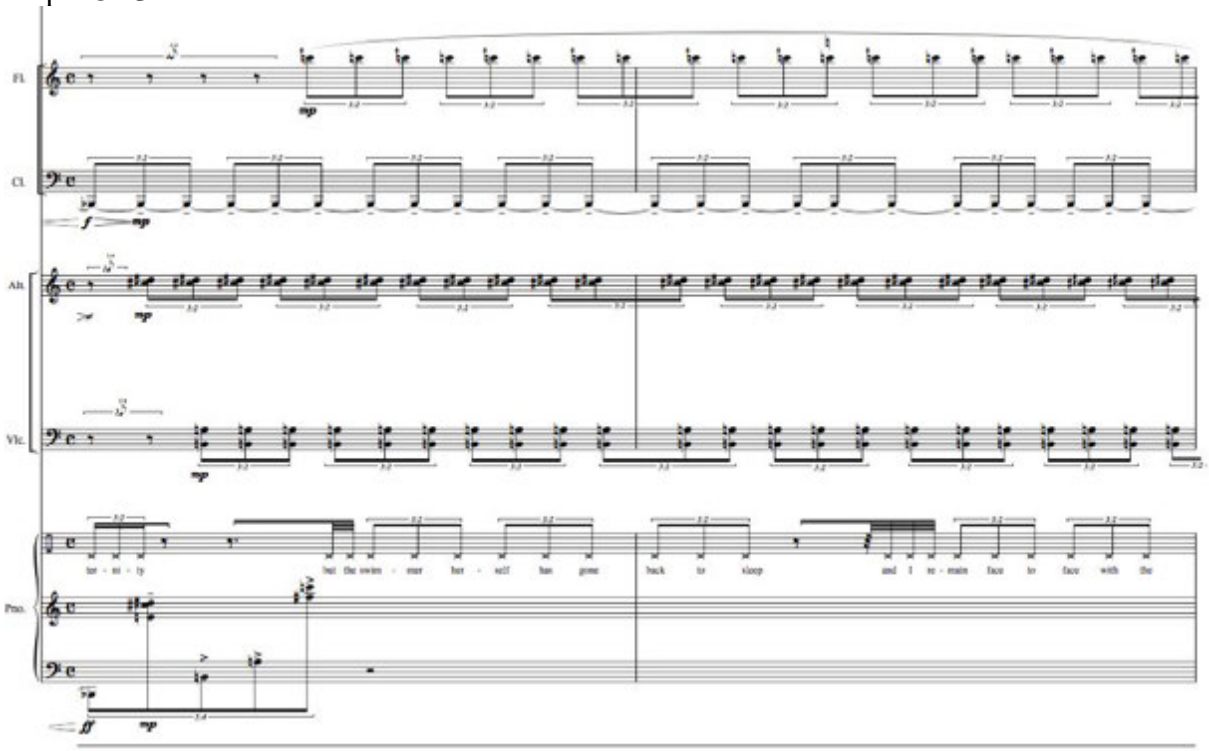

Figure 12 Tzortzis, Emak Bakia, mes. 143-144

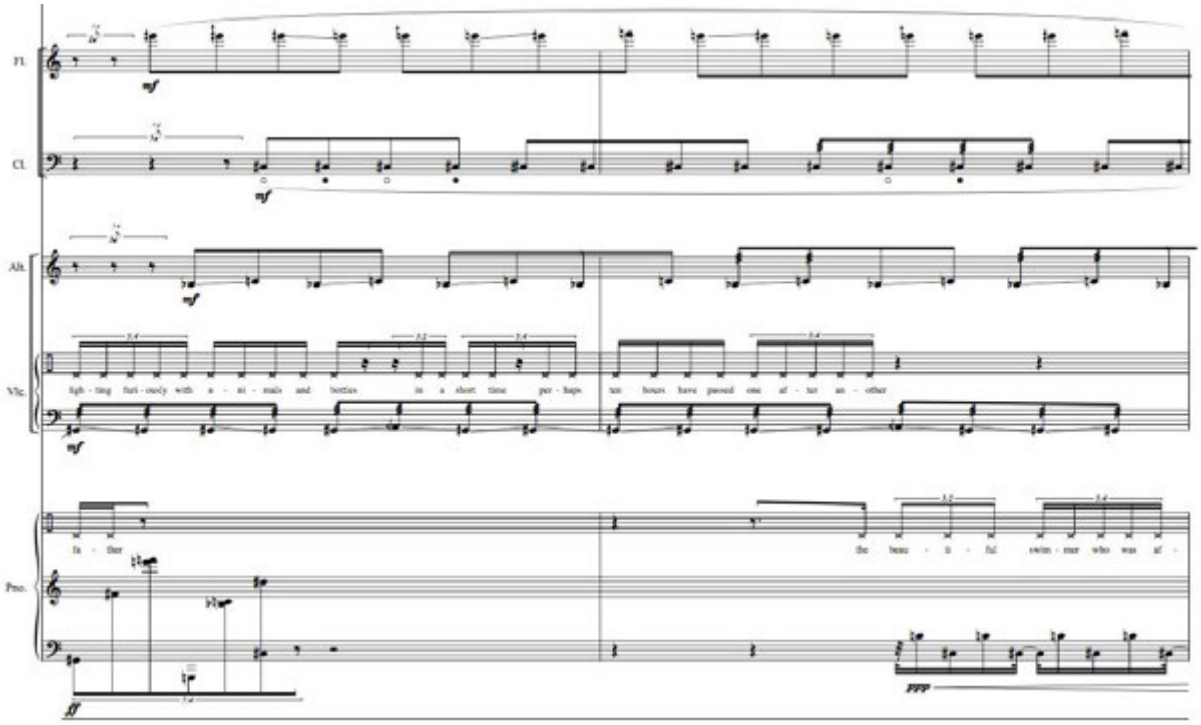

Figure 13 Emak Bakia, mes. 151-152

Later on in the piece (mes. 180), the echoing lines are blended with the logic of the arborescences, the former morphing into the latter, again incorporating the broken tuplets within a xenakian logic of ever-evolving densities. This particular moment thus sees two quite xenakian textures from different periods of his work blend into one.

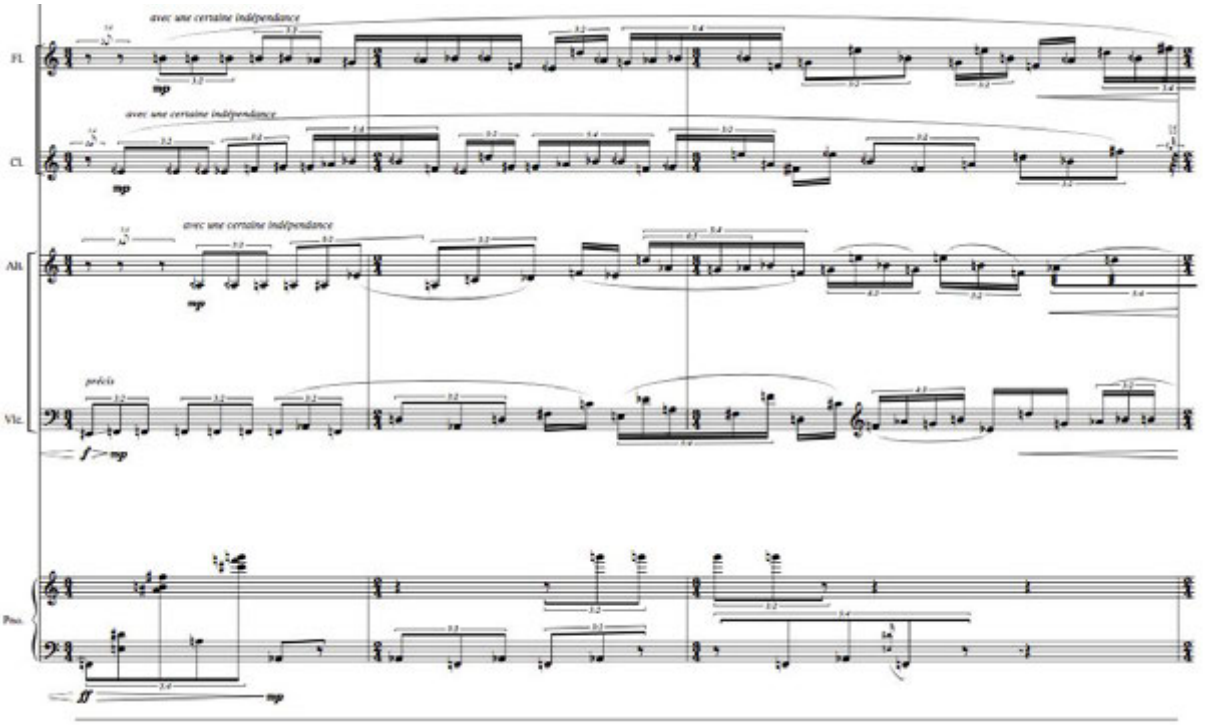

Figure 14 Emak Bakia, mes 189-190

The farthest I have taken this logic so far is to be found in my piano concerto "*Contre tous, hommage à Nikos Galis*", a work once again written for pianist Pavlos Antoniadis. Up until that point, the wyschnegradskian logic of "any number of units within the space of any other number of units" always referred to integer denominators. In the following two examples, this logic is broken and the denominator is the sum of an integer and a fraction:

In the first case, we have a group of ten 32nd notes in the space of six 32nd notes plus four 32nd notes of a quintuplet, and in the second case we have a group of seven 32nd notes in the space of four 32nd notes of a quintuplet, plus two 32nd notes.

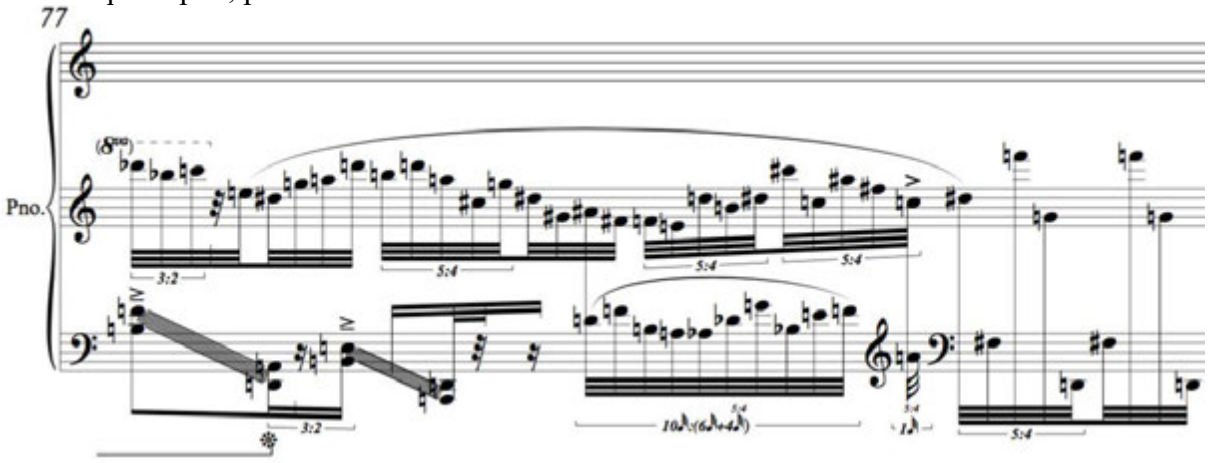

Figure 15 Tzortzis, Contre Tous, m. 77

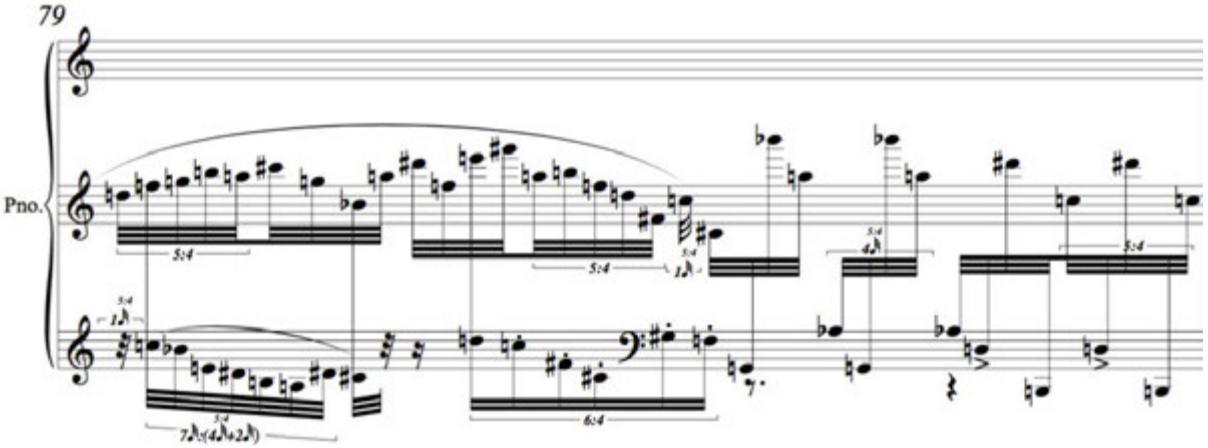

Figure 16 Contre Tous, m. 79

This could be the next step of the xenakian/wyschnegradskian logic, where literally any space between two given points in time could be the container for another group. This way, the notion of interdependent lines becomes even more relevant, since in this particular case it's not only the starting point of a line that is dependant on another line, but also the end, taking the idea of a music that self-regulates even further.

In my logic, and this is where I distance myself from the new complexity school and in particular Brian Ferneyhough, the rhythmic writing must allow, even encourage and facilitate the communication between the different layers, and not be thought of only as materials without any relation to each other, as is often the case in the music of the British composer.

3.4 Criticism on the new complexity: Ferneyhough, Finnissy, Mahnkopf,C ox

The rhythmic writing of Brian Ferneyhough and the new complexity school (Michael Finnissy, Claus-Steffen Mahnkopf and Frank Cox, among others), was another point of departure for me, as it contains certain characteristics that I wanted to question in "*Incompatible(s) V*", in particular the technique of nested tuplets, suggesting my own point of view on this issue.

Following the previous logic and how, in xenakian writing, the junction points of rhythmic groups are always on a sixteenth-note grid, I looked at works of the new complexity (focusing on works for solo piano, Brian Ferneyhough's "*Lemma-Icon-Epigram*" and "*Opus Contra Naturam*", Claus-Steffen Mankopf's complete piano works, Michael Finnissy's "*English Country Tunes*" and Frank Cox's "*Doubles*") to see if they provide a solution to this problem.

In spite of a very precise notation that is full of multiple indications, and even if this musical situation is present in some cases, the notation remains, only in this specific case, imprecise and approximate. Let's take a look at a few examples first:
In this sequence, we see that the beginning of the first passage of the bottom staff is synchronized with notes inside a figure in the top staff. Yet, for this to happen, this entire sequence is under the same bracket, first a 3:2 ratio, and then a 21:17, which, contrary to appearances, makes the logic the same with Xenakis', except that here the grid is defined in relation to the rhythmic ratio that dominates the measure, that could also be understood as a tempo change.

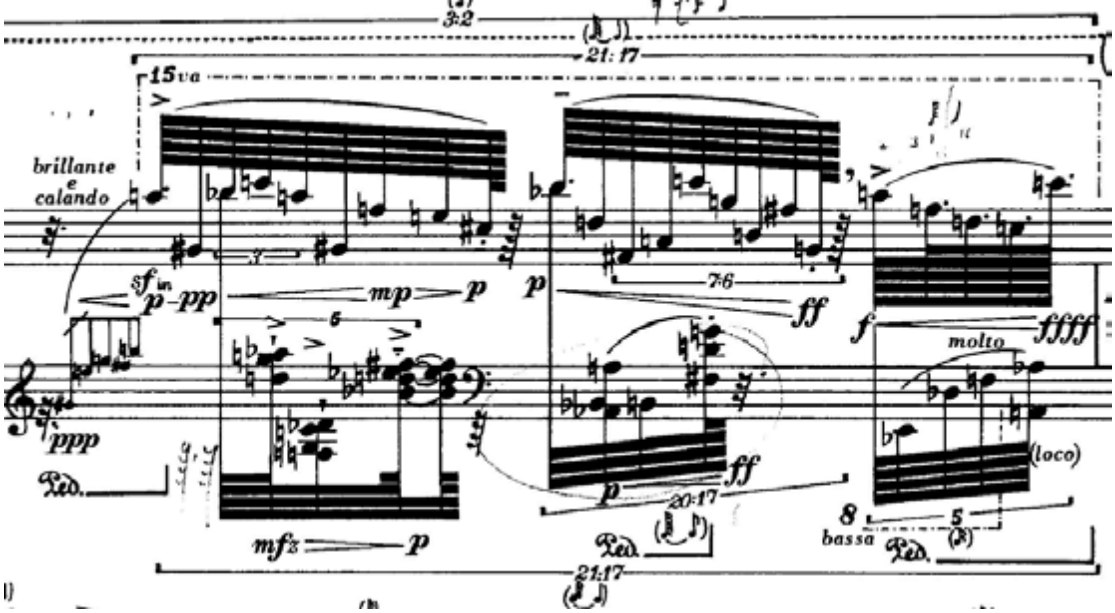

Figure 17 Brian Ferneyhough, Lemma-Icon-Epigram, page 9

Claus-Steffen Mahnkopf's "Kammerstück" offers similar short sequences, except that, here too, it is a writing that does not solve the problem of independent groups, even though the score could visually suggest otherwise. In the following example, the groups of 5:3 and the following triplet in the lower staff seem to be independent, except that they actually belong to the upper septuplet. Everything is once again subject to a logic of hierarchy, where everything must be expressed in relation to this hierarchy and can only exist under its umbrella. In "*Incompatible(s) V*", one of the issues was indeed to question this hierarchical "oppression" and to free the rhythmic writing from it, thus serving the idea of autonomy.

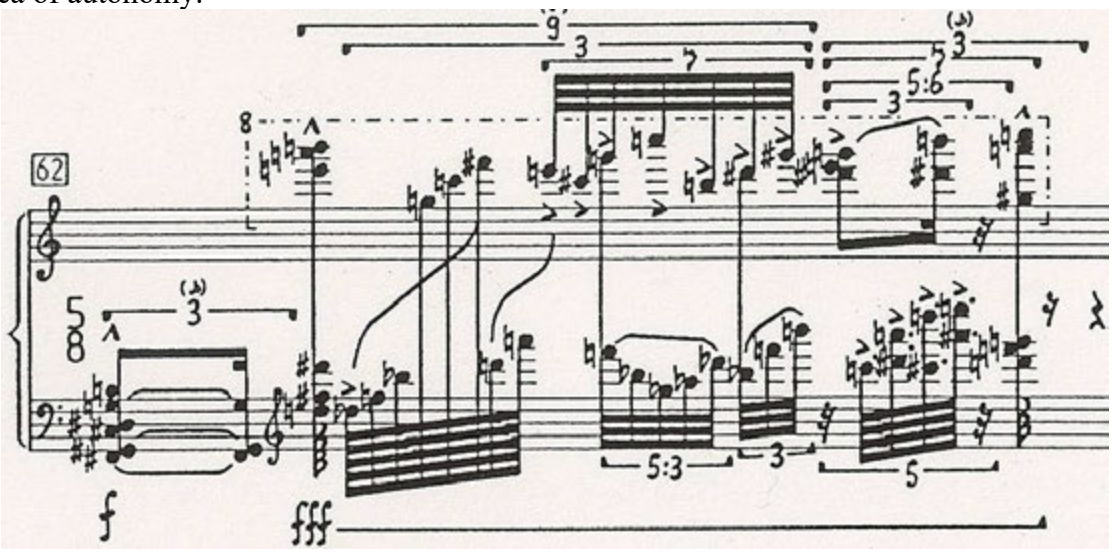

Figure 18 Claus-Steffen Mahnkopf, Kammerstück, m.62

However, having an independent line that starts within a tuplet is not something foreign to the musical logic of the new complexity except that in this case the notation becomes inaccurate, breaking away from the logic of absolute precision.
In the following example, we see figures that emerge from within a rhythmic group, but, contrary to Ferneyhough's usual writing style, these figures are notated in small notes, whereas they could have been written in a precise manner, like the rest, without being subjected to the predominant hierarchy and thus amplifying their independent character, as the presence of the small notes and the different articulation suggest. Even more striking is the fact that these rapid passages appear very briefly and without a specific end point, as if they were figures outside the discourse, whereas such a logic could have been exploited more, following the polyphonic and complex nature of Ferneyhough's music.

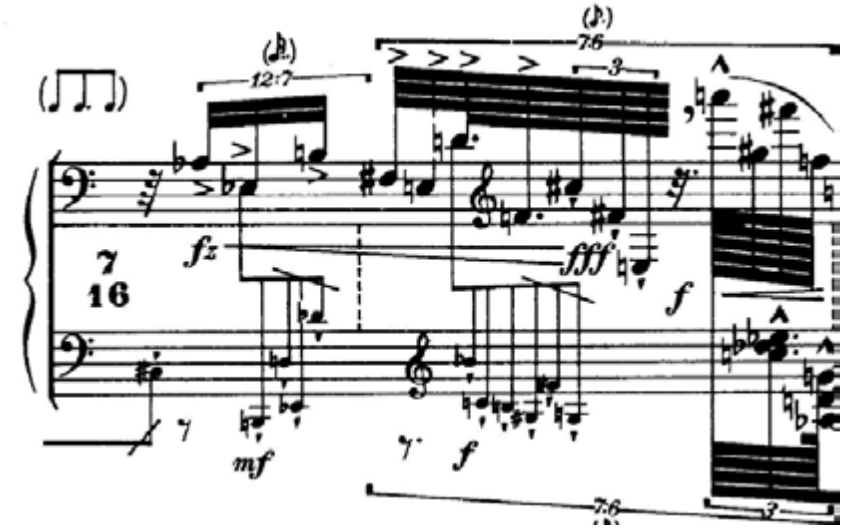

Figure 19 Lemma-Icon-Epigram, p. 5

Another, even clearer example is found in Michael Finnissy's "*English Country Tunes*". The lines that come out of a rhythmic group are, in a way "out of time", always played as fast as possible, when they could have been also approached otherwise. It is interesting to see composers, who have pushed the limit of what is legible and playable to the maximum, not writing something that would be absolutely compatible with their logic and their research on rhythm and, from a more general point of view, on writing itself. Perhaps the logic of the hierarchy and of the nested tuplets did not yet allow for its combination with another logic, in order to allow more freedom.

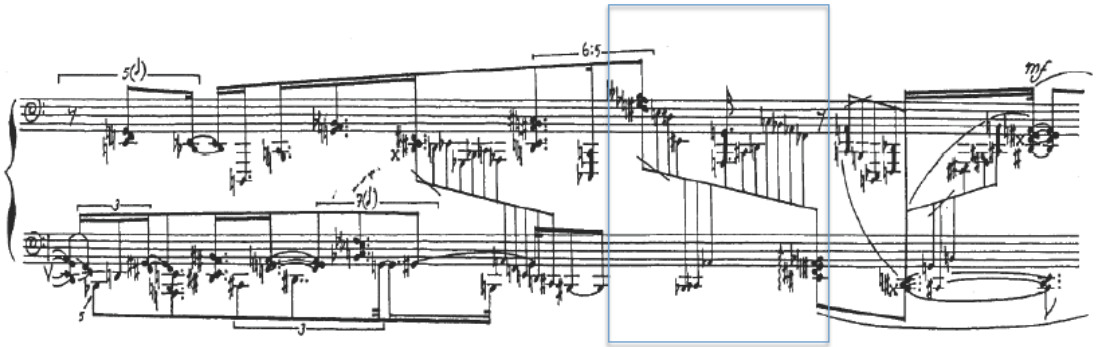

Figure 20 Michael Finnissy, English Country Tunes, p. 39

Staying on the question of hierarchy, one often sees, in Ferneyhough, a whole bar unfolding under a long tuplet, even in solo pieces. I say "even in solo pieces" because, in a chamber music piece, one can imagine why an instrument would have such a passage to play in order to change tempo locally, allowing every instrument to function separately, without asking the conductor to beat multiple tempi at once. For a soloist, this writing seems to complicate the music for no apparent reason. I will not get into the debate of why Ferneyhough decided to write it this way, this is not the purpose of this text, but what interests me is to demonstrate this approach and show where I decided to distance

myself from it. Here are some examples of "*Opus Contra Naturam*", for speaking pianist, a work that is part of the opera "*Shadowtime*":

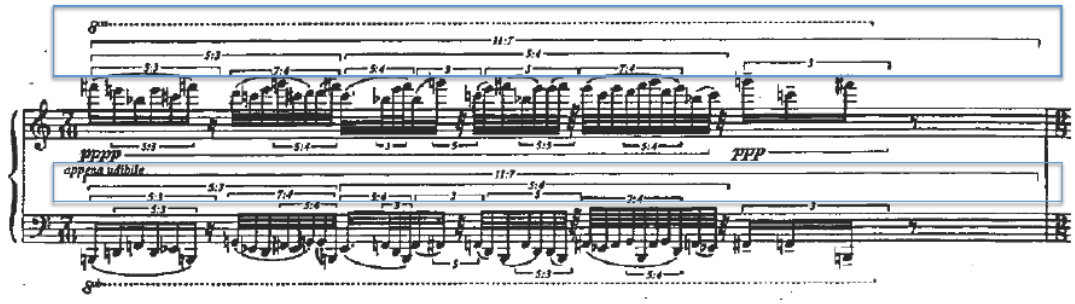

Figure 21 Ferneyhough, Opus Contra Naturam, m.1

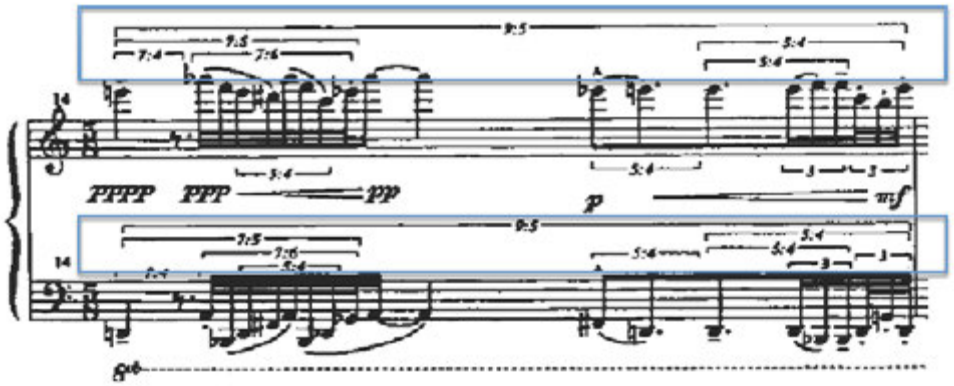

Figure 22 Opus Contra Naturam, m. 14

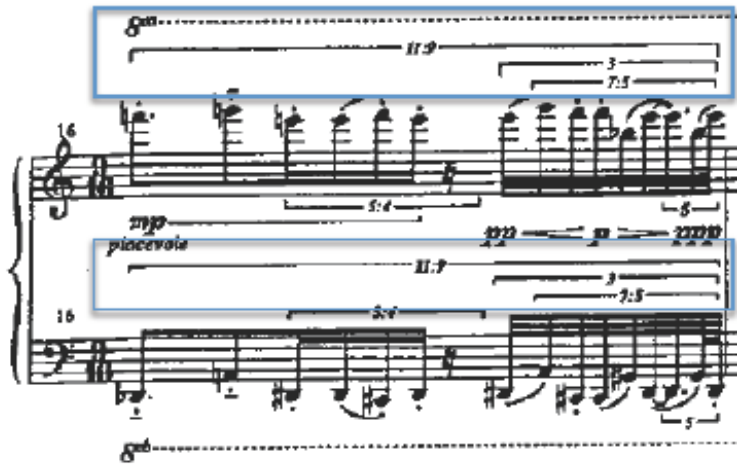

Figure 23 Opus Contra Naturam, m. 16

There are even two consecutive measures under the same ratio, a 5:3, something that could easily be understood as a tempo change:

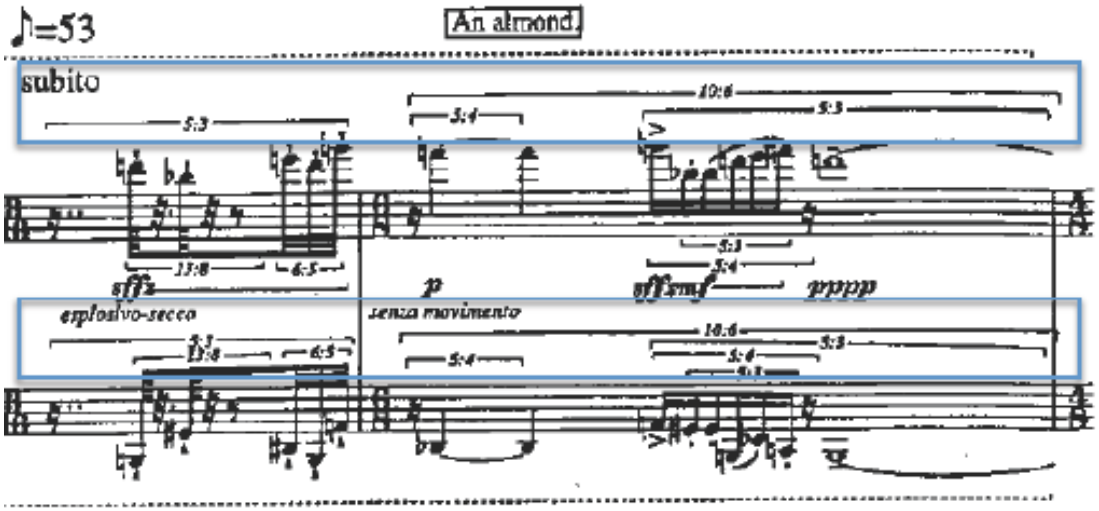

Figure 24 Opus Contra Naturam, m. 17-18

In a piece where the tempo changes very frequently, even after each measure, and that very often has irrational values, one can ask the question why opt for this type of writing and not for a lighter notation, which would perfectly respect the written values, but would not require the performer to do a long and tedious work of simplification, changing the temp and eliminating the unnecessary groups, which is common practice amongst musicians. Finally, the question that emerges more precisely is "why write something in one way when another way would be equally precise but more efficient?" It would not be a matter of changing the identity of the music, nor of over-simplifying it, but of opting for a notation that could not be written otherwise.
Going back to "*Incompatible(s) V*", in the following example, we see five rhythmic layers evolving independently and each in its own way:

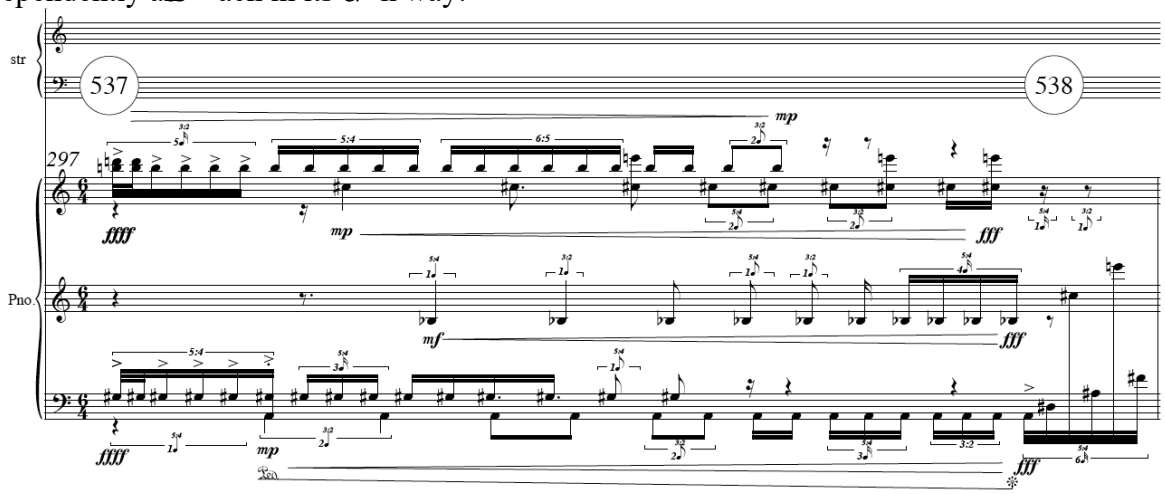

Figure 25 Incompatible(s) V, version 1.2 m. 297

The degree of complexity is very high, but it is a writing that allows a great deal of freedom within the bar and each line separately, each value is shown for what it is, and no conversion is necessary to understand the duration of each note.
Another example:

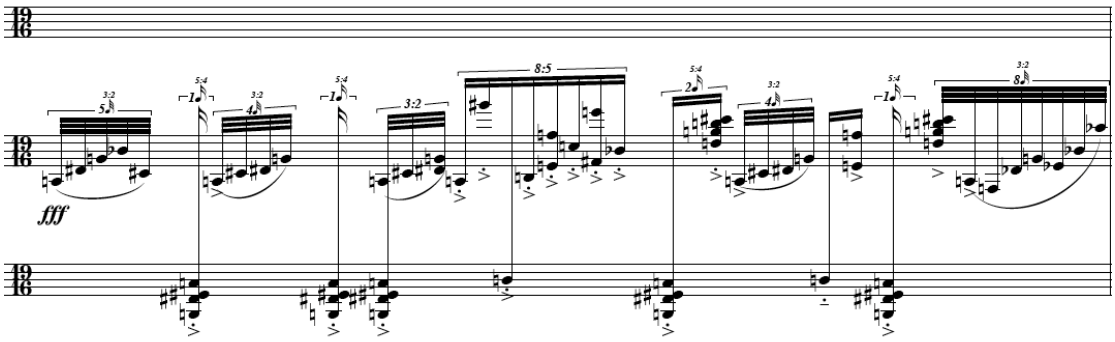

Figure 26 Incompatible(s) V, version 1.2, m. 271

In this measure, we have four rhythmic values: triplet 8th notes, quintuplet 8th notes, 8:5 16th notes, normal 16th notes.

Each of these values, and the figures associated with them, goes beyond its common use and becomes almost an object, dissociated from its peers: we see groups of five, four or even eight triplet 32nd notes, quintuplet 16th notes played one by one, freed from the obligation to exist in groups of five. It is, in fact, a 19/16 measure that could be summarized as a set of irrational measures as follows:

5/48, 1/20, 4/48, 1/20, 6/16, 2/20, 4/48, 2/16, 8/48

In this precise context, where the writing is basically monophonic, one could have opted for this notation, even if I find it too fragmentary and breaking the global gesture and the directionality of the music. This notation, present in Ferneyhough, has been widely used by Frank Cox, cellist, composer and new complexity theorist.

In his piece "Doubles", for piano and tape, Frank Cox takes this irrational measure writing to its limit. The problem with this writing is, among other things, that it quickly becomes unreadable, as can be seen in the following examples:

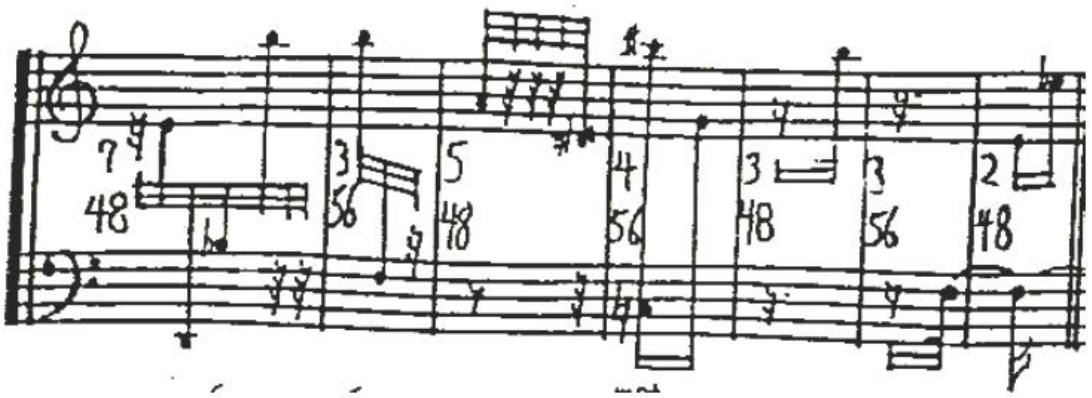

Figure 27 Frank Cox, Doubles, ex. 1

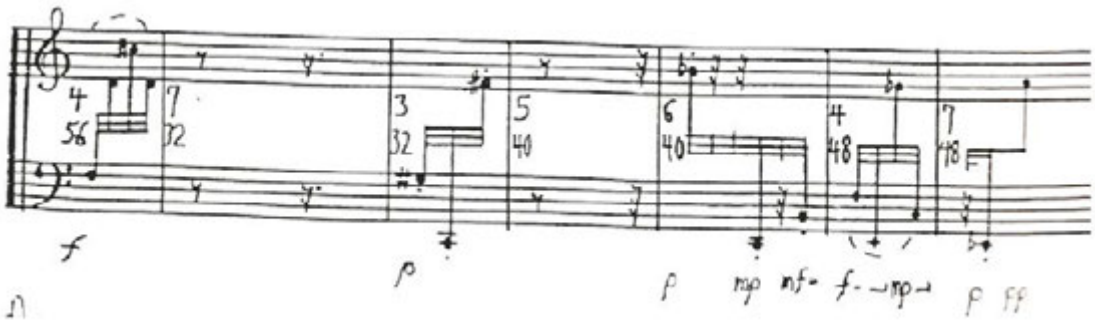

Figure 28 Frank Cox, Doubles, ex. 2

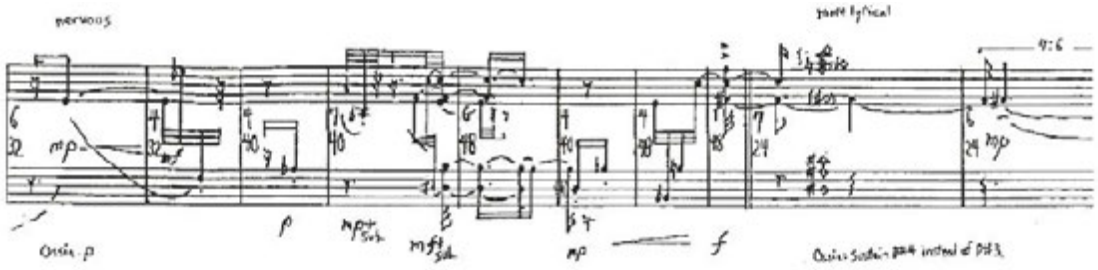

Figure 29 Doubles, ex. 3

Apart from the considerable task of constantly having to keep in mind that 1/8 is a triplet 32nd note or that 1/56 is a septuplet 32nd note, the problem with this writing is that it does not allow polyphony, because such short measures do not allow other, longer layers to exist.

In "*Incompatible(s) V*", Cox's logic is ever present, but the writing allows the presence of virtual irrational polymetries, in simple measures such as a 3/4. The motivic logic and the speed micro-variations of a cell can coexist with other layers, other temporalities and even allow them to go beyond the bar line, if necessary, if they do not fit into the given "box".

The following examples clearly show how some staves follow the logic of irrational time signatures, while others follow a different logic:

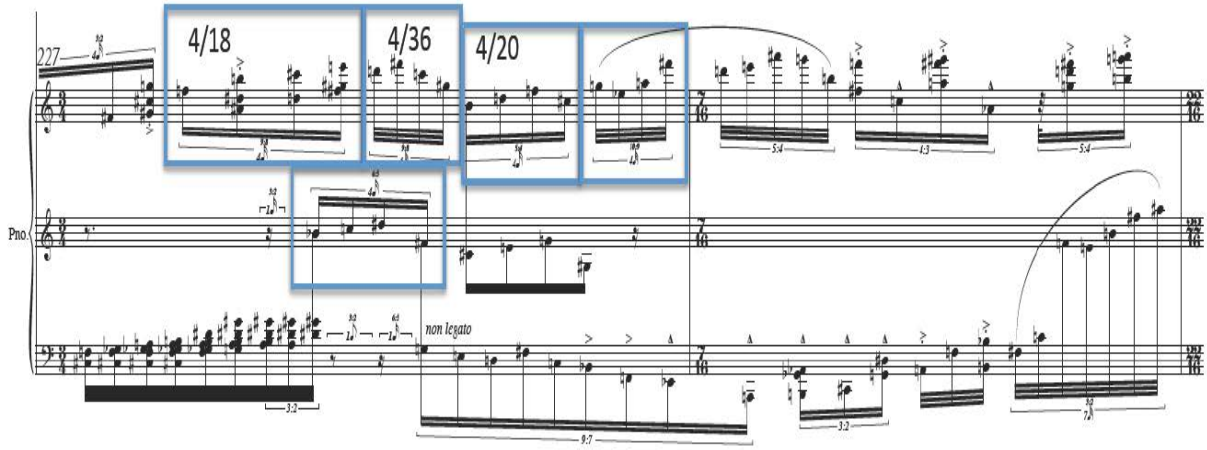

Figure 30 Incompatible(s) V, version 1.1, m. 227

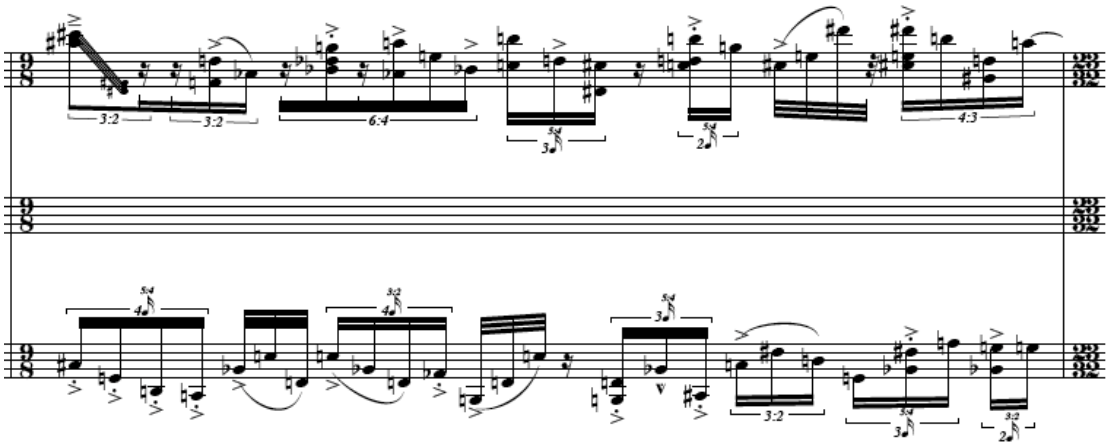

Figure 31 Incompatible(s) V, version 2.1, m. 238

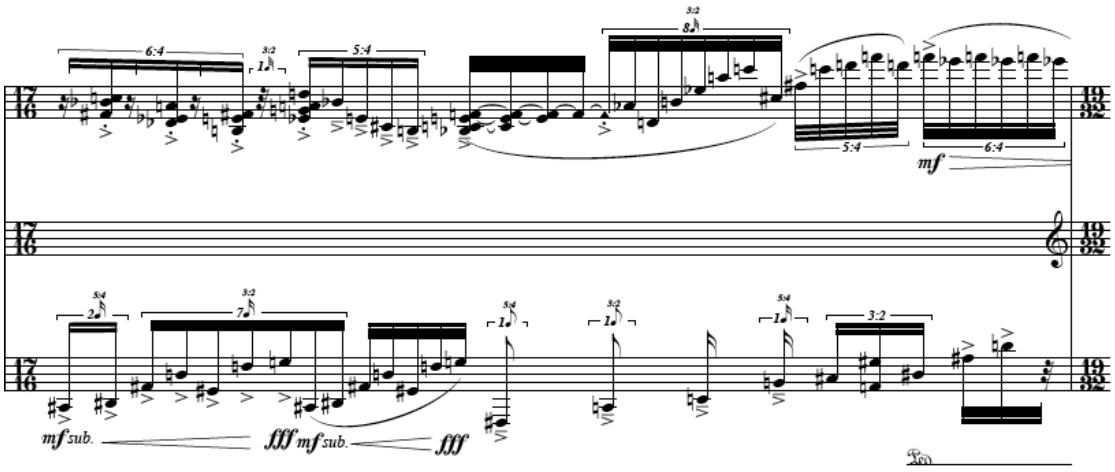

Figure 32 Incompatible(s) V, version 2.1, m. 255

Another problem that exists in Frank Cox's logic is that only rational rhythms can be used, i.e. rhythms that can be expressed in relation to the whole note, 1/48, 1/20, 1/10, 1/24 etc. being all exact subdivisions of a 4/4 measure. Therefore, a group of four 16th notes of a 7:5 group or a 6:5 group or a 9:7 group etc. cannot be written using this notation, whereas, in the logic of "*Incompatible(s) V*", even irrational rhythms are available for any kind of manipulation.

In this example, apart from the polyrhythm which would already be a problem for irrational measure notation, even the left hand would be impossible to write down. One would have to write 7/8 - 2/16 - then a measure of 7/8 doubles of a 6:5 in "*Doubles*", Frank Cox envisages this scenario.

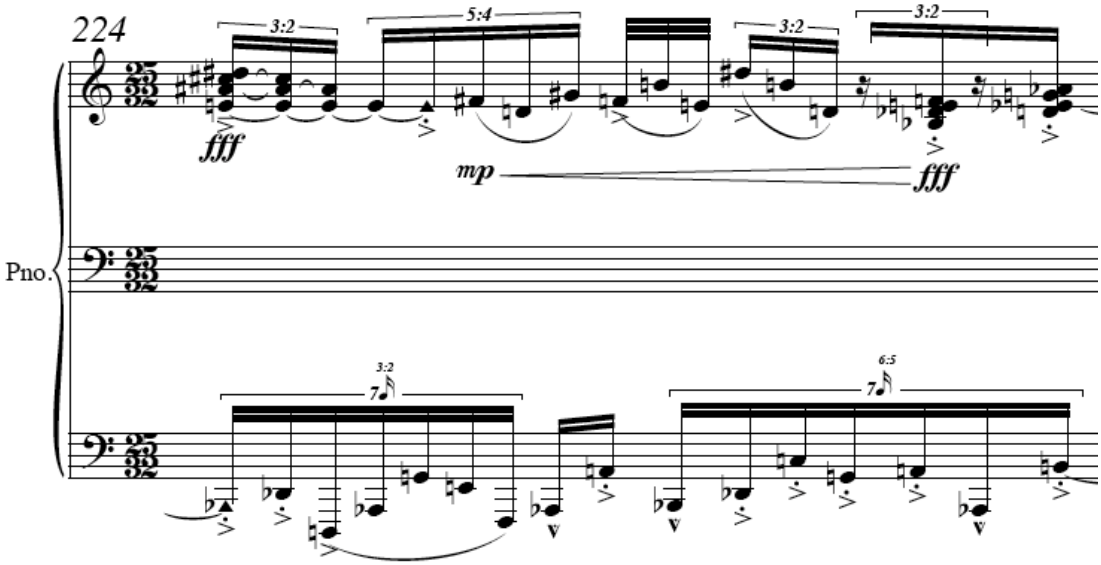

Figure 33 Incompatible(s) V, version 2.1, m. 224

The "broken" tuplets brought forth by "*Incompatible(s) V*", "*Digression*", "*Emak Bakia*" and other works of mine, are present in too small a sample size, almost anecdotally in Ferneyhough and Mahnkopf, but in their case, apart from the fact that they are so rare that they risk going unnoticed, the other consideration is the notation chosen by the two composers, which I consider to be unclear, even confusing, contrary to their general approach to musical notation. Both composers write above each note the number that would correspond to its rhythmic value (3 for the triplet, 5 for the quintuplet), but it is only afterwards, at the end of the measure, that it is really explained, once the group is closed

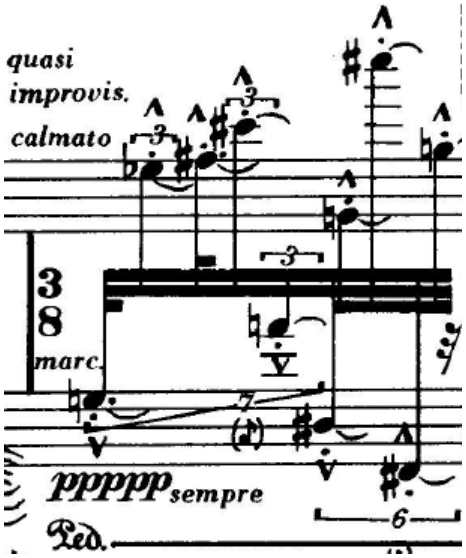

Figure 34 Lemma-Icon-Epigram, p.24

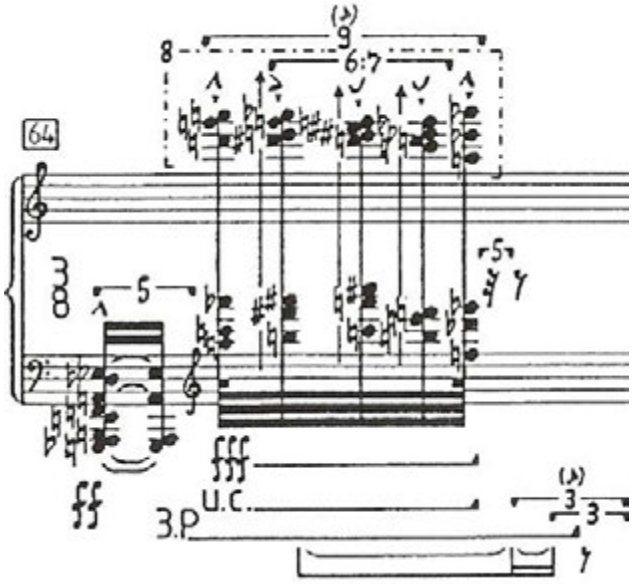

Figure 35 Kammerstück, p. 10

"*Incompatible(s) V*" uses a notation that seems more accurate to me, as each note/group immediately displays its exact value.
More precisely:
Each irrational value (played note or silence), being part of a "broken" group is defined by three parameters: a bracket that shows the total duration on the score, a number that shows the quantity of values that are under this bracket, and finally the value in question. In this particular example, we find:

3:2
4 that means four triplet 32nd notes

5:4
3 that means three quintuplet 32nd notes

3:2
4 that means four triplet 16th notes

Elsewhere in the score one finds, namely,  four 16th notes of a 6:5 group,  seven 16th notes of a 9:8,  five 16th notes of a 9:7,  four 32nd notes of a 10:9 etc. Each different speed can function independently and could even say that this approach is basically emancipating the different ratios, and rhythm in general, from their usual syntax.

First by its precision and its clarity, then by its flexibility, this approach to rhythm allows things that pre-existing writing did not: a) the communication between the different layers, and this at any point for any rhythm, b) the extreme rhythmic breakdown, without disadvantaging polyphonic writing, and c) the virtual polymetric writing with local tempo changes, pushing the xenakian logic towards its outer limits.

4. Conclusion

All of the afore-mentioned thoughts on rhythm, and their subsequent applications within works of mine from 2011 to 2017, find their source in the works of Iannis Xenakis, especially the ones from the mid 1970s, and would have been unthinkable, had it not been for his innovations on the subject. Having recently discovered the theoretical writings of Ivan Wyschnegradsky, I claim one could draw some parallels between the two men's approach to rhythm and I think that this relation would be worth further studying, in order to comprehend how deep this connection actually was.

I believe that my own contribution can act as an expansion of Xenakis' thinking, taking the idea where it was meant to go all along. The new approach and the tools developed for the realization of "*Incompatible(s) V*" and the pieces that followed could allow composers to rethink the possibilities offered by the arborescences, liberate the individual lines from the hierarchy of the time signature and create complexities that are much more efficient in the way they are conceived and presented

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Site-specificity and Sonic Grains : An approach to sound synthesis by mapping point clouds of a specific site using granular synthesis techniques.

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Abstract

In this paper we investigate the creation of sound by mapping point clouds of a specific site into parameters used in granular sound synthesis. Our hypothesis it that such point clouds can be used as the input clouds for granular synthesis in order to create complex sounds. Based on the Asynchronous Granular Synthesis method (AGS) as it was described by Curtis Roads in his introduction to granular synthesis, and on Xenakis' pioneering concepts involving granular synthesis, we employ a series of steps for mapping spatial parameters into sound. These steps involve the direct parametrisation of spatial to sonic attributes, as well as theoretical ideas based on the concept of screens by Xenakis, in the form of a thought experiment.

Granular sound synthesis spans several decades of formalisation and use in sound synthesis and electronic music composition. It is based on the concept of treating sound as having a quasi-quantum identity, a grain or particle defined by certain properties. Dating back to scientist Isaac Beeckman and through time to physicist Dennis Gabor and mathematician Norbert Wiener (Roads 1996, 168-169), composers developed various granular sound synthesis methods and tools. Iannis Xenakis extended the application of this concept to sound composition on the micro and macro scales, with Curtis Roads and Barry Truax making very significant contributions to this synthesis method thereafter, among many others. Point clouds are collections of data points in space, which are usually produced by 3D scanners or photogrammetry tools. Each point of the cloud has a unique set of 6 parameters: x, y, z for its location and R,G,B for its color.

The data set is taken from the former Archaeological Museum of Chania using Structure from Motion techniques and has been edited in CloudCompare. Part of the data was processed using Mathematica. Some initial sound experiments were performed in the granular synthesis engine of Symbolic Kyma, through which we gained further insight into the parametrisation.

By elaborating this methodology, we aim to initiate a research process linking space and sound that functions in a twofold way: on the one hand, it appends an attribute to sound synthesis that may be valuable to composers in the compositional process at the microlevel. On the other hand, setting the ground for creating a new mapping tool for designers and architects, that could enable them to perceive spatial aesthetic characteristics

of a specific site in a new way; Transposing granular synthesis from the field of space into the field of sound, might be seen as an attempt to distill sound or space into its core grains and then identify their affiliations on a micro scale.

1. Introduction

Fascinated by the concept of grains, which has permeated many fields of research, such as information theory (Moles,1968), architecture (Jakovich, 2007), cosmology (Rovelli, 2016) and music (Miranda, 1995) for several decades, we investigated the relationship of space and sound through the mapping of point clouds to sound, via granular synthesis techniques. Our methodology proposes a mapping from the spatial to the sonic domain at the microlevel, based on an amalgam of existing granular synthesis methods and concepts, aiming to expand this transformation on a creative level. It involves the treatment of point clouds of a specific site as the grain clouds that are used in the sound synthesis. The data points were organized as clouds consisting of different numbers of grains. The various clouds of grains were utilized in our experiment in a twofold manner : first, they were defined in terms of the basic parameters of duration, grain duration, density of grains, bandwidth of the cloud, amplitude envelope of the cloud, and waveform within the grains, as they are described in the Asynchronous Granular Synthesis model by Roads (1996, 176-178). Secondly, in an initial thought experiment, we treated the point cloud data set as screens, as a means of visualizing our data on the frequency-intensity plane, and further considering other possible implications and conceptions with respect to sound and space. In AGS, each point in the input cloud is a sonic grain, with its tone color being determined by its frequency and waveform (Roads 1991, 146-185). In our mapping, we proposed that the grain frequency consisted of three frequencies based on the y values multiplied by the scaled RGB values. The bandwidth was defined by the extreme values of the RGB counts, the amplitude (intensity) was determined by the z-values and the overall duration of the cloud by the x-values. The grain duration was kept constant at this stage of our research, although we experimented with durations of 10, 20 and 50ms and the waveform within the grain was sinusoidal. According to Xenakis' formulation, screens consist of elemental rectangles $\Delta F \Delta G$ in a slice of time Δt , in which the grains create a density unique to each elemental rectangle, employing the parameters of frequency, intensity and grain density (1992,50-56). Additionally we explored the parameters of frequency jitter and grain duration jitter, which were part of the granular synthesis engine of Kyma which we used to experiment with our parametrization and gain a hands-on experience.

2. Related work

2.1 Xenakis addressed musical issues and problems by applying operations of abstraction which led to the formulation of new concepts, and some of these concepts (such as density, determinism-indeterminism, continuity-discontinuity, etc.) belong to the sciences (Solomos, 2004). Among many groundbreaking conceptions relating music, mathematics and philosophical thought, he has been credited with applying the concept of grains in music composition, postulating that "all sound, even all continuous sonic variation, is conceived as an assemblage of a large number of elementary grains adequately disposed in time" (1992,43). In his treatment of granular sound synthesis there was a link between algorithmic processes and creating sound (Georgaki, 2005). His experimentations with granular synthesis and granulation made with magnetic tape in his works *Analogique B* and *Concrete PH*, were followed by experimentations and explorations in the digital realm by Curtis Roads and Barry Truax (Thomson, 2004). In 1978, Curtis Roads, developed a model of "scattering grains into sound clouds, based on Xenakis' theory of granular synthesis (Roads, 2012). About a decade later, Barry Truax contributed with a "real-time implementation of granular synthesis and signal processing" (Truax, 1988). Granular synthesis has been employed in a plethora of research projects involving data sonification in 3D sound spatialization settings, such as the spatial encoding of individual grains (Deleflie, 2009) in a granular model multidimensional spatial sonification [Wan Rossli,2015], in designing an interface based on a technique which uses images as spatial sound maps

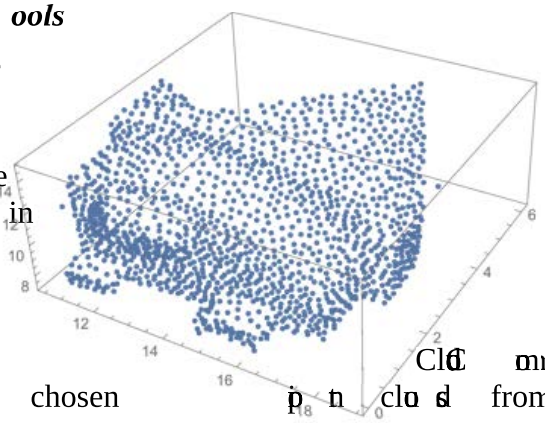
(Delelfie, 2010) among many. Point clouds are data sets representing objects in space. They can be produced by various techniques and tools, most often generated using either laser 3D scanners and Lidar technology or photogrammetry. Each technique has its own advantages and weaknesses, laser scanners usually offer higher accuracy but photogrammetry on the other hand offers color capturing for each point in space, resulting to colored point clouds. In this research color information was crucial in order to include the sense of materiality into our mapping to granular sound synthesis parameters. More specifically, a large number of photos properly shot were utilized following the Structure from Motion (SfM) technique in order to produce different point clouds.

3.1 Data set

The data set consisted of point clouds taken from the former Archaeological museum in Chania using Structure from Motion techniques and has been edited in CloudCompare. Out of this massive data set we chose to focus on a small part of the Museum and its corresponding values, by exporting 40 points (fig.1a, 1b). For each point in the data set there was a unique set of six values : x, y, z and RGB, extracting the data set to ASCII and converting to cvs. In order to utilize this data set and the chosen tools effectively for the purposes of our experiment (see 2.2), we had to choose suitable scaling for the x,y,z -values as well as for the RBG (see. 3a and 3b). Also, for simplicity purposes, the grouping of the data points into clouds was sequential in the data list, so it was not possible to have a pronounced relationship between the data points and the image they represented in relation to original image.

3.2 Tools

The point clouds were edited in CloudCompare. The chosen point clouds from the



dataset were then fed into small blocks of code in Mathematica, with each block performing a certain operation and producing the corresponding results, in the form of lists, tables and graphs. The granular synthesis engine of Symbolic Kyma was used to test various aspects of our parametrization and produce sound.

4. Methodology-Implementation

Granular sound synthesis involves the use of grains of sound of the order of 10-50ms employing high densities of grains which demand computational power. The function of granular synthesis occurs at two levels: at the grain level and at the cloud level (Roads, 1988). The particular suitability of granular synthesis in representing sound lies in the fact that it combines time-domain information with frequency-domain information, as opposed to methods using samples, or employing Fourier synthesis methods (Roads 1991, 145). Initially, we specified the clouds in reference to the parameters described in the AGS model by Curtis Roads. Our main premise was that the input clouds consisted of grains which were the result of the direct mapping of the point clouds from the data set, whereby one grain was mapped to one cloud point. In the original AGS model, the grains are scattered

statistically over a specified duration in the frequency-time plane and, as already mentioned, high densities of hundreds to thousands are used in order to create complex sounds (Roads 1978,145). In making use of this model in this first experiment, we created a simplified version by creating different clouds with few, fixed grains, varying from 1 to 50. The parameters in our data set were x, y and z values, as well as R,G,B values for every point and. We plotted some of these clouds in Mathematica, in two dimensions. (fig.2a, 2b).

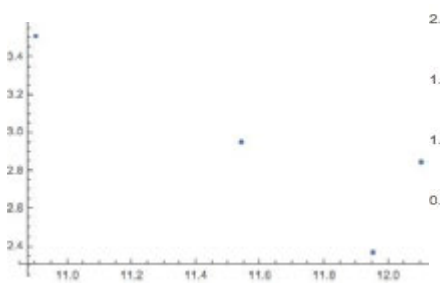


Figure 2a

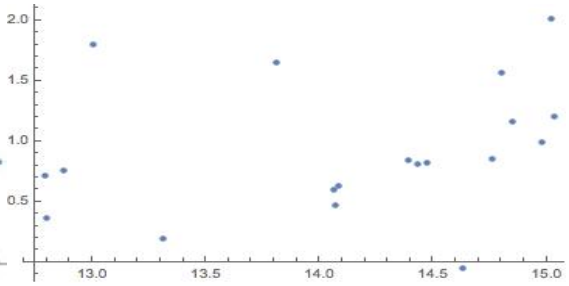


Figure 2b

The parameters involved in the sound synthesis were the cloud duration, the grain duration, the density of grains per second, the bandwidth of the cloud, the amplitude envelope of the cloud and the waveform within the grain , for synthetic grains (Roads, 1978). The parameter of spatial distribution was not relevant to our investigation at this stage. In the experimentation with Kyma, we tested the parametrization and we also expanded and defined some new parameters, since the engine uses a different system. Further, we explored the Xenakis' concept of Screens in terms of its possible application to our research, at a theoretical basis. "A screen is described by a set of clouds that are themselves a set of elemental rectangles ΔFΔG, which may or may not contain grains of sound in a slice of time Δt", where the density of grains per unit volume ΔFΔGΔT and the "elemental volume ΔFΔGΔTΔD" are new concepts (1992,56). If the elementary density is high enough then it is possible to have two grains overlapping, otherwise simultaneity is not possible (Xenakis, 1992). There were two main points of interest which drew our attention. The first was to utilize the concept of the graphical representation of grains on the two-dimensional Frequency-Intensity (FG) plane, with the approximation that Δt is constant or small enough, as also mentioned in Xenakis' theory, thus, treating each cloud that we constructed as a screen and visualizing a grid on the plane. The second point of interest useful to our research, was the one regarding the "topographic fixity of the grains on the screen" (1992,52). Xenakis reasoned that in order to allow for the creation of new timbres in electronic music one should allow for "mobility and the statistical distribution of grains around positions of equilibrium" (1992,51). In Xenakis' mind probabilistic laws were strictly connected with a quantum-oriented understanding of sound (Di Scipio, 2015). Taking this powerful conception under consideration in relation to the data of fixed points with fixed x, y, z and RGB values, we reasoned on the possible implications this application would have on the sounds produced, as well as on possible spatial (re)-transformation based on the created sounds.

4.1 Treatment of Data - Mapping

Out of the data set of 1400 points we constructed clouds consisting of 2 to 50 grains. The x axis was set to describe time, as a Xenakian influence in terms of how the interval between two points on a line, can be identical with the duration. (Xenakis 1992, 4). In our mapping, the two dimensional plot of the x and y points was treated as the time-frequency plane, the y and z points formed the frequency-amplitude (FG) plane (fig. 3a), with the overall three-dimensional plot of x, y and z points representing the time-frequency-amplitude respectively (fig. 3b).

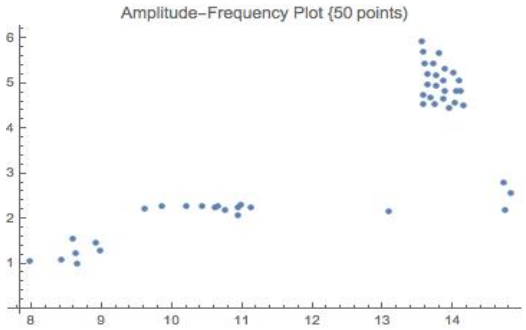


Figure 3a

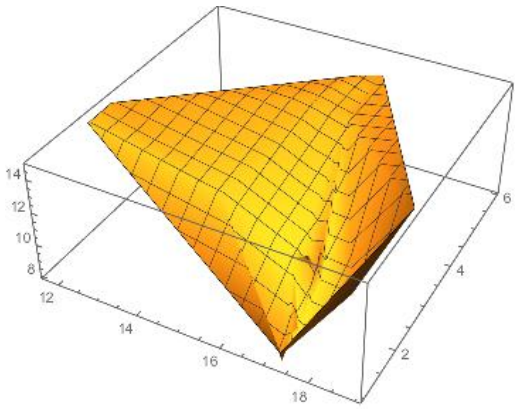


Figure 3b

The original RGB values were divided by 254 in order to obtain a scaling between 0 and 1, in two decimal places. In working out the frequency corresponding to each grain, we multiplied the y-value with each of the scaled R, G, and B values. The necessity to employ the unique color values for each point in determining the frequency content of the corresponding grain, led to this decision, resulting in obtaining three frequencies for each grain. A quick observation would then be that unless the RGB values were all equal to 1, each grain's frequency would consist of three sine waves having three different frequencies. In the table below, the corresponding frequencies for four random y-values are shown (table 1). The original RGB values were divided by 254 in order to obtain a scaling between 0 and 1, in two decimal places. The resulting value of the frequency was multiplied by 1000 to ensure it would be at a fair audible part of the spectrum.

y - value	R	Freq (R) [y*R*1000]	G	Freq (G) [y*G*1000]	B	Freq (B) [y*B*1000]	Bandwidth
1.69	0.5	**845**	0.4	**676**	0.3	**507**	507-845
0.83	0.52	**431.6**	0.41	**340.3**	0.35	**290.5**	290.5- 431.6
0.15	0.75	**112.5**	0.71	**106.5**	0.68	**102**	102-112.5
6.15	0.49	**3013.5**	0.39	**2398.5**	0.28	**1722**	1722- 3013.5
3.11	0.48	**1492.8**	0.39	**1212.9**	0.31	**964.1**	964.1-1492.8

Table 1: y-values and corresponding frequencies from RGB values

The RGB values were therefore treated as factors, by which a *fundamental* frequency (the y-value) was multiplied, as if producing different *harmonics.* Figure 4 shows a 3D plot where each grain has the colour resulting from the combined values of RGB. The grain duration was set constant to 10ms. The waveform within the grain was chosen to be a sine wave for simplicity purposes and the amplitude envelope for each cloud to follow a Gaussian distribution. The frequency bandwidth of the cloud was determined by the R and B values, the two outermost values for each point. The z-values determined the amplitude of each grain and defined the outer boundaries of the envelope of the cloud. The x-values were used to determine the duration and average density of the cloud by calculating an average number of clouds per second. Examples of such average densities of the grains per second were 7 grains/sec in the 50-point cloud, 5 grains/sec in the 30-point cloud, 3 grains/sec in the 2-point cloud, etc. In the context of this implementation the starting time of the cloud was not a relevant parameter.

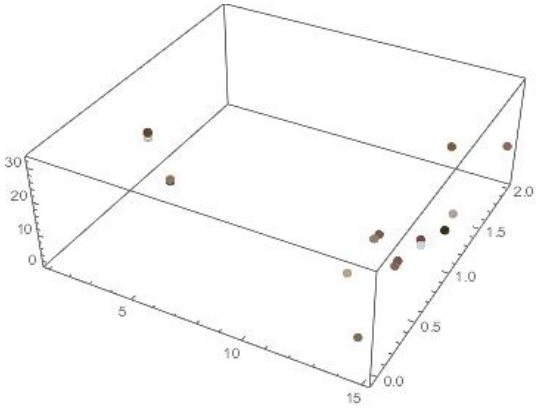
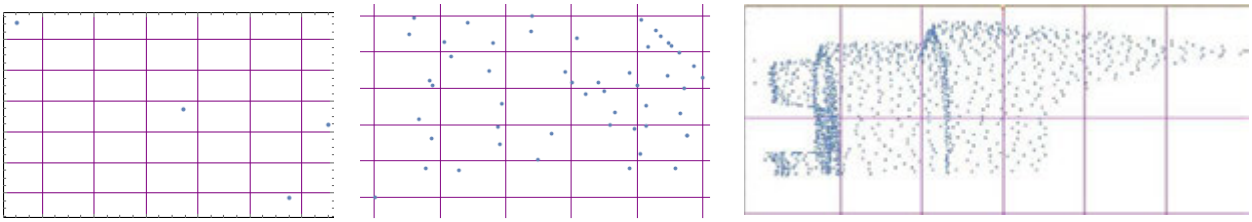


Figure 4

The same parameters, e.g. a sine waveform, a Gaussian envelope for each grain, the frequency of the oscillator were used in Kyma and the grain duration was set constant, experimenting with 10ms, 20ms, and 50ms. We also implemented the parameter of *frequency jitter*, which we defined as the ratio of the lowest to highest frequency for each grain, and the parameter *grain duration jitter*, which we defined as the cloud duration divided by the number of grains .In adopting elements from the theory of screens, we set up different clouds of grains on the FG plane, where each cloud or sets of clouds represented one sound. Alongside the examples presented by Xenakis, we set up a grid consisting of rectangles FG (figures 5a,5b,5c), depicting FG planes of 4 points, 50 points and the



400 points respectively. Xenakis, in calculating the elements ΔFΔGΔtΔG and posing the question of how the grains are distributed in this elemental volume, set the mean density of the grains equal to the number of grains per unit volume. Instead of working out a probability problem in four dimensions he proposed the calculation of each of the four coordinates independently according to laws of continuous probability and stochastic laws. (1992, 51). Following Xenakis' rationale even further we focused on one of the cells, ΔFΔGΔt, "which varies in time by fluctuating around a mean density d_m" and considering that these fluctuations exist, and given that the sound is long enough, they will obey the laws of chance (1992, 54). Going back to one of the cross sections of our point clouds ΔFΔG in a length of time, the probability that d grains would be found in the elemental volume ΔFΔGΔt would be calculated by Poisson's formula, considering that dm is small enough (1992, 54-

55). Although extensive calculations of this formula exceed the scope of this paper, we nevertheless experimented with a few small values for d_m in order to grasp a sense of its dimension (table 2).

d_m value	P(1)	P(2)	P(3)
1	0.37	0.19	0.12
2	0.27	0.27	0.18
3	0.15	0.23	0.23

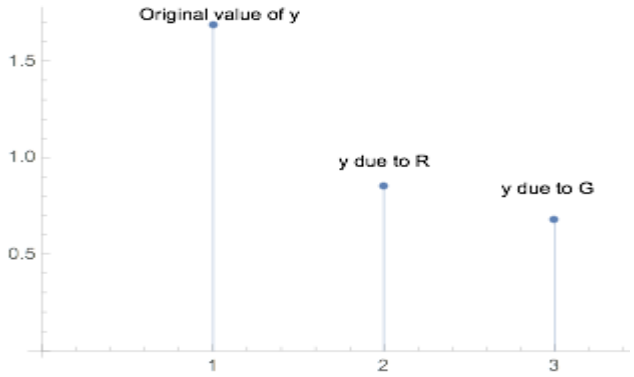
Table 2: Calculated Probabilities for Values of dm based on the Poisson Formula

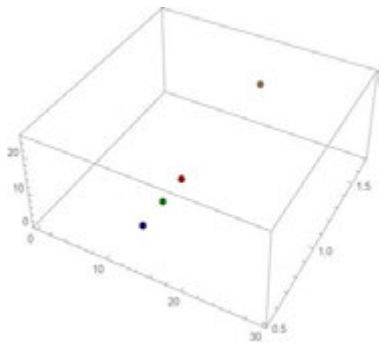
More importantly, we focused on a thought experiment on how the method of screens could allow for the transformation from the sonic medium back to the spatial. This involved the tessellation of the entire point cloud two-dimensional surface into elemental rectangles which have already been parametrised to synthesize sound. After an application of the laws of probability in terms of calculating the parameters of time, frequency, intensity and density we speculated that we would obtain a transformed list of parameters of our original data.

5. Results

We constructed clouds of predetermined number of grains (point clouds) from our data and treated them as input clouds of grains used in granular synthesis . Mapping fixed point clouds to granular synthesis parameters used in the Asynchronous Granular Synthesis model seemed somewhat of paradoxical nature, since the latter involves statistical processes and high-order implementation. However, the at this stage of our research it was important to retain a low level organization. We theorized on clouds consisting of 1, 2, 30, 50 and grains. We implemented a frequency mapping by using the y-values of each point multiplied by the R,G and B value, which proved to have interesting implications. The main consequence was that each point's frequency content consisted of 3 values, multiples of a "fundamental" frequency (original value of y) with the RGB factor, yielding different harmonics, or subharmonics. For RGB values where one color was only fully dominant, i.e. (1,0,0), (0,1,0) and (0,0,1), or all colors were fully dominant (1,1,1), the synthesized sound would be based on one frequency. Similarly, we deduced that if the RGB values were of the form (1, 0.5,0) or any other equivalent arrangement including 1 and 0.5, the resulting sound would include two frequencies which would be one octave apart. In this case the synthesized sound would include a strong harmonic relation of an octave. The same reasoning would apply for other numerical percentages corresponding to other partials in the harmonic series, or any other more consonant or dissonant collection of intervals. In the case of value a in table 3 for example, the lowest frequency value computed from Blue was the lowest, so it was treated as the fundamental. The ratio with frequency from Green was 0.75, corresponding to an interval of a perfect fourth and the ratio with frequency from Red was 0.6, very close to a perfect fifth. In our "variation" of the AGS model, using a very low, fixed numbers of grains in the input cloud, therefore not driven statistically, results in less sonic complexity. However, we value that this loss of complexity was, to an extent, compensated by the fact that we used three frequencies for each grain, as having the possible advantage of varying the grain duration as a function of the frequency (Roads 1991, 148), as in the example 4 in table 3 . This would also pave the way for creating a *polychrome* or *transchrome* as the *colour* of each grain, concepts defined by Roads (Roads 1991, 161). The main implication regarding space is that there would be three equivalent values of y, as a result of being "weighted" by the R,G,B factors. An image resembling that of a spectrum (fig. 6a) implies a spatial collection of values for every y-point. This, would agree with Xenakis' aforementioned concept regarding the topographic fixity of points, where the three different computed frequencies for every original frequency can be viewed as the

topographic fluctuations for each point, leading us to employ a more probabilistic spatial arrangement of the original data (3D plot, fig.6b).





As a step further, we could apply Poisson's probability law for small densities to this volume of points, as already computed above. On this important remark, it is worth pointing out that it was a logical choice to employ Xenakis' concepts of screens; on one hand, as a way of visualizing and projecting the data points in the F-G plane and then to hear the results exploring a meaningful application through the elemental volumes and stochastic processes of the data. In Kyma we experimented primarily with one point, by implementing a series of modifications in the grain density parameter, by setting it to a low fixed number and having 1 as the maximum number of grains which can play at one time and. For the simultaneous three sinusoids of (Table 3) we varied the grain density (0.1, 0.3 and 0.9 out of 1.0) and the grain duration (10ms, 20ms, 50ms). In 1a we got a more-crackling sound, where the frequency ratios were not particularly audible, once the density increased near mid-range the frequency content was more discernible with the cracking sound still there (1b), and for a very high density the granular texture disappeared, giving its place to a continuous sound bathed in the sonorities of perfect fourth and fifth (1c). In varying these parameters in 2 and 3, we observed that the most differentiated sound compared to the 10ms was the one with shortest grain density duration and that as the grain duration increased the granular texture disappeared, without noticing any significant changes in the frequency content, as expected. The parameters frequency and duration jitter in Kyma, provided an interesting ground for experimentation. We defined the frequency jitter as the ratio of the lower to the higher end of the frequency bandwidth, and the grain duration jitter as the difference in value on the x-axis from this point to the next divided by the number of points. The results can be heard in the examples below, where a frequency jitter of 0.6 /1.0 gives very pronounced randomness in frequencies (4a), whereas a grain duration jitter of 0.25/1.0 produces a flickering around the frequencies (4b). In the last examples, one can hear the combined effects of the two parameters (5a, 5b), whereas in 5c these parameters combined with a large density and short duration produce a noisier, dense texture. In extending to the spatial domain, these parameter jitters could be thought of as the randomness within the fixed values of the point, but extending to the other dimensions, i.e.. the x and z dimensions, therefore in a three dimensional space.

Example name	Sound File Link	Grain Density	Grain Duration	Frequency Jitter	Duration Jitter

1a	https://soundcloud.com/nicoleta-chatzopoulou/example-a/s-mdKExgvnswg?in=nicoleta-chatzopoulou/sets/kyma-paper//s-9oF9NsFY7C2	0.1/1.0	10 ms		
1b	https://soundcloud.com/nicoleta-chatzopoulou/example-b/s-uMjUqKDI8dU?in=nicoleta-chatzopoulou/sets/kyma-paper//s-9oF9NsFY7C2	0.1/1.0	10 ms		
1c	https://soundcloud.com/nicoleta-chatzopoulou/example-c/s-ukyp1ADbY6l?in=nicoleta-chatzopoulou/sets/kyma-paper/s-9oF9NsFY7C2&utm_source=clipboard&utm_medium=text&utm_campaign=social_sharing	0.1/1.0	10 ms		
2a	https://soundcloud.com/nicoleta-chatzopoulou/example-2a/s-Qv8VWxkZyYL?utm_source=clipboard&utm_medium=text&utm_campaign=social_sharing	0.1/1.0	20 ms		
2b	https://soundcloud.com/nicoleta-chatzopoulou/example-2b/s-RkBviZAtph4?utm_source=clipboard&utm_medium=text&utm_campaign=social_sharing	0.3/1.0	20 ms		
2c	https://soundcloud.com/nicoleta-chatzopoulou/example-2c/s-SFDSwTqNZ3e?utm_source=clipboard&utm_medium=text&utm_campaign=social_sharing	0.9/1.0	20 ms		
3a	https://soundcloud.com/nicoleta-chatzopoulou/example-3a/s-WgLCGi0uazl?utm_source=clipboard&utm_medium=text&utm_campaign=social_sharing	0.1/1.0	50 ms		
3b	https://soundcloud.com/nicoleta-chatzopoulou/example-3b/s-gSLUOMKF8hi?utm_source=clipboard&utm_medium=text&utm_campaign=social_sharing	0.1/1.0	50 ms		
3c	https://soundcloud.com/nicoleta-chatzopoulou/example-3c/s-Gs2D2FGw7df?utm_source=clipboard&utm_medium=text&utm_campaign=social_sharing	0.1/1.0	50 ms		
4	https://soundcloud.com/nicoleta-chatzopoulou/grain-dur-varying-with-freq/s-iAItL3mm2Va?utm_source=clipboard&utm_medium=text&utm_campaign=social_sharing	0.3/1.0	10ms (h. freq) 20ms (m. freq) 50ms (l. freq)		
5b	https://soundcloud.com/nicoleta-chatzopoulou/example4b-fjitter/s-zUTgzn8RRZV?utm_source=clipboard&utm_medium=text&utm_campaign=social_sharing	0.3/1.0	50 ms	0.6	
5bii	https://soundcloud.com/nicoleta-chatzopoulou/example4b-durjitter/s-uXCE8EBGpz0?utm_source=clipboard&utm_medium=text&utm_campaign=social_sharing	0.3/1.0	50 ms		0.25
5c	https://soundcloud.com/nicoleta-chatzopoulou/example4a-fd-jitter/s-MgLhJozprSP?utm_source=clipboard&utm_medium=text&utm_campaign=social_sharing	0.1/1.0	50 ms	0.6	0.25
6b	https://soundcloud.com/nicoleta-chatzopoulou/example4b-fd-jitter/s-xGDpGl3iNn6?utm_source=clipboard&utm_medium=text&utm_campaign=social_sharing	0.3/1.0	50 ms	0.6	0.25
6c	https://soundcloud.com/nicoleta-chatzopoulou/example4c-fd-jitter-duration-10ms/s-jf9HEhzd08B?utm_source=clipboard&utm_medium=text&utm_campaign=social_sharing	0.9/1.0	10ms	0.6	0.25

Table 3: Some Results with links in the form of Sound Examples

5.1 Issues

The data was used by drawing numbers in sequence from the results table. Originally this troublesome because it was not possible to have a visualization of the fraction of the image that was used as a cloud in the sound synthesis. However, in the end it proved helpful in contributing to our method since it led us to map the RGB values in the way described. Another issue was that, for

simplicity purposes, we used the parameters of the AGS model without employing clouds with large numbers or large densities of grains driven statistically or based on algorithmic processes. Although a useful approach, it did not make use of the vast possibilities of granular synthesis, particularly in producing complex sounds . One other point of concern was whether the amplitude should be set to a logarithmic scale, since our research did not deal with sound on the perceptual level. Designing a thought experiment based on Xenakis' theory of screens proved to be a research paper in itself.

6. Future Work

One, main focus point for future work would be to further explore the spatial implications as described in the results. To evaluate the effect of scaling of the data of parameters such as frequency, amplitude and time and provide a more explicit relation to linear and logarithmic scaling. From an architectural point of view, would be interesting to employ textural aspects of space, specifically in relation to the parameter of waveform inside the grain, combining it also with the established parametrization regarding the grain *colour.* Using a higher order granulation by employing clouds with higher grain densities and more parameters would be a fertile ground for sonic exploration and textural complexity, especially since the AGS model can contribute greatly on this level. Extending the experiment to all scales, from micro to macro form by further exploring various operations on screens as proposed by Xenakis and the composition on meso and macro scales as proposed by Roads. Finally, establishing collaborations with different disciplines, such as a computer scientist and signal processing expert, could result in designing a tool that would allow both architects and composers to create on the micro and macro scales.

7. Conclusions

We proposed a method for transforming spatial data into sound, by combining steps and simplifying concepts employed in granular synthesis techniques and theories, such as the AGS model and the theory of screens. The mapping of point clouds, each having a unique set of six values (x, y, z, R,G,B), to sound parameters was performed on the premise of setting the product of the y-values times the RGB scaled values to frequency and obtained three frequencies for each point, also defining the cloud frequency bandwidth. The z-values gave the amplitude for each grain and the x-values defined time. A Gaussian curve was used for the grain envelope, a sinusoidal waveform inside each grain and used a very low level implementation was employed. We tested our parametrization in the sound synthesis engine of Kyma and gained a hands on experience by exploring the parameters of density, grain duration and defining the parameters of frequency and grain duration jitter values as a ratio of the bandwidth values and the time range divided by the number of grains, respectively. We initiated a thought experiment based on the theory of screens by setting clouds of points, as screens on the frequency-intensity plane. By applying a grid on the screens, we got a different picture of our data set on the F-G plane in conjunction with the stochastic music applications as proposed by Xenakis. We combined the results from the proposed mapping with Xenakis' theory of screens, where the three different frequencies for every grain could be interpreted as the topographic fluctuations for each point. In this way we extended our original thought experiment to include a probabilistic analysis of the density, frequency, intensity and time dimensions on the existing point cloud data as a means of investigating a transformation from the sonic medium to the spatial. We were thus led to consider a future exploration in combination with the theory of screens. Through this initial experiment linking spatial data and sound, we set a ground for exploring ways to create more sonic complexity elaborate the transformations between the spatial and sonic mediums, first at the microlevel and consequently at the level of form.

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Stochastic Modeling of the Cicada Chorus

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Abstract

The sounds of nature are a rich source of musical information, in which stochastic phenomena create sonic textures of extreme rhythmic complexity. Describing sounds as "natural" suggests they have a character of familiarity, yet actually trying to understand aspects of these sounds, like their rhythmic qualities, leads to difficult analytical questions. Cicada songs are a particularly fertile target for musical analysis, with individual cicadas producing irregular rhythms and groups of cicadas adapting their rhythms to one another in a behavior known as "chorusing."

In this work we present a working computer simulation of a cicada chorus, by analyzing the rhythm of three levels of cicada behavior: (a) the stochastic parameters of the rhythms of a single cicada, (b) how these parameters change in the presence of other singing cicadas, and (c) the overall sound of the produced polyrhythms in a group of cicadas. This research is inspired by the stochastic methods of Iannis Xenakis for characterizing sonic events in terms of their statistical qualities. Applying these methods computationally to simulated natural sounds produces a system for music composition. It also suggests models of stochastic rhythm that can evoke complex yet natural feelings of movement in music.

1. Introduction

Cicada orni is one of the common cicada species throughout the Mediterranean area, recognizable by the striking songs produced by its males during summertime. It is distributed from the Iberian Peninsula to Greece and Turkey and some countries in the near East and around the Black Sea (Pinto-Juma et al. 2005). It dwells in high shrubland and woodland, olive trees, pine trees, oak trees, eucalyptus, and vineyards (Simões et al. 2000).

The song of *Cicada orni* is produced by males that can sing continuously from a single site for hours, producing a loud acoustic signal that is used to guide females towards them (Sueur and Aubin 2002). They produce this song by expanding and contracting their abdomens, causing corrugated exoskeletal membranes on either side of their abdomens to vibrate rapidly, producing fast clicking sounds (Sanborn and Phillips 1999). The cicada's body acts as a resonance chamber to amplify the sound. The sound of the cicada is unidirectional, and through this males indicate their localization, identity, and availability to females. The calling songs are frequently complex with changes in rhythm, amplitude modulation and, in many species, frequency modulation. Songs vary according to

physiology of the species, temperature, and time of year.

Cicada orni songs are made up of short (300-500 ms) "chirps," sometimes interspersed with "screeches." When several cicadas emit these streams of chirps together, they often display a behavior known as "chorusing": the phases of their chirps—that is, when each chirp starts and stops—synchronize. Cicadas will pass from long periods of extended chorusing into periods where their chirps are not in phase, and vice versa.

Cicada chorusing is remarkable for two reasons. First is the extreme precision with which the cicadas synchronize, erring no more than a fraction of a second from perfect unison (Greenfield 1994). In fact, this is achieved even though their collective frequency fluctuates randomly chirp by chirp. Second is the lack of any top-down governing mechanism making them synchronize their chirps. There is no cicada "conductor." Yet they fall into this state of near-perfect synchrony extremely quickly—it commonly only takes less than a second for a cicada to lock its chirps into phase with its neighbors' chirps. The way this behavior emerges has been studied by entomologists and mathematicians, and several models have been proposed. In this paper we use one model to pursue a computer simulation of the cicada chorus.

Biological and mathematical models of the mechanism of chorusing in cicadas and other insects have been proposed and studied by Greenfield (Greenfield 1994; Greenfield et al. 2021), Mirollo and Strogatz (Mirollo and Strogatz 1990a), and Winfree (Winfree 1980), and will be discussed in detail in 5. The evolutionary significance for cicada chorusing and other kinds of insect synchronization is not yet fully understood, and several possibilities have been discussed. It may facilitate the courtship between males and females. The resetting of an insect's signal rhythm by its neighbours' signals may be a means of overcoming signal blocking in a crowd. Thus perfect synchronization could actually lead to disaster and extinction, and therefore different species in the same trophic chain may develop different circadian rhythms to enlarge their probability of survival. Greenfield et al. (Greenfield, Tourtellot, and Snedden 1997) discussed cases of both synchronization and alternation in insect signals, and, using Monte-Carlo simulations, showed that each is evolutionary stable.

2. Cicadas and Xenakis's stochastic music

Xenakis referenced the song of cicadas as one of several illustrations that motivated his stochastic compositions (Xenakis 1992). He mentions it at the beginning of Chapter 1 of *Formalized Music*, before proceeding to the detailed technical explanation of the calculations involved in the composition of *Pithoprakta* and *Metastasis*. The cicada song is not itself an aspect of these calculations; it is merely an illustration that motivates them—a naturally occurring "cloud of sounds," in which the overall auditory aspect results from the collective behavior of the many small sounds the cloud comprises. But cicada song is a particularly apt illustration here, because the chorusing behavior reflects the movement from order to disorder which Xenakis privileges as an important feature of soundmasses. These two states, order and disorder, can be defined clearly in terms of mathematical parameters, and the movement between them effected by changing these parameters. The differences in the sonic results define formal aspects in Xenakis's stochastic compositions.

Cicadas chirping in near unison represent an extremely high ordered state. In the language (from physics) of phase transitions that Xenakis uses, a cicada group not in chorus (i.e. their chirps are random and unsynchronized) is analogous to a liquid or gaseous state, in which the molecules are moving at random. Chorusing is analogous to a solid state of matter: the phases of all the cicada chirps line up, as the molecules in a solid stay in specific positions. The speed with which cicadas pass from unsynchronized to synchronized chirping is particularly interesting when viewed through the analogy of physical phase transitions. The sudden passage from extreme disorder to order is a rare occurrence in physics: a solid becoming a gas without ever moving through a liquid state ("sublimation[1]"), or

[1] Xenakis actually opens the first chapter in *Formalized Music* by invoking this term: "Art, and above all music, has a fundamental function, which is

vice versa (“desublimation”). Since the phase parameter of cicada chirps exists along the time axis, as opposed to space axes as in the molecular analogies, chorusing behavior is analogous to "time crystals" (Shapere and Wilczek 2012).

3. Related work

Besides the detailed technical elaboration of stochastic music theory Xenakis presents in *Formalized Music*, his procedures and their results have been investigated by many, notably (Solomos 2020; Di Scipio 1998). Hallam (Hallam 2012) analyzes Xenakis’s view that political action is ruled by the same stochastic laws as natural sounds (cicadas and rain), finding this correlation made explicit in the sound production in Federico Fellini’s *Roma* (1972). Hoffmann (Hoffmann 1996, 2009) recreates Xenakis’s *Gendym* system (Xenakis 1992), which uses a similar stochastic model to different (specifically timbral) parameters for sound synthesis. Di Scipio investigates the perceptual qualities of stochastic soundmasses in Xenakis’s *Concret PH* and *Analogique B* and Beilharz (Beilharz 2004) discusses the correlations between natural phenomena and the mathematical principles that Xenakis applies in music composition (and architecture).

In an installation created by Codognet and Pasquet (Codognet and Pasquet 2009), a music soundscape is created using a multi-agent simulation based on a model of swarm intelligence. Another installation by Salter (Yerbury 2017), *N-Polytope*, is a light and sound environment consisting of a network of tiny speakers producing sonic grains, creating swarms of cicadas-like sounds. Its machine learning algorithms create different rhythmic and temporal patterns in light and sound, creating a 25-minute performance that self-organizes in time, inspired by Xenakis’s Polytopes. A walk-through performance environment continually swings between order and disorder. Georgaki and Queiroz (Georgaki and Queiroz 2015) studied the basic patterns, timbre and rhythmic models of cicada calls and shrilling sounds with a micro-temporal, a meso-temporal and a macro-temporal model.

4. System Architecture and Model Implementation

To determine the features of the *Cicada orni* chorus to simulate, we made audio recordings of both individual and grouped cicadas in Greece: Aegina and Kea, in the summers of 2019 and 2021, respectively. We found a rich variety of textures from these recordings, ranging from polyphony to unison chorusing, with heterophonic states lying in between these. We even found examples of antiphonic and half-time chorusing described in (Greenfield 1994). They also show many interesting polyphonic and heterophonic types of behavior.

From both numerical analysis and listening, we extracted three levels of stochastic behavior that characterizes the protean sound of the cicada chorus.

The rhythm of the cicada song is the musical feature of interest, as the timbre of a cicada chirp does not modulate meaningfully in terms of frequency. This rhythm exists on more than one temporal level. We focus our analysis on two of them. First, there is the the "microlevel,’ characterizing the stochastic nature of a single cicada’s chirp, defined by the probability distribution of its chirp ontimes and amplitudes. Second, there is a "macrolevel," describing the spacing between the entrances and exits of individual cicadas or clusters of cicadas into and out of the chorus over time.

Applying audio filtering to remove noise from the recordings, we converted the audio data to numbers and smoothed it, and applied a simple algorithm to the smoothed data to extract the ontimes and amplitudes of each chirp in a cicada’s song.

to catalyze the sublimation that it can bring about through all means of expression (Xenakis 1992).” Although in this case it is meant in the metaphorical sense; it is a reference, continued in the second paragraph in references to “transmutation” and “possession,” to the Orphic trance state music was believed to cause in Attic philosophy. Though he never again uses the term in this chapter, the processes he describes are examples of sublimation in terms of physics.

While the amount of data captured (approximately six hours) is too small to be considered representative of cicadas as a species, it contains a substantial number of data points (a cicada chirps between approximately two and five times a second; multiply that by six hours) which show remarkable consistency among certain stochastic variables.

Added to the two rhythmic levels described above is the chorusing phenomenon, which, in terms of our features, is described as the synchronization of ontimes between cicadas singing together. We thus have three levels of stochastic behavior which we have implemented computationally in order to simulate a cicada chorus.

We describe our model and its implementation in terms of these three levels. The process of its construction can be seen as beginning with a simple model of a single cicada "chirp," and then applying stochastic transformations to its operations in three stages to produce the three levels of rhythmic interest described above. The first stage modulates the rhythm of a single cicada's song. The second stage modulates the entrance and exits among cicadas in a chorus. The third stage applies the chorusing element. The first two steps are straightforward and will be described at the same time of their implementation. It is the third step, the integration of the Kuramoto model to produce chorusing, that is the particularly interesting modification, so we will spend some time on its necessary biological and mathematical background before proceeding to describe its implementation. The single stochastic variable derived at this third stage, the "coupling strength," is the governor of phase changes in the cicada model.

Analysis of the audio recordings was done in the Python programming language. The simulation is also implemented in Python, fit out with a real-time communication system with Max which controlled real-time sound production. Details will be described in the discussion below.

Cicada rhythms (onsets, durations, and amplitudes) are generated in Python, while Max handles the cicada sound synthesis. The program is run at real time to produce sound as well as the data used in the figures presented below.

4.1. Base Architecture

An excellent design for simulating the complex timbre of the vibrating tymbals is given in (Farnell 2010). White noise is filtered into two sharp peaks at 5.5 kHz and7.5 kHz and amplitude modulated with a 500 Hz signal to produce the "clicks." In Farnell's model, the envelope of a chirp is produced by amplitude modulating this filtered noise by a sinusoidal function, producing pulses at regular intervals.

This model is perhaps the simplest possible: an object that produces an infinite stream of pulses at regular intervals, like a metronome that never winds down. We began with this model as our base material. At the heart of our simulation is an agent (a Python object) that has only one job: at any given time, it outputs a value between zero and 1. This value is passed to a filtered noise stream (as described above and generated in Max/MSP) as an amplitude modulation. (Though the complex timbre described is an important aspect of the cicada simulation, it is not involved in any of the proceeding calculations, which are about rhythm and not timbre.)

Each agent represents a single cicada, and a simulation of a variable number of these agents. We continually advance each cicada by a very small time step (12 ms), producing a continuous-sounding stream of amplitude values applied to the noise. As a starting point in the construction of our model, the amplitude an agent outputs is calculated according to a sinusoidal function. The function we use is

$$amplitude = sin^2(\omega t + \phi) \quad (1)$$

where ω represents the cicada's frequency (measured in chirps per second), t the current time, and ϕ phase angle. In our case, we set the phase angle to zero, so that cicadas always begin chirping at

volume zero—they never begin "mid-chirp."

This function works well as an amplitude envelope for a "chirp" sound because it takes only positive values ranging between 0 and 1, and its rounded contours and gentle peaks and troughs.

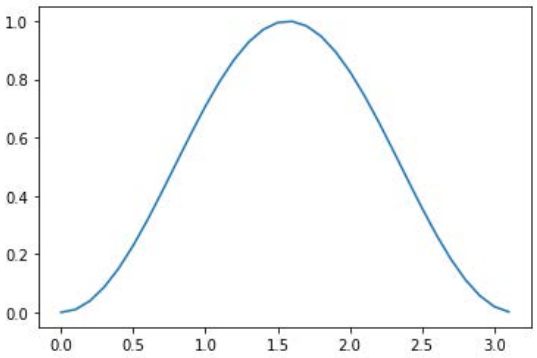

Figure 1: A single simulated cicada chirp: $amplitude = sin^2(\omega t + \phi)$, *(3)*

An agent is initialized with a given frequency. Six cicada agents with the same frequency chirping together produce amplitude envelopes like the following:

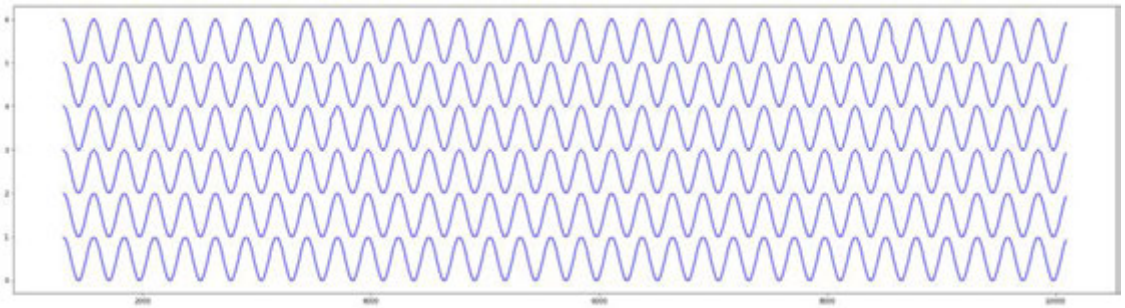

Figure 2: Base level: Six cicada agents chirping in exact unison

2.3 Single Cicada Ontime Distribution

The first level of stochastic transformation we perform is to randomize the chirp lengths of each individual cicada agent. Analysis of audio recordings of a single cicada chirping shows a distribution of ontimes that cluster about one or two peak values. This distribution can be modeled as a normal distribution whose left side is truncated at zero. Even when there are two peaks this is a reasonable model, because they are so close together. (It is worthy of continued research to investigate the bimodality of these distributions.)

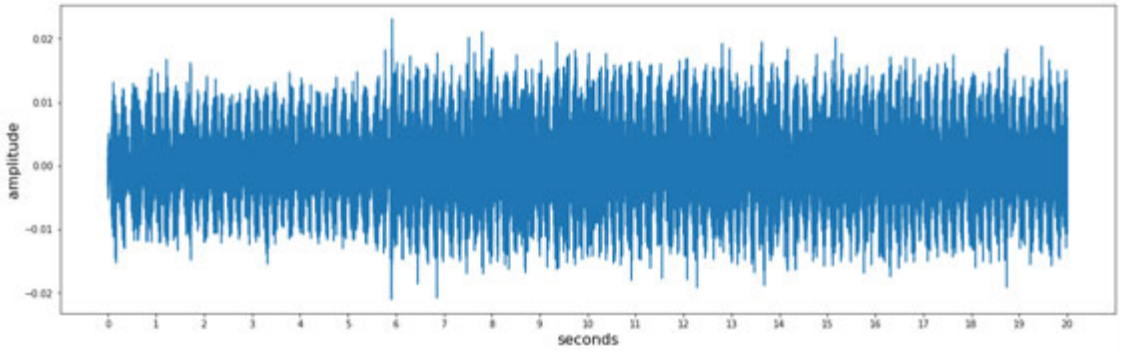

Figure 3: Audio waveform

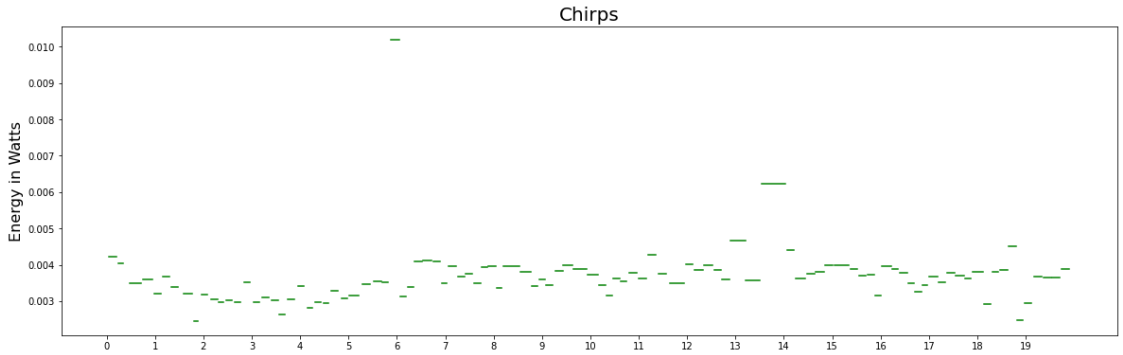

Figure 4: Chirps

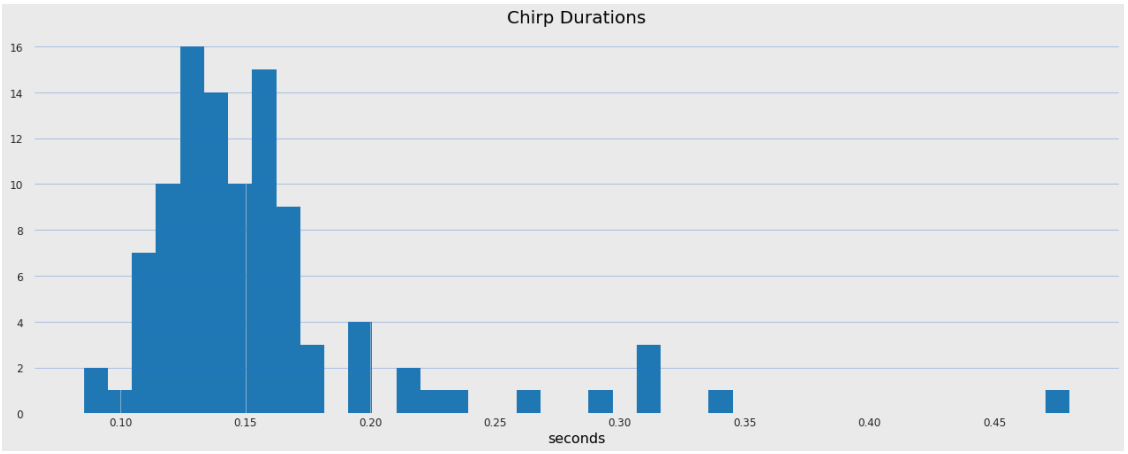

Figure 5: Distribution of chirp durations

To implement this, at the beginning of each chirp (when $amplitude = 0$), a cicada calculates a new period for its next chirp based on a normal distribution derived from the data. The distribution in figure 5 gives, for instance, a mean value of 266 ms per chirp with a standard deviation of 46 ms. A resulting simulation of six cicadas with these stochastic values is shown in 6.

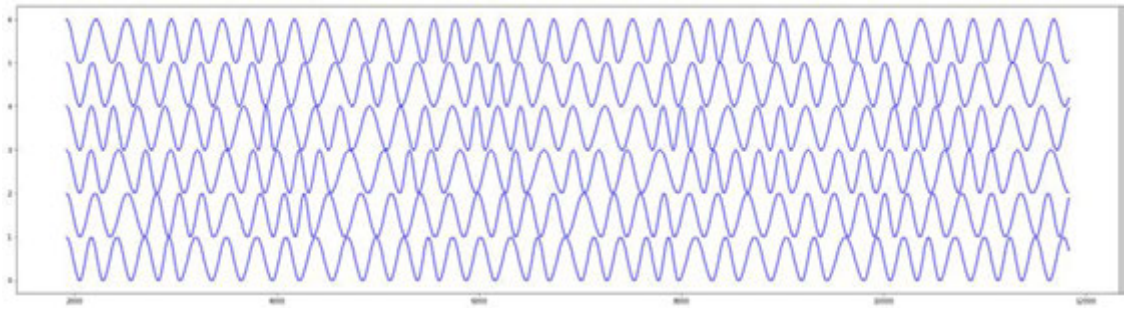

Figure 6: Stochastic deformation stage 1: Cicada simulation with rhythms according to normal distribution

In modern audio production terms, this is the equivalent of "humanizing" a drum beat. In this sense, we are "cicadizing" the rhythm.

4.2 Entrances and Exits

Cicadas start and stop chirping at times that seem random, though the presence of other chirping cicadas seems to increase the propensity for a non-chirping cicada to start chirping, and reduce the propensity of a chirping cicada to stop. The latter seems especially true when the cicadas are chorusing: individual cicadas seem reluctant to leave the chorus.

Analyzing this behavior would require more involved experimentation than we were able to perform: audio recorded from a single recorder placed at a point does not allow one to identify songs with individual cicadas, because cicadas closer to the microphone drown out those that are farther away. Many microphones placed in different positions would be necessary to capture enough data to make precise statements about the statistics of cicada entrances and exits. Nevertheless, we can posit some measurements that adequately inform a model that reflects the phenomenological aspects of these entrances and exits.

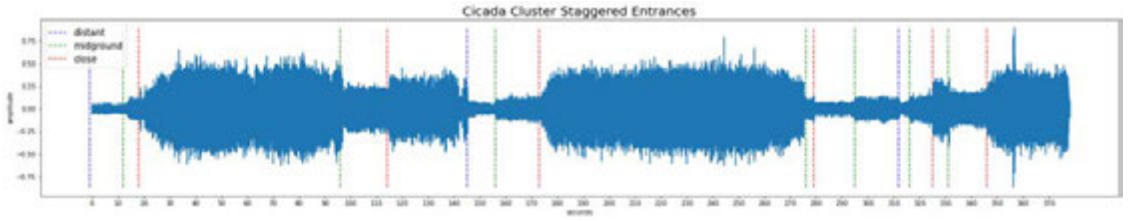

Figure 7: Staggered entrances of cicadas

To manifest stochastic entrances and exits, each cicada has a base start-chirping probability and a base stop-chirping probability. At each time increment, each cicada makes a random choice based on the relative probability to change its state. As this amounts to a succession of Bernoulli trials given a "weighted coin," this produces an exponentially distributed segments of silence and chirping for each cicada.

We modify this model to reflect a cicada's propensity to begin or continue chirping in the presence of other cicadas by giving each cicada knowledge of the other cicadas and of it. We increase each cicada's start-chirping probability by a factor proportional to the number of chirping neighbors a cicada has, and decrease its stop-chirping probability similarly. This produces longer periods of cicadas chirping as a group.

With this second level of stochastic deformation, our cicada simulation sounds like this:

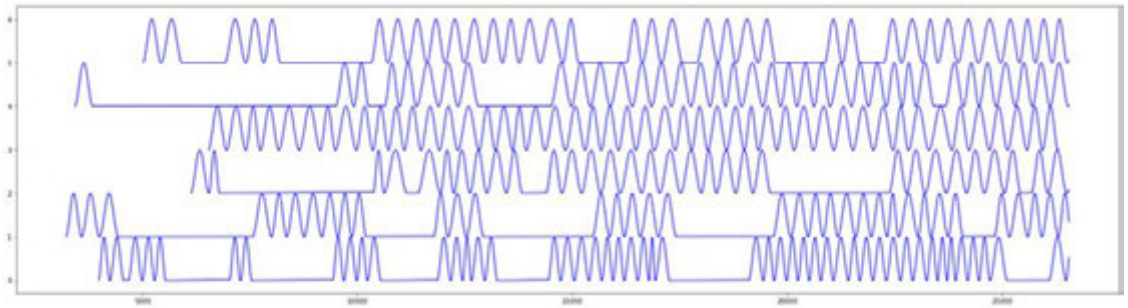

Figure 8: Stochastic deformation stage 2: Cicada simulation with staggered entrances

5. Chorusing: mechanism of action

The third stage of stochastic deformation we apply to our cicada sound is to apply a mechanism which creates "chorusing," also known as synchrony: the convergence to unison chirping heard in cicada groups. This is a striking phenomenon heard (or seen, as in fireflies) among many species of insects, and its process has been investigated both biologically and mathematically.

Male cicadas probably chirp to attract females. The adaptive reason for synchrony of their chirps is described in (Greenfield 1994). The mechanism by which cicadas and other insects achieve near-perfect synchrony of chirps (or, in the case of fireflies, pulses of light), has been modeled in two ways.

5.1. Integrate-and-Fire Model

The first of these, the “integrate-and-fire” model, was introduced by Peskin in 1970 (Peskin 1975) to explain how electrical impulses moving through cells in the heart muscle line up to produce rhythmic heartbeats. It was later picked up by entomologists who showed a similar chemical-electric event taking place before the onset of an insect’s chirp when the insect is stimulated by the sound of other chirps.

In this model (Greenfield 1994), a single insect male has a central nervous oscillator which moves from a base level (“at zero”) up to a peak level. When it hits the peak level, the insect chirps (“fires”), and the oscillator drops back down to zero. When the insect finishes chirping, the oscillator begins creeping upward again, to fire a new chirp when the peak level is again obtained. If, while the oscillator is moving upward, the insect hears a chirp from a neighboring insect, the oscillator is “bumped up” toward the peak level, resulting in the next chirp being fired sooner than it would have been without an external stimulus. The length of the resulting chirp is extended or shortened based on when the external stimulus was perceived (Greenfield 1994). The dynamics of this simple mechanism become very complex because each chirping insect uses it, creating a feedback loop between every pair of insects in a group. One result of all these feedback loops running together has been shown mathematically to be synchrony of calls (Mirollo and Strogatz 1990b).

5.2. Kuramoto Model and Synchrony

The second model, the “Kuramoto model,” was developed later and is more generalized. It is a mathematical model of oscillators that influence each other, introduced by Kuramoto in 1975 (Acebrón et al. 2005; Novikov and Benderskaya 2014). Its attractiveness comes from its combination of simplicity and generality, which have led it to be applied in many fields, including insect signal synchronization (Novikov and Benderskaya 2014).

It does not describe an actual biological mechanism, but rather assumes the existence of some such environmentally-aware mechanism in an agent, and goes on to describe the behavior of signaling within a network of such agents (Kuramoto 1975, 2003). These two models, the integrate-and-fire and the Kuramoto, were shown to be more or less mathematically equivalent (Politi and Rosenblum 2015). We therefore use the Kuramoto model because of its ease of mathematical modeling and computational implementation. This means we leave out trying to model the actual biological mechanism that generates a cicada’s chirp timing. This lets us focus on its qualities as a musical phenomenon rather than an entomological one (the authors are musicians, not entomologists).

5.2.1. Kuramoto Mathematical model

Suppose we have *n* cicadas, where the *i*th cicada’s chirp frequency is denoted by ω_i, and its phase is represented by ϕ_i,The Kuramoto formula is

$$\frac{d\phi_i}{dt} = \omega_i + KA \qquad (2)$$

where K is the "coupling strength" and A, the "Kuramoto average," is the average of all the differences between the phases of cicada i's and each of its neighbor's phases. More plainly stated, A is the average difference between when cicada i started its last chirp, and when each of its neighbors did. Mathematically this is stated thus:

$$A = \frac{1}{N}\sum_{j=1}^{N} \quad sin(\phi_j - \phi_i) \quad (3)$$

Equation (2) says that the phase of a cicada in this model is not fixed as in equation (1), but instead is constantly changing as a result of the influence of the other cicadas' chirp phases. The coupling strength, K, is the interesting and useful quantity. It varies between -1 and 1, and describes how strong an influence the Kuramoto average A has on a cicada. This can be thought of as how much a cicada is influenced by the calls of its neighbors, or as the attention each cicada pays to its neighbors' chirps. Sonically, K values correspond to levels of Xenakis's "ataxy" as depicted in [fig:xenakis_ataxy]: values close to zero produce high levels of disorder, while values close to 1 produce order. (Negative values also produce a different kind of order, which we will briefly mention later.)

5.2.2. Implementation

To implement the Kuramoto model computationally, we convert from continuous to discrete time:

$$\frac{(\phi_i + \Delta\phi_i) - \phi_i}{\Delta t} = \omega_i + \frac{K}{N}\sum_{j=1}^{N} \quad sin(\phi_j - \phi_i) \quad (4)$$

Calling the new phase value $\phi_{i'}$ $(= \phi_i + \Delta\phi_i)$, we get

$$\phi_{i'} = \phi_i + \omega_i \Delta t + \frac{K}{N}\left(\sum_{j=1}^{N} \quad sin(\phi_j - \phi_i)\right)\Delta t \qquad (5)$$

This is the equation we use for our computer-modeled cicadas. At each time step each cicada's phase is recalculated according to equation (5), and subsequently the volume of its chirp according to equation (3).

The first stage of stochastic deformation we made, randomizing the individual cicada's chirps, is not included in the Kuramoto model, which assumes a single "natural frequency" for each of its oscillators. Our simulations show that, when this random fluctuation is added, the simulated cicada chorus still converge almost immediately to synchrony, although the period of each unison chirp still fluctuates randomly! This amazing dynamic is, indeed, heard in the data. It produces a life-like aspect from the pure Kuramoto model, in which the cicadas have a machinelike repetitiousness.

6. Sonic Results

At various levels of K, we observe the different levels of ordered and disordered calling heard by real cicadas.

At $K = 0$, we hear no chorusing: a cicada pays no attention to its neighbors at all and does not modify its chirp. Several cicadas all chirping with K set to 0 will produce a random cacophony of entirely independent chirps–Xenakis's "total asymmetry," or, in phase-transition terms, a "gaseous" state.

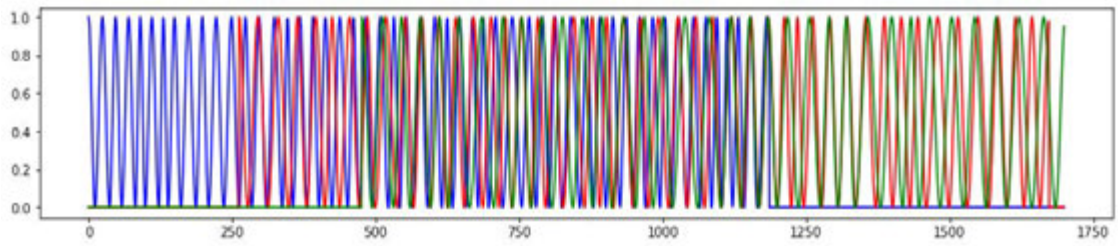

Figure 9: Coupling strength (K) = 0

In 9, when several cicadas are chirping at the same time, the graph looks like a tangle of lines, because their chirps are not in sync with each other.

At $K = 1$, each cicada is strongly influenced by its neighbors. So strongly, in fact, that a group of cicadas will, after only one or two chirps, enter a state of almost perfect synchrony, despite their different fundamental mean chirp frequencies and their random chirp distributions! We can see this clearly in 10: when several cicadas are singing together, we can still see the chirp outlines clearly.

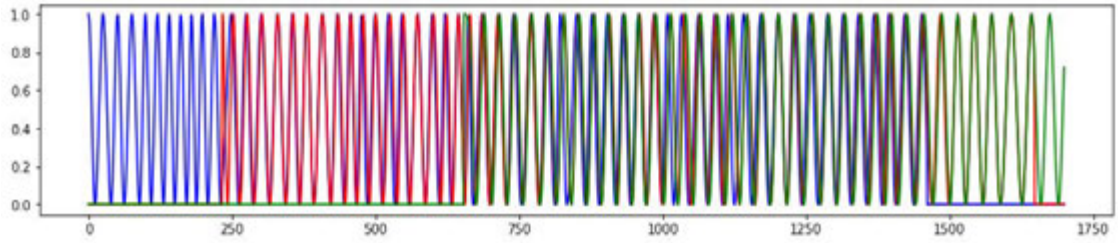

Figure 10: Coupling strength (K) = 1

Applying this coupling strength variable to the six-cicada simulation, we now produce a texture like this:

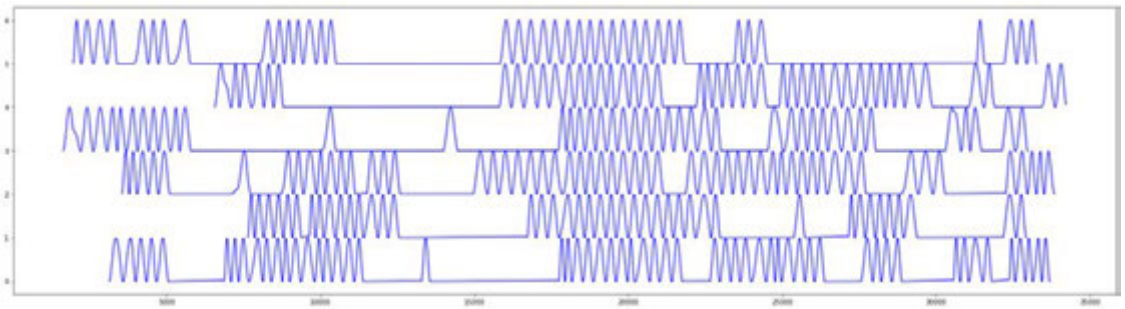

Figure 11: Deformation 3: six cicadas chorusing

Contrast this with 8. When cicadas enter, they now synchronize quickly to match their chirps to the other cicadas. It is perhaps easier to see the difference between the two simulated examples if all six cicadas' chirps are superimposed on top of each other, as in figures 11 and 12.

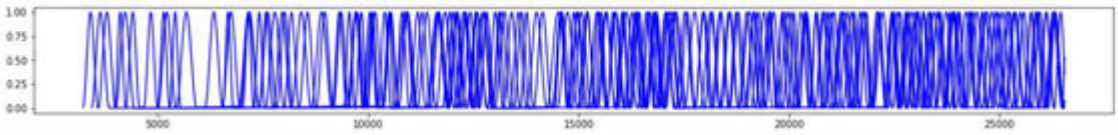

Figure 12: Coupling strength (K) equals 0

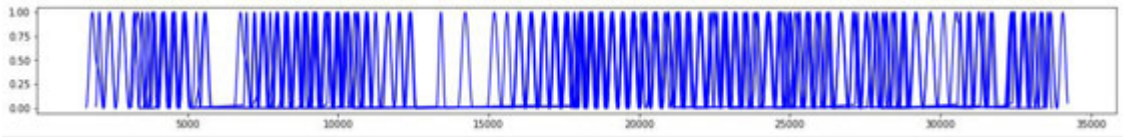

Figure 13: Coupling strength (K) equals 1

At values beside zero and one, different fascinating sonic phenomena are heard. For instance, at $K = -1$, we hear hocketing (Greenfield 2015). Between zero and one, various levels of polyphony and heterophony arise.

We can also vary the k value in real time, creating sonic entities which dissolve between order and disorder at different speeds:

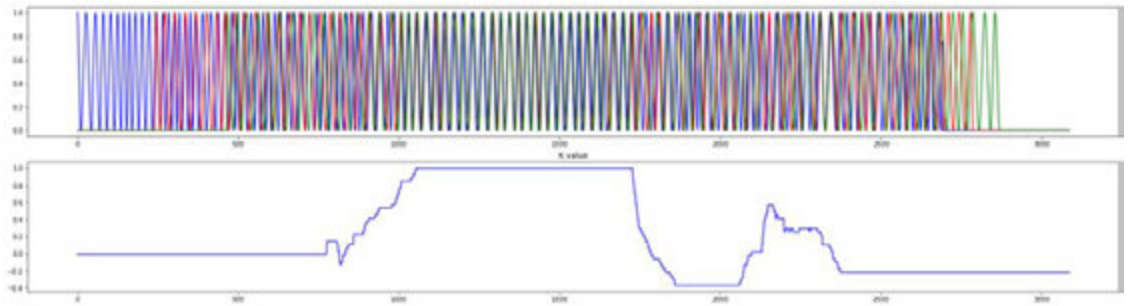

Figure 14: Coupling strength (K) varies

7. Discussion and Future Work

We have provided here a model consisting of a small set of parameters corresponding to stochastic deformations of a sonic material, in order to produce behavior exhibited by a cicada chorus. The examples of simulated behavior are only a beginning; they merely illustrate how these stochastic parameters can affect the sonic material. Our final result is a tool that can be used to create and mold macroscopic sonic states with a minimum of constraints. It is an answer to Xenakis's question "What is the minimum of logical constraints necessary for the construction of a musical process?" (Xenakis 1992). Within the three levels of stochastic deformation presented, there are four features which operate on the macroscopic sonic texture: single cicada chirp length probability distribution, cicada start and stop probabilities, and the coupling strength. All of these can be modulated to produce different macroscopic sonic states. Their effects on different topologies of cicada groups can also be studied: cicadas can respond differently to neighbors at different distances. All these factors can also be applied to granular synthesis, of which the model presented here is an example using lower and longer "grains" than those typically used.

The rhythmic simulation of cicadas and their organization in choruses by stochastic modeling is useful for the study of ecoacoustics and biophony. While our data focused on the Greek landscape, cicada calls and organizational behavior change according to habitat and species. Our analysis can thus also be taken as a starting point from which to study insect sound phenology. In the future, frequency range, density, space could be taken into consideration. In addition to the rhythmic features we analysed. The resulting computer program could also potentially be a tool for composers to promote the upcoming dangers of climate change.

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An attempt at extending Xenakis' compositional design of *Herma* through computational tools

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Abstract

In this paper, we describe and exemplify research involving computational tools that generate works with characteristics analogous to the referential piano piece *Herma* (1961) by Iannis Xenakis. The piece was described by Xenakis in his book *Formalized Music* at a level of detail that allows the implementation of computational models recreating essential elements of the final score. On the other hand, as some authors noticed–notably Eugene Montague, Ronald Squibbs, and Robert Wannamaker–Xenakis' final product does not quite fit his description of *Herma*. Carlos Agon et al. agree when presenting a formalization of the compositional processes. We tried to fill this gap by implementing some features–related to the underlying *In-Time/Outside-Time* structures in *Herma*–that, in the end, make our programs capable of producing musical outputs that approximate Xenakis' final result. As a testing tool for Xenakis' compositional design, we developed the applet *Herma* in Matlab during a course on Formalized Music promoted by the MusMat Research Group from the Universidade Federal do Rio de Janeiro. The application simulates in detail the steps indicated by the composer about the segmentation of pitches into sets and their presentation in combinations defined by Boolean operations. It also covers the time intervals shown by Xenakis in Figure VI-15 of his book. As a result, the application produces, in a single step, a MIDI file with the original proposal's random characteristics. Although some dynamic curves and temporal events closely reflect the overall dynamics of the piece (agogic, rhythmic texture, pauses), some pitch structures, resulting from the stochastic process suggested by Xenakis, are sensibly distinct from the original music. To overcome this and other incompatibilities between the method described by the composer and the result shown in the piece, we developed the software *Hermoser*. It generates musical fragments based on the *Herma* compositional structure, but including the modulation of critical parameters–the total number of pitches, the cardinality of the involved sets, the note durations, etc.–to accommodate different esthesic results. This software aims to put Xenakis' intentions to the test, helping us approach our fundamental question: How can one communicate boolean algebra expressions through music? It may be a complicated answer to achieve. Still, the experiments produced with *Hermoser* give us some insights into the nature of Xenakis' symbolic music, which are expounded in the present work. *Hermoser* application shows that it is possible to establish additional features for Xenakis' compositional scheme, which suffice for a more noticeable esthesic result for pitch segmentations and combinations. The evaluation of the

outcomes produced by the program ended up bringing together some essential relationships from the Musical Set Theory (such as Allen Forte's K and Kh relations) and has a remarkable possibility of didactic application. Furthermore, one can apply these same relationships to other musical domains, such as rhythm and timbre, a subject we leave for future work.

1. Introduction

Iannis Xenakis is known for using *algebra* and *logic* as an essential part of his process of the composition of some pieces, particularly of *Herma*. Some of the intentions pursued and strategies adopted by Xenakis in the making of *Herma* are scattered in two main public sources: his long interview with Bálint Varga (Varga, 1996) and the chapter VI of his book *Formalized Music* (Xenakis, 1992). Concretely, these intentions and strategies take the form of a general scheme that fills pages 170-177 (Xenakis, 1992). As the first realization of this scheme, we have the score of the piece, published by Xenakis (Xenakis, 1967). We also have a more radical level of realization of this scheme in the recorded performances of the musicians who ventured to try to produce the effects that Xenakis wanted, supported by the indications he left in the score (References). Thus, there are *at least* three manifestations of *Herma*: the first in the form of a set of descriptions that can be distilled from Xenakis' public writings; the second in the form of a score published with indications of what Xenakis intended to achieve; and the third in the form of recorded performances that can be considered the final manifestation of the piece.

Several works analyze these three manifestations of the *Herma* of Xenakis (Montague, 1995; Wannamaker, 2021; Agon et al., 2004; Squibs, 2000; Gibson, 2019, among others). As a result, various discrepancies between what Xenakis describes in words and what he gets as a result of the score are exposed and analyzed. In this work, we follow a complementary path. Considering the criticisms made by the previous authors and making critical analyses by ourselves, we collected a series of compositional procedures that can be applied in the production of pieces that can correspond to a greater or lesser degree to the result obtained by Xenakis in *Herma*. More specifically, by implementing some features–related to the underlying *In-Time*/*Outside-Time* structures in *Herma* – we, in the end, designed programs capable of producing musical outputs that approximate Xenakis' final result.

2. Review

It is well known that *Herma* was commissioned to Xenakis by the Japanese pianist Yuji Takahashi in 1961, who was also the first to perform the piece in February 1962. From what Xenakis tells Varga, besides his sympathy for Takahashi's request, *Herma* has its origins in his desire to justify what he was doing when using stochastic processes in his compositions. As usual with Xenakis, this should be taken as a very general question. Not just how and why he is applying those calculations to the composition of those pieces, but what it means to be able to use and effectively use stochastic mathematical tools in music. The attempt to understand this process led Xenakis to even deeper questions such as "what is time?", "what is pitch?", "what is the relationship between time and pitch?" etc.

After reading and thinking, Xenakis arrived at his first fundamental conclusion that time is nothing more than a kind of structure. So, it can be counted, expressed with real numbers, and shown as points on a straight line. More thinking led Xenakis to the conclusion that music is not only time, as other composers claimed. In fact, he concluded, music is basically outside time, and time serves just for it to manifest itself. This conception led him to his second fundamental conclusion that, in music, the question of form, structure, harmony, counterpoint, and so on are all outside time. Consequently, Xenakis started trying to find a way to mix the properties of sound on a more abstract level without taking into account the time structures when manipulating sound events.

From these considerations, it was a natural step for Xenakis to adopt the idea that composition proceeds in three major main steps. These can be roughly described as follows. First, one chooses sets of sound elements and plays with them. The sets are based on the sound characteristics: one set is composed of pitches, another of intensities, a third of durations. After defining the sets comes their combination. Finally, at some point, the moment arrives at which the achieved material is organized in time, and the music manifests. As Xenakis says: "That's how I wrote *Herma*. All these ideas were in my head when Takahashi asked me to write a piano piece, so I took the opportunity to try them out in practice."

From the beginning, the description of *Herma* presented on pages 170-177 of *Formalized Music* clarifies that *The Herma* described there is just a concrete example of a more general conception of what we may call *Herma-like compositions*. This description may be seen in two ways: forward or backward. For the forward view, we extrapolate from Xenakis' text, considering that the very possibility of *Herma-like* compositions derives from the ability to independently choose sets of sound events (from a given set taken as the universe) and combine them through set operations.

Based on this and in what shows up in Figure VI-15 (*ibidem*, p. 177), we define a set of general prescriptions that can describe the class of such pieces. So, according to a stochastic law, the *a priori* choice of sets of sound events may represent the first step in the composition of a *herma*. The second step is to present these sets in sequence, which must occur so that each set is recognizable in relation to the others. Xenakis uses the artifice of presenting the set followed by its complementary set regarding the universe set, so we use this as a prescription to follow in the construction. Then, we also consider that describing a sequence of operations on these sets producing, as a result, a final set is the next step of the process. But, as Xenakis clearly remarks before describing the construction of *Herma*'s that he put in the score, "after these general considerations (...) we must look for a need, a node of interest." Xenakis' node of interest is realized by using and comparing two different, but equivalent, Boolean expressions built by applying the Boolean operations on the initially chosen sets – two expressions representing the same final resulting set but having a different sequence of operations applied on the initial sets.

The general structure of *Herma*, described above, raises many problems from the compositional and computational points of view. In this paper, we deal with some of them. Others, indeed the majority of them, are left for further investigation.

2.1. What is Herma About?

Many scholars analyzed the piece and pointed out that *Herma*'s final score inconsistencies have made the set algebra unrecognizable. Indeed, one cannot perceive a set *A* and its complement *nA* if they share some pitches. That kind of mistake took Montague and Wannamaker to raise the possibility that Xenakis had intentionally swapped some pitches with aesthetic purposes, a hypothesis that Gibson contested. In his work, Gibson brings out correspondences (among other evidence) that explicitly reinforce Xenakis' intentions to correct the pointed inconsistencies. Even so, regardless of what causes the mistakes in *Herma*, the deviations from the model do not seem to be the factor that most interferes in the perception of the piece.

Both Gibson and Squibbs minimize the relevance of the pitch structures to the perception of *Herma*. The former highlights the "contrasts of dynamics, densities, and resonance between clouds of sounds" as the main elements of *Herma*, while the latter mentions that the stochastic distributions used to build *Herma's* large-scale temporal structure were responsible for most of the esthesic result. However, Xenakis himself introduced the piece as an example of Symbolic Music, in which the set algebra handles the expression of symbols from the propositional logic. The enumeration of the pitches in a set, obtained by playing them sequentially in any order, should be capable of communicating boolean algebra expressions through music. *Herma* is, or at least should be, about pitches. But what went "wrong" in the process that obfuscated the set structures in the piece's sonic result?

As we have seen, most researchers agree that Xenakis' extensive argumentation on his Symbolic Music theory does not suffice for turning the set algebra formalization into a central element of *Herma*. This curious fact is the starting point for our research, which motivated the computational tools built to investigate the expressiveness of pitch sets like the ones used in *Herma*.

22.Shortcomings

The flow from the composer's expressed ideas to the esthesic process of the listener go through three chronological steps (Figure 1):

1. Xenakis formalized his intentions into a compositional method described in his book.
2. This method was applied with particular parameters, which yielded the original score of *Herma*.
3. This score was performed by musicians (or virtual players), allowing the music to be perceived by the listeners.

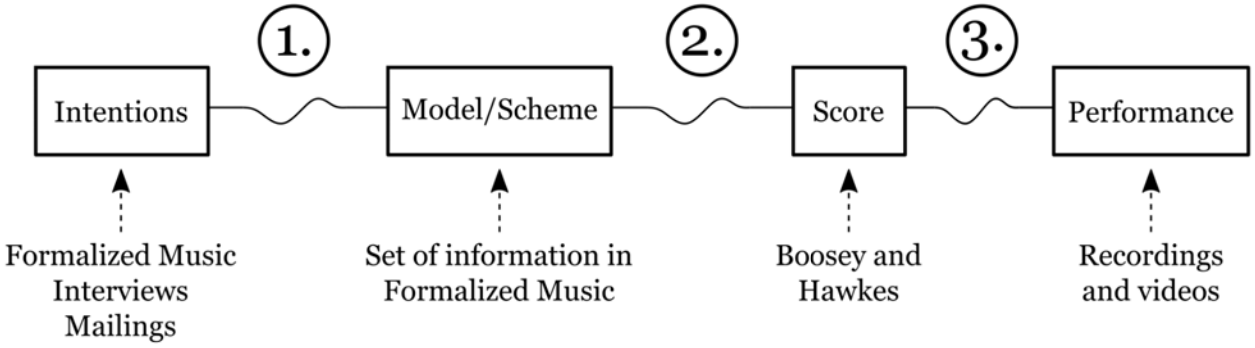

Figure 1: Three chronological steps of the composition of Herma.

This enumeration of the steps is not extensive. For example, the graphic scores used by Xenakis before putting the music into traditional notation could be another stage of this flow, as could be the recordings. However, the steps described above should be enough for our analysis.

As can be expected from a compositional process, it is unlikely that the composer's ideas will reach the ears of his audience intact. Thus, each step has some shortcomings that affect the communication, making it hard to recognize what exactly prevents the pitch structures from becoming an essential element in the final result.

At the performance step, these shortcomings are probably consequences of the difficulty of the score, which causes most performers to commit mistakes when playing the piece, as Gibson points out. Nonetheless, a virtual performance from a midi file eliminates this issue, and it is possible to conclude, according to Claude Helffer (cf. Gibson, 2001), that few performance errors do not effectively harm *Herma*'s global sound.

Thus, the weakening of the *Outside-Time* structures that act over the pitches must occur in one of the previous manifestations of *Herma*, which are the piece's score and the descriptions contained in *Formalized Music*. These two elements are, indeed, the focuses of our investigation.

The shortcomings at the score level correspond to those pitch inconsistencies pointed out in the literature. The origin and intentionality of the mistakes have already been extensively debated, and attempts to implement the method removing the inconsistencies have also been made. However, there is still room to analyze the *artificial Hermas* produced by these corrected implementations, checking if they also bring the pitch structures as minor perceptive elements.

The first level of the diagram is probably the hardest one to examine. A shortcoming at this step is any kind of misconception that Xenakis could have done while formulating his method. In other words, to analyze this step is to check if Xenakis' model is capable of expressing his intentions, a task that, so far, has not been the focus of most researchers.

3. Inspecting the model

From now on, we will present our results and observations on the nature of *hermas*. Two computational tools developed to aid our research generated the analyzed pieces. One of them is the software *Hermoser*, which implements some modifications over *Herma*'s original model and will be the focus of section 4. The other one, named *Herma Applet*, is a *Matlab* application. It outputs pieces with the same method that was used in the original piece, helping us to inspect Xenakis' model.

Implementing the original model through a computational tool is not new. For example, Carlos Agon et al. have presented an *OpenMusic* implementation that, despite some operational decisions, is quite similar to our program. Maybe the main difference between them is their purpose since *Herma Applet*'s implementation is not the focus of our research. Instead, the software is only a means to generate the musical material that we were in need for our analysis. Still, implementing Xenakis' model was a valuable process for us to understand *Herma* better.

3.1. Intervalar invariance under complementary relation

One of the most prominent features of the compositional design of *Herma* is the intervalar similarity between a set and its complement. This relation is the main subject of the expositive section and the basis from which the development section is constructed.

Musical Set Theory considers the similarity between a set and its complement based on *intervalar invariance* – the amount of intersection of occurrences of each interval class between two pitch sets. In cyclic pitch spaces, the pitches stand in closed loops of pitch classes, and any set has in its complement the most invariant configuration among the sets with complementary cardinality (Straus, 1991, pp. 16-17). For instance, for a trichord *A* – let's say, [0, 1, 3], its complement *nA* [2, 4, 5, 6, 7, 8, 9, 10, 11] is the nonachord where we find the highest number of occurrences of versions of *A* (under transposition, inversion, or both). Their intervalar vectors, [111000] and [777663], also have similar profiles of distribution of interval classes (*ibidem*, p. 17).

In the case of *Herma*, on the other hand, the universe-set (called by Xenakis as *R*) comprises the 88 piano keys, constituting a space with no cyclic recurrence. Robert Morris calls this type of linear distribution a *p-space*, and the correspondent internal pitch structures as *psets* (Morris, 1987, pp. 36-58).

Measuring the similarity between a *pset* and its complement is a more complex task. The low and high limits of the universe-set create constraints for canonical operations[1]. Therefore, each version of the same *pset* generates complements with distinct intervalar structures and particular grades of similarity with the original version (ibidem, p. 55).

For instance, considering the universe set *R* = [0, 1, 2, 3, 4, 5, 6, 7], and versions derived from *pset* [0, 1, 3], there are 10 distinct cases for *A* and *nA* (Table 1). Version O0 [0, 1, 3] have higher intervalar similarity with its complement than O2 [2, 4, 5], and both have more intervalar invariance in relation with its complement than O1 [1, 3, 4].

1 In this paper, just transposition and inversion (see Morris, 1987, p. 55).

A	*nA*	*f(A)* ⊂ *nA*	*nA*'s intervalar vector	Distr. type
O0 [0, 1, 3][2]	[2, 4, 5, 6, 7]	[2, 4, 5], [4, 6, 7], [4, 5, 7]	[3 3 2 1 1 0 0]	[0 1 3]
I4 [4, 6, 7]	[0, 1, 2, 3, 5]	[0, 1, 3], [0, 2, 3], [2, 3, 5]	[3 3 2 1 1 0 0]	[0 1 3]
I0 [0, 2, 3]	[1, 4, 5, 6, 7]	[4, 5, 7], [4, 6, 7]	[3 2 1 1 1 1 0]	[0 2 3]
O4 [4, 5, 7]	[0, 1, 2, 3, 6]	[0, 1, 3], [0, 2, 3]	[3 2 1 1 1 1 0]	[0 2 3]
O1 [1, 2, 4]	[0, 3, 5, 6, 7]	[3, 5, 6]	[2 2 2 1 1 1 1]	[1 2 3]
I3 [3, 5, 6]	[0, 1, 2, 4, 7]	[1, 2, 4]	[2 2 2 1 1 1 1]	[1 2 3]
I2 [2, 4, 5]	[0, 1, 3, 6, 7]	[0, 1, 3]	[2 1 2 1 1 2 1]	[2 2 3]
O2 [2, 3, 5]	[0, 1, 4, 6, 7]	[4, 6, 7]	[2 1 2 1 1 2 1]	[2 2 3]
I1 [1, 3, 4]	[0, 2, 5, 6, 7]	-	[2 2 1 1 2 1 1]	[1 3 3]
I3 [3, 4, 6]	[0, 1, 2, 5, 7]	-	[2 2 1 1 2 1 1]	[1 3 3]

Table 1: Intervalar Intersections between psets *derived from [0, 1, 3] and its complements. The distribution types are established from positioning of pitches relative to the median point of universe-set R = [0, 1, 2, 3, 4, 5, 6, 7].*

Table 1 also shows pairwise arrangements of [0, 1, 3] versions related to the specular structure of *p-space* (*ibidem*, p. 55), called here as *distribution types* (Table 1, last column), always formed by a pair of original/inverted versions of the *pset*. They share complements with the same intervalar vector and are described by specular indices, taking the center of the universe-set as a reference. For instance, coupling the universe-set *R* = [0, 1, 2, 3, 4, 5, 6, 7] with the positions indices I = [0 1 2 3 3 2 1 0] give us five distribution types ([0 1 3], [0 2 3], [1 2 3], [2 2 3], and [1 3 3]), that describe the situations of each of the pairwise versions.

The topology of these segmentations implies some symmetries involved in Forte's K relation. For example, the pair O0 [0, 1, 3] and I2 [2, 4, 5] divide the aggregate into 013|67|245. *nA* [67245] and *n(f(A))* [01367], as any other pair or intersection, are in a K relation.

The *psets* defined by Xenakis in *Herma* (named *A*, *B*, and *C*) are way longer (26, 21, and 25 pitches, respectively). Unlike the previous example, there is no complete intersection of versions between these *psets* (*f(A)*, *f(B)*, and *f(C)*) and their complements (*nA*, *nB*, and *nC*). To assess the intervalar invariance, we must then consider all possible intersections between the complement and all the *subpsets* found in all the versions. This prospection applied to the *psets* of *Herma* is shown in Figure 2. *Subpsets* cardinality range from three to the cardinality of the *pset* itself. In the resulting graph, each marker represents a *subpset* that matches with pitches of the complement of the original *pset*. Each circle represents a transposed version of the original *pset*; each dot stands for an inverted version.

The widest intersections found in each set/complement pair indicate, through an index (henceforth, *IIUC — interval invariance under the complementary relation*), how much of the original *pset* intervals can be found in its complement, considering the number of derived pitches – the unity

2 *O* stands for the normal form and *I* for the inverted one. The number indicates just the first (or, in this context, the lower) pitch of the version.

corresponding to an integral intervalar intersection, and zero to a null intervalar intersection.

1. A/nA: IIUC = 0.88 (23/26) – version I40.
2. B/nB: IIUC = 0.9 (19/21) – versions I16 and I31.
3. C/nC: IIUC = 0.88 (22/25) – version O18.

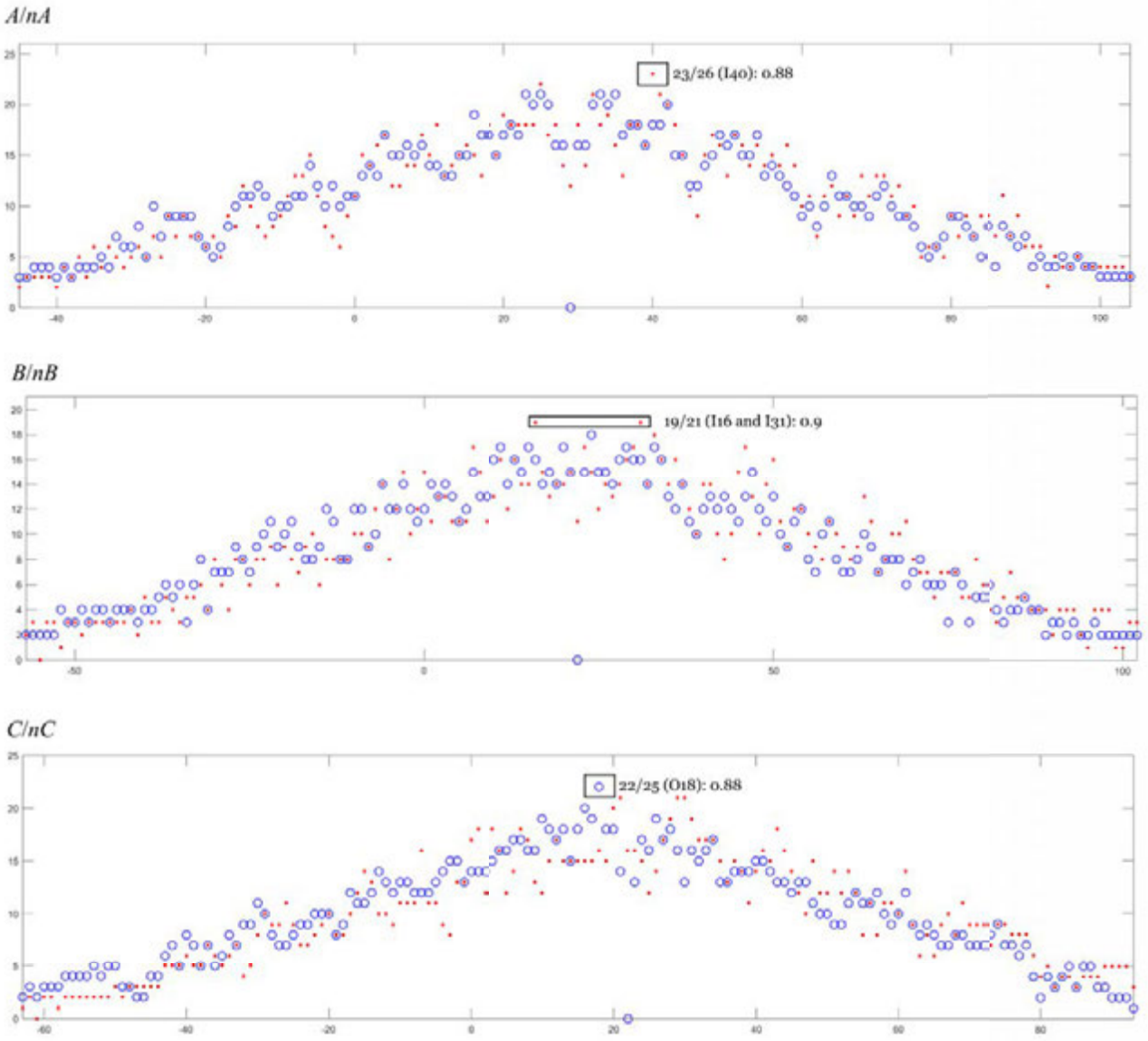

Figure 2: Intervalar invariance between psets A, B, *and* C, *from* Herma *(Xenakis, 1992, p. 173) and their complements* nA, nB, *and* nC. *The vertical dimension reflects the cardinality of the* subpset. *A square marks the maximum intersection, displaying the number of pitches of the intersection, number of pitches of the original* pset, *version name, and intersection index.*

To understand these indices, one must consider the relationship between the scopes of sets *A* (29-98), *B* (22-105), and *C* (22-108), all very close to the limits of the universe set (21-108). The positions of the sets are very interspersed, as noted by Wannamaker (2001, 3.8 and 4.13). Even with this level of overlap, the intersection rate is high. This level of matches can be just the result of a random distribution of points with this density - 88% matches in 88 keys, in the case of set A.

The case of partial intersection between a *pset* and its complement implies another relation devised by Forte: the *Kh*. The *IIUC* of the pair *A/f(A)* involves the partitioning *A | A∩f(A) | nA∩f(A) | f(A)∩A*. In this expression, the union of the three last segments corresponds to *nA*. On the other hand, the first three segments are the complement of the intersection that generates the *IUCC* index

Let's take three sample files rendered by *Herma Applet* (*AltHermas*, which are built based on discrete uniform random distribution) as a reference for comparison. One can see the inverse relationship between the density of the file and the IIUC, as all *psets* have the same approximate overlap with the universe set (21-98, 21-108, and 22-108). As an illustration, there are three versions of the *pset A* in the list below. The first and second are comparable in cardinality to the Xenakis' *pset A* (20 and 24 pitches), resulting in an equally correspondent IIUC (0.86 and 0.82). On the other hand, the third *pset* is denser (55 pitches) and, although it presents a scope similar to the formers, the result is a lower IIUC (0.47):

1. *AltHerma 01*, *A/nA*: 86 (20/23) — versions O26, O27, O31, I34, and 35.
2. *AltHerma 02*, *A/nA*: 82 (24/29) — version I20.
3. *AltHerma 03*, *A/nA*: 47 (26/55) — version I22.

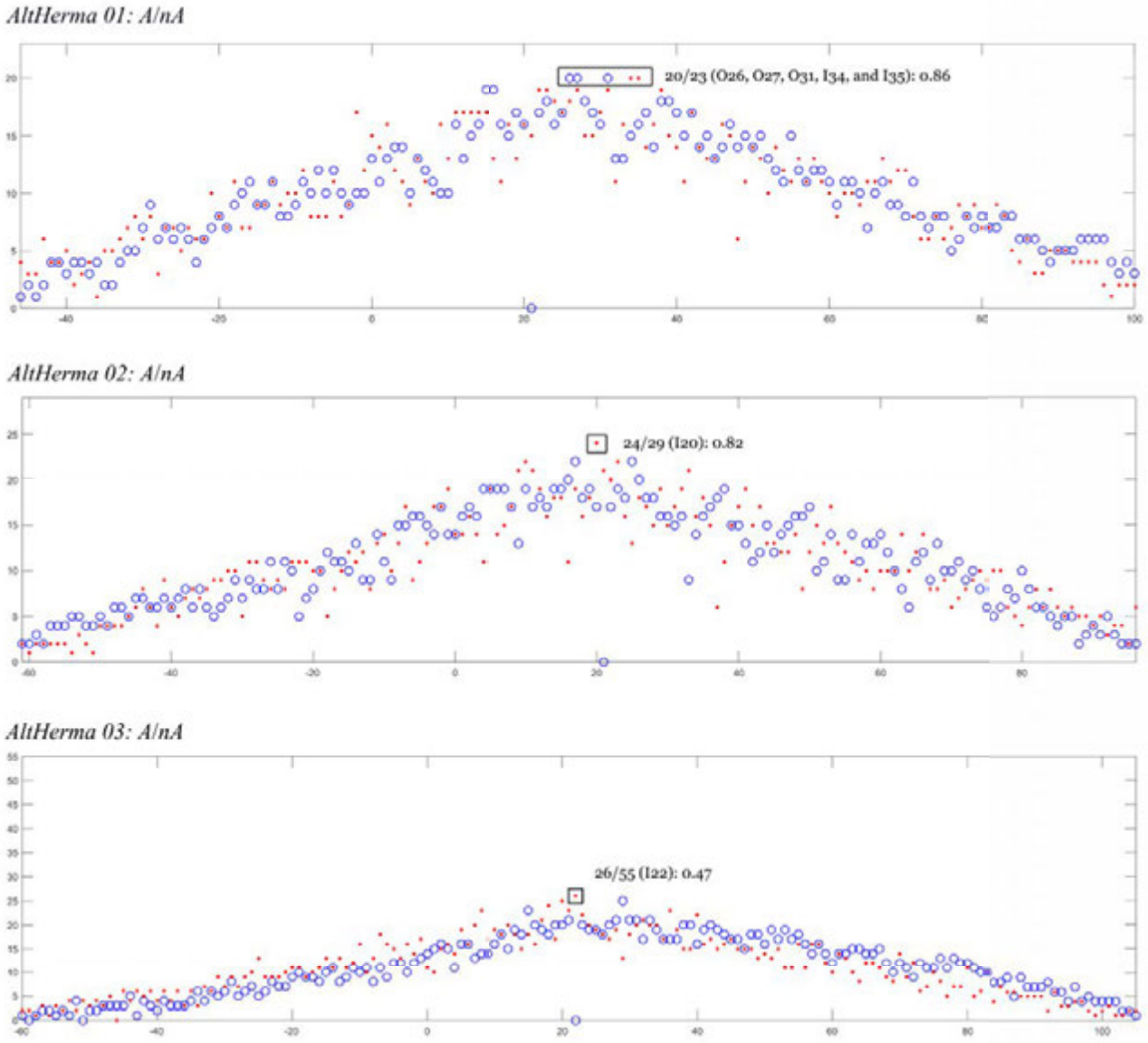

Figure 3: Intervalar invariance between psets A *and their complements* nA *in three sample files rendered by the program* Herma Applet *(Gentil-Nunes, 2022; see Figure 2)*

The random uniform distribution can produce IIUCs comparable to *Herma*'s *psets*. Even so, this observation must be coped with the work of Squibbs (2000, p. 6), related to the linear distribution of intervals and an exponential distribution of other dimensions of the piece, or the option for the *ArcSin* distribution of pitches by Agon et al. (2004, p. 150). Refining and expanding the method of comparing IIUCs in distinct distributions is a task for future work. The contrast between the *psets* of *Herma* and its complements is likely to be negligible, a circumstance which will constitute a critical point to

address in the following sections.

4. Extending the method

Aiming to explore new creative possibilities and complement our analysis of the compositional design used in *Herma*, we have implemented a modified version of Xenakis' theoretical model. The resulting software, capable of producing musical fragments with this alternative modeling, was named *Hermoser*, developed in the programming language *Python*. In the following lines, we will explain *Hermoser*'s main features, report our experiments, and analyze some of the software's outputs.

4.1. Proposals: Size Parameter and Interval Constraints

We must now explain the possibilities of generating musical outputs using *Hermoser*. At first, the user may set the two basic parameters for the music generation. The first one concerns the size of the universe pitch set. As Wannamaker mentions, using large sets makes it hard to perceive the respective collection of pitches as a unit, which harms the listener's ability to recognize when the same pitch set (or a related one) returns at another part of the music. To overcome this issue, *Hermoser* has a *size* parameter that allows the user to configure the universe set comprising 12, 24, or 88 pitches, which is *Herma*'s original value. The advantage of outputting a small-sized *herma* is to provide a well-behaved environment where the nature and expressiveness of *psets* can be more clearly studied.

The other parameter for running the software is the *generation method*. The user may choose between Xenakis' original approach (but with the possibility of varying the universe size) and our extended one, which we have called the *Set-Oriented* method.

The *Set-Oriented* method is based on some modifications at the pitch selection step for sets *A*, *B*, and *C* and the musical parameters manipulated by the set algebra operations. As mentioned in the previous section, the complementarity relation over *psets* by itself does not guarantee a sense of contrast. A set and its complement can share a considerably large number of interval substructures, depending on its range and position in the universe. Furthermore, this is not the only contrast to consider if the listener's ability to distinguish over the different *psets* is desired: it is also important to look at the intervalar content of sets *A*, *B*, and *C*. It is evident that randomly choosing the primary sets brings some similarity between them in many cases, especially on small-sized fragments.

For instance, if one chooses sets *A* and *B* to be the pentachords [0, 1, 3, 4, 8] and [2, 5, 6, 7, 10], respectively, their intervalar vectors (in *pc-space*) would be the same: [2, 1, 2, 3, 2, 0][3]. In other words, it means that under the interval perspective, these *Outside-Time* structures are very similar to each other. Thus, there is a considerably high chance of repeating interval patterns (or their inversions) when randomly manifesting them in time.

So, the *Set-Oriented* method tries to ensure the difference between the sets by adding some constraints when drawing the pitches. The first set to choose, set *A*, is randomly drawn without any restriction. The following sets are also selected randomly, but they are only accepted if we can assert that the intervalar vector of each one presents a minimum difference from the vectors of the other two. This reference value is computed as the summation of the element-wise difference between the vectors. Let us consider the sets [1, 3, 6, 8, 11] and [3, 5, 7, 9, 10], which the respective intervalar vectors are [0, 3, 2, 1, 4, 0] and [1, 3, 1, 2, 2, 1]. Their difference would then be 1 + 0 + 1 + 1 + 2 + 1 = 6. Indeed, we have defined this arbitrary value of 6 as the lower bound for a set to be accepted and used in the process.

3 It is, not by accident, a pair of Z-related sets.

2.2 Proposals: Duration and Dynamics Sets

In *Formalized Music*, Xenakis extensively explains his conception of the three algebraic constructions that give a basis for the Symbolic Music theory. At some time in the explanation, the author presents an *Outside-Time* sonic event as a <*h*,*g*,*u*> vector, in which *h* represents the pitch value, *g* is the intensity and *u* is the duration of the event. The author brings these three components as the main elements of a sonic event. However, at the presentation of *Herma*'s compositional design, we see that the set algebra manipulates only the *h* parameter. This fact must seem like a minor issue since one could claim that the intensities and durations are also being handled at the *Outside-Time* domain, as the composer chooses these parameters to enhance the perception of the set operations. But the point is that, since Xenakis wanted the sets to be heard and recognized, it would also make sense to encapsulate durations and intensities within sets, so that any prominent element in the piece would reflect a property of the respective set.

For this reason, the *Set-Oriented* method also uses sets to manipulate these two other parameters. The entire process follows these steps:

1. At the start, each set receives five pitch-classes, constrained by the minimum intervalar difference value. Depending on the chosen universe size, the pitch-classes are extended to the remaining octaves, filling the *p-space*.
2. The durations related to each set are also drawn from an arbitrary duration universe, in a process similar to that of the pitches.
3. A quantity of prime numbers is randomly selected for each set, which will serve as a basis for computing the *midi velocity* value, representing the dynamics of the respective section.
4. Then, for each section of the piece, the notes are played with random pitch and duration, drawn from the corresponding set. The intensity of the note is the same for every note within the same section.

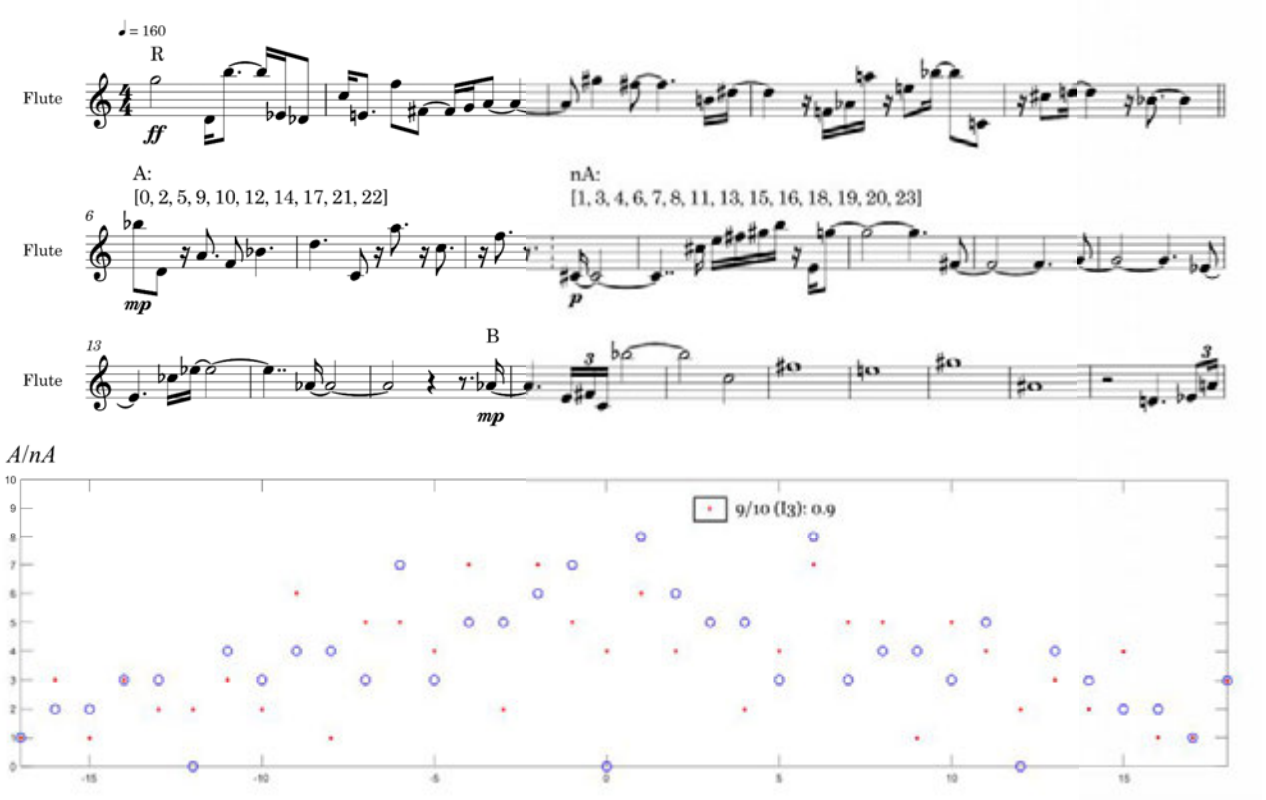

Figure 4: Intervalar invariance between psets A *and their complements* nA *in a* small-sized herma *rendered by the*

program Hermoser *(Simões, 2022; see Figure 2).*

The third step can bring a certain surprise to some of the readers. Why distribute prime numbers to the sets instead of the *midi velocity* values? The motivation for this is that handling the dynamics in the same way that we handle pitches and durations would mean that each note would have a different intensity, which would probably make the music even harder to play. Another possibility could be to distribute the dynamics but select only one value for each section. However, it would harm the set recognition since the same set could appear multiple times with different dynamics.

Thus, to handle the dynamics, it was necessary a Boolean algebra in which a set could be represented only by a single value. This representation is accurately done by a *square-free Boolean algebra* – an algebra whose domain *A* is the set of all the divisors of a given product *pqr*… of prime numbers and whose Boolean operations *or/union*, *and/intersection*, and *not/complementation* are respectively GCD(m,n), LCM(m,n), and *pqr*…/*n* (the quociente of *pqr*… by *n*), for all members *m*, *n* of *A*.

For a glance at this procedure, we take an example of small-sized herma-like composition in Figure 4. First, a two-octave universe set (*R*) is exposed in the first five measures, followed by the presentation of the set *A* and its complement, *nA*. The IIUC between *A* and *nA* is near Xenakis' *B pset* — 0.9, with an intersection of 9 out of 10 pitches between *nA* and *I3*. In this short excerpt, the pitches, durations, and dynamics follow the *Set-Oriented* method, enhancing the recognition of relations between the involved *psets*.

5. Perspectives

As we have seen, the evaluation of the outcomes produced by our programs ended up bringing together some essential relationships from the Musical Set Theory (such as Allen Forte's *K* and *Kh* relations). Measuring IIUC in *p-space* through surveying all intersections between *subpsets* has a remarkable possibility of didactic application in musical analysis and composition. Generating *Herma-like* compositions through the *Set-Oriented* method can also be a fruitful application for pedagogical and creative purposes. Furthermore, one can apply all of these procedures to other musical domains, such as rhythm and timbre, a subject we leave for future work.

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Xenakis's Matrix to Image Matrix: A Sonification Method Inspired by *Achorripsis*

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Abstract

This paper presents research on data sonification that primarily focuses on digital image data to compose algorithmic music. The main focus is escaping from the bottom-up approach that is ingrained in generative music and building the ground for multiscale formal strategies on sonification. The proposed composition method is inspired by the theories and techniques developed by the composer Iannis Xenakis (1922 - 2001). He creates a matrix for his piece Achorripsis (1957) with columns that represent time and rows are groups of timbres. He employs the Poisson formula to fill the cells with values to manifest his macrocompositional design. Even though he uses a probabilistic distribution method for his algorithmic way to generate music he managed to avoid the pitfalls of bottom-up strategy and has control over the form of music as a composer. The matrix has a strong resemblance to a digital image which is a collection of pixel values in a rectangular shape. Even further we parse a digital image file and convert it to an actual matrix in the programming environment. An image has its own formal structures that we can observe easily. Each cell which is a pixel or a group of pixels is already filled with data that can be subjected to sonification. In this research to preserve the high-level relations that occurred in images, a machine learning algorithm is used for segmentation. Selecting few segments generates large chunks of data which helps us to define high-level, form-defining elements. The procedure is repeated with a higher number of segments to let us make more granular-level decisions. Our method is backed by a bespoke computer program written by the author to streamline technical processes and aims to be flexible to support diverse artistic ideas. The software is built on Python programming language (the leading platform for data analysis and machine learning) and processes input data to generate audio with Csound audio programming platform. Using a digital image in this method has the following advantages over other types of data sonification: The structure of image data is well-defined and helps us to automate data-specific laborious tasks like cleaning, fixing, and restructuring that makes the research repeatable with different sources conveniently; an average size image file provides sufficient data points; it is easy to access a wide variety of image files; the current research on digital image analysis and processing (including machine learning) has the potential to create new opportunities for our work. The musical work will exemplify the main workflow and mapping strategies to handle multiscale strategies will be discussed.

1. Introduction

Data sonification is a technique of translating data into non-speech sounds. (Kramer, et al. 1999) It can be regarded as a scientific procedure that prioritizes accuracy and tries to achieve objectivity or

artistic practice which seeks convincing narrative and relies on subjective matters. Considering sonification as a tool in algorithmic composition or generative music, (Spiegel 2018) helps us to put that effort into musical perspective. Many sections of algorithmic music that utilize the mapping data value onto musical parameter suffer from the problem we present here in the sonification domain: The process of composing bases on bottom-up approach (Roads 2015) which musical form is expected to reveal itself over time depending on the fluctuations of data. Composers abstain from constituting macro-level organizations. This approach works very well in large time scale works with days of duration and sound art which are not considered to be consumed by an audience from start to finish. But if the composition is assumed to listen to in one sitting then the audience should work with their memory to construct and relate sections of music temporally. Our proposal is a multi-scale composition model that employs image data sonification with inspirations from theories and works by Iannis Xenakis. We present the preliminary results of the experiment to demonstrate how the model can be applied to compose electroacoustic music.

Supper (2001) presents that composers deliberately build the formal structures by constructing algorithms for their musical expression needs either to realize established tonal or serial music like Lejaren Hillar and Koenig did or a novel form as Clarenz Barzow in his piano piece *Cogluotobusisletmesi.* In both cases, the algorithms are only a tool to help composers. On the other hand, he examines the use of extra-music algorithms like L-systems derived from chaos theory by the composer Hanspeter Kyburz. In this case, the form is the direct outcome of the algorithm without leaving too much to the composer. Roads (2015) discusses the design strategies regarding material-form relations. “The top-down approach starts by predefining a macroform, a template whose details are filled in at later stages of composition.” Traditional forms like sonata, rondo, etc. can be considered as an example of the top-down approach. They are a set of rules that composer creates suitable sound materials. On the other hand, the bottom-up approach “constructs form as the final result of a process of internal development produced by interactions on low levels of structure” Sequence layering, indeterminacy, and generative algorithms are examples of the bottom-up approach. Roads proposes the multiscale strategy that the composer can employ both approaches moving in different (micro and macro) timescales according to the needs of the composition process.

Nick Collins (2009) states that form was not one of the main concerns in algorithmic music. Yet he lists the following generative techniques that might result in novel formal structures:

1) Self-similar structures; recursive definitions, fractal music;
2) Stochastic music, information theoretic constructions;
3) Emergent form (as a by-product of complex lower level activity);
4) Artificial musical grammars.

We can argue that “self-similar structures” and “emergent form” can be considered as a part of the bottom-up approach whereas “artificial musical grammars” as top-down. Iannis Xenakis shows that in “stochastic music” a composer can employ both approaches that link us to multiscale form building strategies as we investigate in this paper.

2. Image data

In order to build a composition model that is based on sonification, we need relatively large data structures so that we can map as many sound parameters, and create mid to large-scale works. A digital image file is made of pixels that are defined as RGB (Red, Green, Blue) values. A 24-megapixel camera captures 24 million pixels with each one holding three values for Red, Green, and Blue which yields 72 million data points. For reference, a simple audification (direct converting data to audio) of that data would produce 27 minutes of audio at a 44.1 kHz sampling rate. The resources are abundant and it is easy to access or create digital images that can help to replicate the experiments with different data files. Since image data is already a visualized form of data, browsing for it and

further exploration is easy and intuitive. The structure of the digital images is well established. JPEG specification which is a widely used compressed image format was first published in 1992 (Pennebaker & Mitchell 1992). Software packages and libraries are developed to parse, convert and manipulate different image formats. This capacitates the automation of laborious data preprocessing for successive experiments. However, the sonification of an image is tricky due to its formal structure and perception that differs wildly from music.

2.1. Achorripsis

Achorripsis is a piece composed in 1957 and can be seen as the realization of the Phases of Composition idea. The piece was composed for 21 instruments which were grouped in seven timbre categories: Flute (piccolo, clarinet, bass clarinet), oboe (oboe, bassoon, contrabassoon), brass (two trumpets, trombone), percussion (xylophone, woodblock, bass drum), pizzicato, string glissandi, string arco (3 violins, 3 violoncellos, 3 contrabasses). He constructed a matrix with 7 columns that each one is dedicated to one of the timbre groups. On the horizontal axis, he used 28 rows as equal time units. The music is planned to endure 7 minutes then each time unit is 15 seconds. Each cell of the matrix was filled with event definitions, like no event, single event, double event, triple event, and quadruple event. Events determine the density of a timbre group at a particular time. The total number of event types was determined by using the *Poisson* formula. The *Poisson* formula is a mathematical equation that calculates the probability of an event based on the Poisson distribution. Xenakis used different probability distributions in his compositions like *Poisson, Cauchy, Gaussian*, and *Uniform* distributions. "*Poisson* distribution is used to model processes where the distribution

of the number of incidents occurring in any interval depends only on the length of that interval" (Attenborough, 2003). The *lambda*, mean value of the distribution was arbitrarily chosen as 0.6 to produce at least one quadruple event, 4 triple events, 19 double events, 65 single events, and 107 zero events. in the 196 cell matrix. The events were spread into cells again using the Poisson formula. We can follow phases in the compositional realization of Achorripsis. Xenakis started with initial ideas (timbres, density of clouds) then created a macro-compositional model with the matrix. From top to down he meticulously calculated every event until he reached the symbolic output of the music which is notation. The formal structure is not emerged due to the musical mapping of stochastic calculation on to basic vector of a note as pitch, duration, and amplitude. "Poisson distribution is used to model processes where the distribution of the number of incidents occurring in any interval depends only on

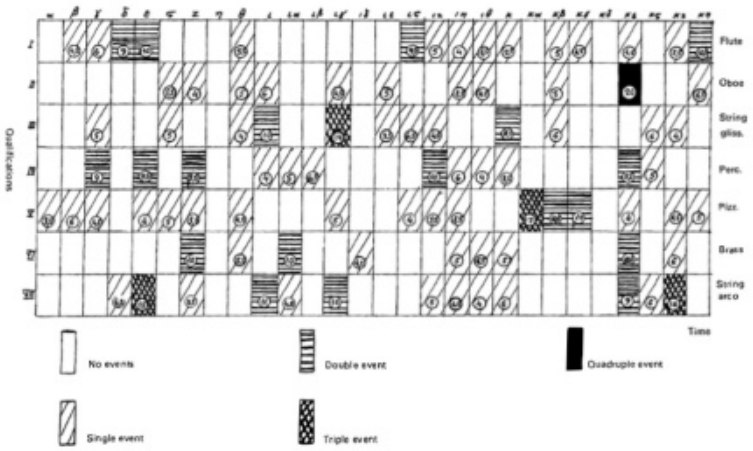

Figure 1: The matrix that Xenakis designed for Achorripsis

the length of that interval" (Attenborough 2003).

3. Xenakis' matrix to image matrix

The pixels are arranged as rows and columns in a typical image file. When we parse an image file in a programming environment we create a matrix structure with rows and columns. Reversely we can generate a matrix and then visualize it. If we wish to create an image with 7 rows height and 28

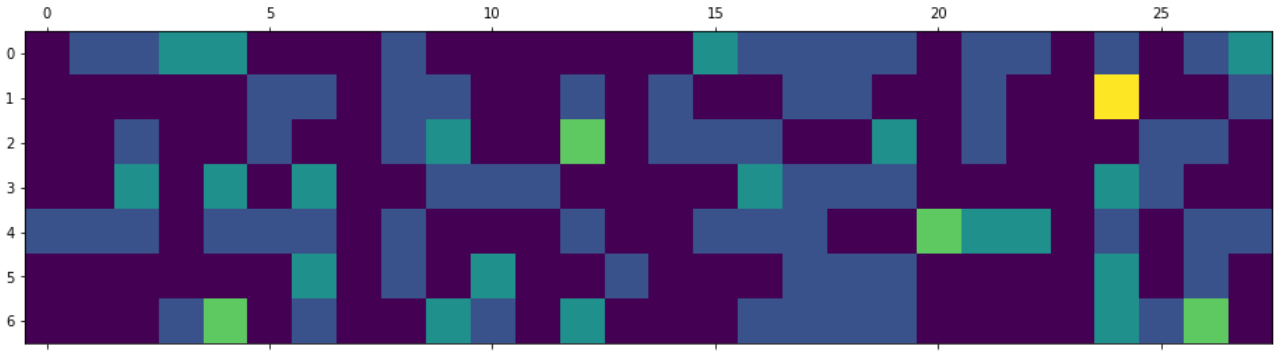

Figure 2: Achorripsis Matrix recreated with color-coding

columns width and assign event values like zero, one, two, three, and four to each cell and color-code them we end up in a two-dimensional space that resembles Xenakis's matrix for Achorripsis.

The visual similarity between an image matrix and Xenakis's matrix sparks the possibility of transferring strategies that Xenakis employed to image sonification. We can set the timbral qualities on the vertical axis and use the horizontal axis for durations. Since an average image file allows plenty of data points we can map many of the parameters of instruments. To begin with the top-level organization of the work, we need to reduce the amount of data. Dividing the time axis equally would result in a pixelated version of the picture which does not present the shapes and patterns we observe in the original picture especially when the pixel size is big. It would also lead to changing the values at the same intervals and synchronously. We need to keep the structural quality of the image while dividing it into sections at different detail levels. The desired process can be illustrated as follows: If we look at a picture from a distance we experience large sections of colors and shapes. When we get closer and closer to the painting new details are revealed at each step until we can see the brushstrokes of the painter, the cracks in the paint layers, subtle color gradients, etc.

The research in computer vision provides tools for dealing with difficult tasks. Superpixel algorithms can group pixels according to similarities in color, brightness, and other low-level properties at a very high success rate. (Ren & Malik 2003) Superpixels are powerful to retain the overall look of an image while diminishing data. The size of the superpixels and the number of superpixels that can be found in an image is inversely proportional. If we divide an image into a higher number of sections we will lose more details but we obtain a more general view that we can use for parameters we demand to change less often. We opted to use SLIC (simple linear iterative clustering) superpixel algorithm that utilizes a k-means clustering, a machine learning algorithm. SLIC is simple to use, fast, and successful at detecting boundaries. (Achanta et al. 2012) Speed of the algorithm is important for testing different segmentation strategies. Depending on the arbitrary number we defined for the number of segments, the SLIC algorithm tries its best to identify similar areas. If the chosen number of segments is low then larger areas are selected by the algorithm. Increasing the number produces smaller segments, hence a more detailed picture. Then the next step is averaging the values in each segment. When we draw a line horizontally through the picture we get changing values that we can use for any parameter in our musical design. Thanks to the vast amount of data an image file can provide we can draw as many lines.

Figure 3: Segmentation with SLIC algorithm at different levels

To test our method we've used a picture with 600 px width and 400 px height that one of the authors took with the Sony A6000 digital camera. The programming environment was Python which is popular amongst the data science and machine learning community. Using the *scikit-image* library we were able to implement the SLIC segmentation (van der Walt et al. 2014). We decided to use 30, 90 and 300 segment numbers and the non-segmented version after experimenting with several other options. 30 segments provided the largest sections as expected. The segment areas got smaller as the segment numbers rose. In image segmentation, the extracted data layer with horizontal lines on the picture was plotted to visualize the transformation for a better understanding of the result of choices with location and segment numbers.

For our purpose of validating the usefulness of the image sonification method the sound generation algorithm should have been relatively simple yet versatile. We picked granular synthesis for the

project since it can generate variable textures with controlling few parameters. Granular synthesis is a method to get the slice of audio preferably less than 100 ms and then combining those sound portions in large amounts to create cloud-like textures (Roads 2001). The sound realization of the piece was accomplished in Csound, the audio programming environment. Csound can work in the orchestra (the instrument definitions) and score (note-events) paradigm (Boulanger 2000) so that we were able to generate a score file in Python as a list of values that describes the changes in instrument parameters. Csound renders the instrument and score definitions as an audio file which can be a short process. This workflow enables us to experiment with several options while keeping the results as Csound score file and audio file for further analysis. The software instrument is based on Csound's *grain*[1] opcode that we chose to map the *grain duration, density, and pitch* parameters since they are the most definitive ones on the sonic quality and the texture. The variability on the sound was achieved using separate *grain* functions for left and right channels while keeping grain duration, density and pitch the same but assigning random values for amplitude and pitch offset parameters. The only parameter for the blandly added reverb is the amount of the effect to the dry signal. The instrument accepted the 567 milliseconds of a cello sound as input which was demonstrating a forced bow gesture. Keeping the duration longer resulted in more like a sampler instrument sound against the granular sound which created enticing contrast throughout the piece. The piece was designed to endure 3 minutes for 6000 data points that allow 30 milliseconds for each data point. At each step, values are calculated and

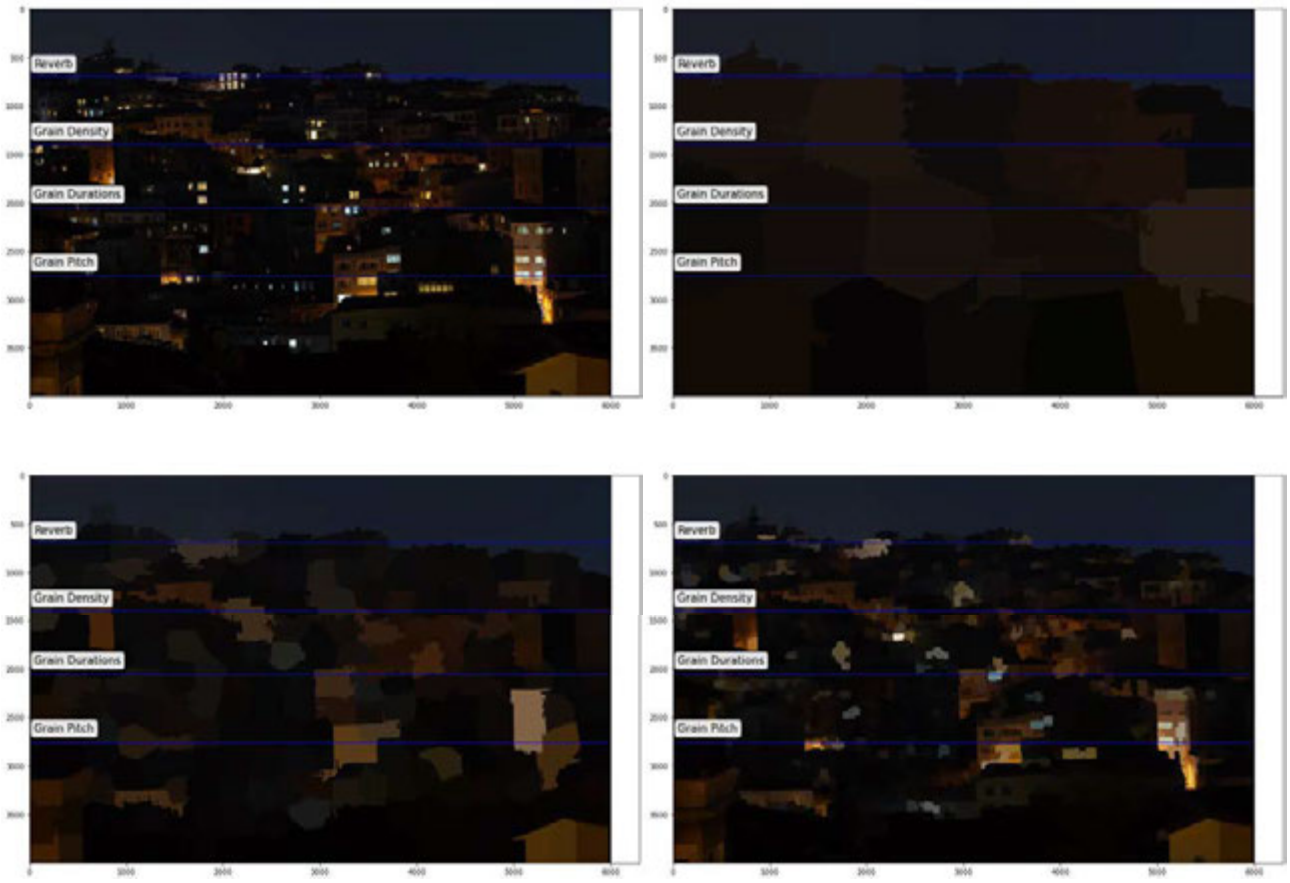

Figure 4: The blue lines represent the music parameter/image data mapping at each segmentation level

written to a text file for rendering in Csound later. The minimum and maximum values for mapping were based on the explicatory needs of the demo piece.

1 https://csound.com/docs/manual/grain.html

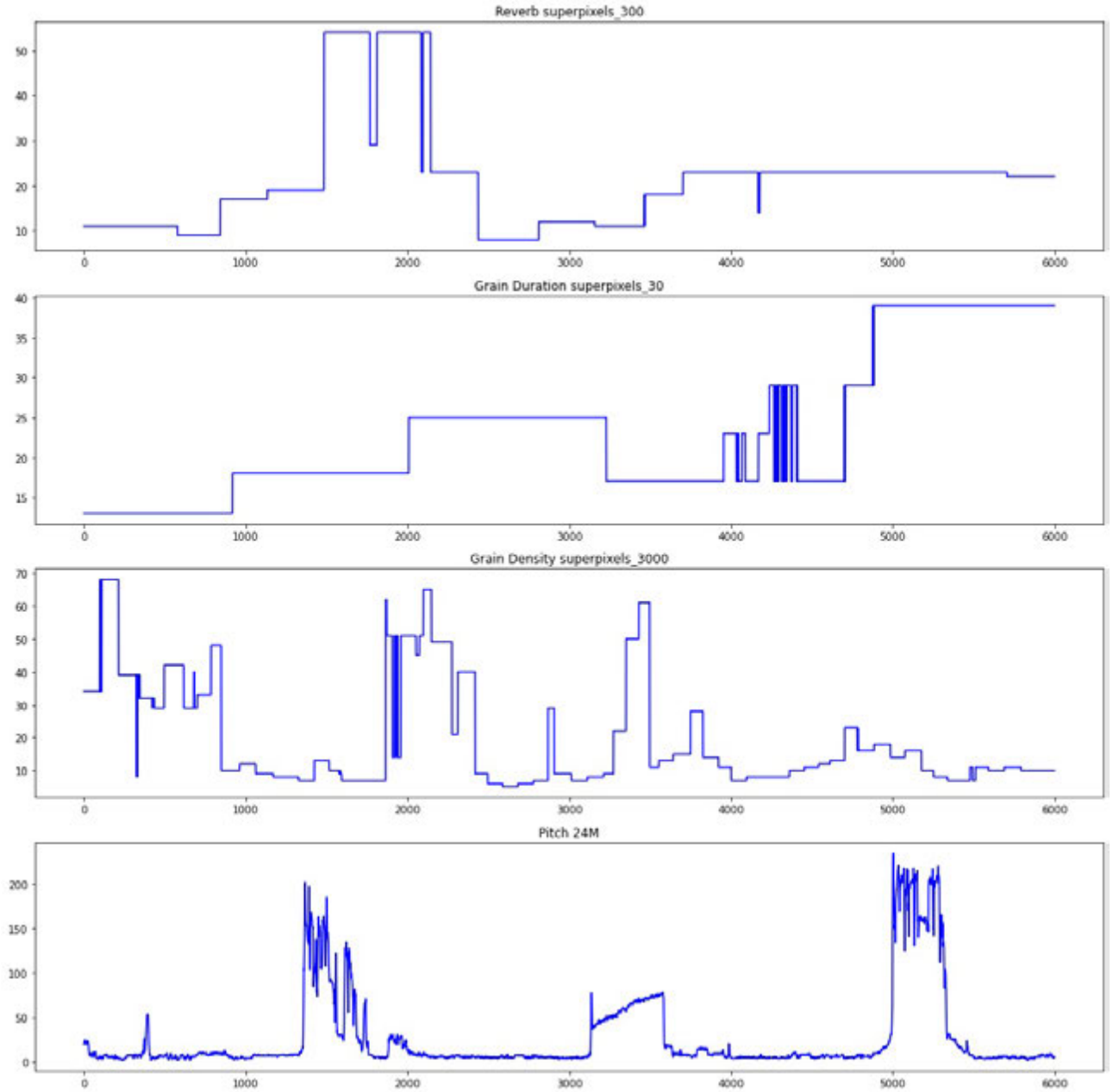

Figure 5: Visualization of extracted data from the image for each parameter and selected segmentation

We mapped data onto musical parameters at different time scales with image segmentation. (fig.3 and fig.4) In the course of the piece, parameter values remained the same for the allocated time which resulted in significant formal structures. The generated audio demonstrated that with image sonification it is viable to create a multi-scale form that overcomes the bottom-up approach inherent to sonification and algorithmic music in general. However, we should note that we had to make some design choices to make this experiment easy to process and evaluate the results: The duration of the piece was rather short; A single instrument with a limited number of parameters was used; Many aspects of electroacoustic music had to be dismissed. The proposed method will be more convincing in large-scale compositions with numerous instruments and parameters.

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Reconstruction and interpretation of ancient history to build a national identity

Focus on the Polytopes de Persépolis by Xenakis (1971) Sahereh Astaneh, Music and Dance Studies, Paris Lodron University of Salzburg, Austria,
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Abstract

On August 26th 1971, the avant-garde composer Iannis Xenakis presented the performance Polytope de Persépolis that was commissioned for the Shiraz art festival in Iran.

The performance took place at the opening of the festival at the ruins of Persepolis. Between the 12th and 16th of October1971, a month after the premiere of Polytope de Persépolis, the Shah held a state reception with heads of government and royals from all over the world in the ruins of the Achaemenid palace Persepolis to celebrate the anniversary of the Persian monarchy. It was a gigantic festival with a sound and light show, which was inspired by "Polytope de Persepolis“, and a parade with costumed soldiers who represented the different epochs of Iranian history. Eight years later, the Islamic Revolution occurred in Iran: A complex movement that led to the ousting of Shah Mohammad Reza and the end of the monarchy in Iran. This article is about the Interpretation of ancient history to build a national identity, with the focus on the spectacle Polytope de Persépolis by Xenakis (1971). The following research question leads the approach of this article: How did Iannis Xenakis interpret and reconstruct the historical Iranian culture for 'Polytope de Persépolis? The present work gives an overview of the consequences of cultural-political decisions in modern Iran. Furthermore, the reactions to the religious and political impact will be examined. In accordance with this, the work consists of three parts: at first, a brief explanation of the Shiraz Festival. The second part deals with the Polytope de Persepolis of Xenakis (August 1971). Finally, both parts are analyzed regarding their religious and political implications.

Nation Building in the Pahlavi-Dynasty

During the Pahlavi dynasty’s rule (1925- 1979), reforms towards the modernization of Persia received great momentum[1]. This unprecedented program of reforms targeted all areas of life including education and culture.

To create a modern Iran, Reza Pahlavi and the state supported Western music and theater as a modern art form, realized its educational potential and intended to use music and theatre as a means to propagate its modernist and nationalist message. Various styles of art flourished during this period, such as ancient Persian culture, folk art and western contemporary art. Because of political and artistic reasons, the Shah tried to strengthen the old Persian culture and combine it with the concerns of Western modernity.

1 Hormoz Farhat, “The Dastgah Concept in Persian Music”, Cambridge University Press, (1990), p.5.

The revival of non-Islamic Persian culture was an important element in the Shah's aim. He represented himself as the successor to the ancient Persian rulers and bringing to Iran speedy modernization and social reforms. [2]

Shiraz Arts Festival

Maria Anna Harley who was working on the Shiraz Festival, said, “To stimulate the interest of the international artistic community in ancient Persian culture, the Shah and Empress Farah Pahlavi selected the site of Persepolis for the annual Shiraz Festival (Shiraz is the closest city to the site of the ancient ruins of Persepolis). The remains of the buildings in this secluded fortress contained symbols of the Persian dynasty's absolute power: reliefs of tribute-bearers and inscriptions praising the king's greatness adorned the walls. In 331 B.C., Alexander the Great conquered the Persian Empire and destroyed the palace. The Site was deserted for the next 2,000 years.”[3]

The Shiraz Arts Festival was first held in 1967 as a performance for royalty. From the late 1960s until 1979, numerous famous avant-garde artists took part in the Shiraz Art Festival in Iran, among them Iannis Xenakis. He was a progressive thinker and activist throughout his life and a member of the Resistance in World War II. He had a successful alliance with the Iranian Shah and his wife. This alliance was of importance for the Shah's aim to reinvigorate ancient Persian culture and combine it with modern western artistic endeavors.

Empress Farah Pahlavi chose Xenakis to create a sound-and-light performance for the opening night of the 1971 Shiraz Festival. Xenaki's motivations were political, sociological as well as artistic. He was himself very active in the political movements and as a composer from Greece he was a good choice for the "Persepolis" project.

Light and Fire – a journey into the past

With his work "Persepolis", Xenakis tried to challenge the audience from different perspectives. As a matter of fact he moved the audience with his music into a liminal space by mediating artistical as well as sociopolitical aspects. In the analysis of the performance, these two perspectives can be differentiated. “Persepolis” is a so called polytopos, a mix of sound, light, colour, architecture and live performances with sculptures in the scenery, a theatre dimension, and a children’s choir. Light and fire play an important role as sacred symbols of the Zoroastrian religion and the government in Iran and are being contrasted with electroacoustic live music. In the Zoroastrian religion eternal life is sought in the patterns of light. [4]

Polytope de Persépolis took place in the middle of the desert and in the middle of summer as the opening spectacle of the festival. “At nightfall, Xenakis deploys an impressive artillery of technical material and human aid for over an hour […]. The material consisted of two laser beams, anti-aircraft projectors, large oil lamps, and torches carried by 150 men.” [5]

Maria Anna Harly describes that “the original performance consisted of 91 circuits for lighting effects scattered throughout the ruins of the palace, as well as eight loudspeakers […] arranged in an irregular semicircular pattern around the public. The listening area was located

2 cf. Harley, Maria Anna: Music of Sound and Light: Xenakis's Polytopes, Leonardo, Vol. 31, No. 1 (1998), pp. 55-56.
3 Ibid.
4 Harley, James: The Electroacoustic Music of Iannis Xenakis, Computer Music Journal, Vol. 26, No. 1, In Memoriam Iannis Xenakis (Spring, 2002), pp. 33-57
5 Gluck, Robert. “The Shiraz Arts Festival: Western Avant-Garde Arts in 1970s Iran,” *Leonardo* 40, no. 1 (2007): 22, http://www.mitpressjournals.org/doi/pdf/10.1162/leon.2007.40.1.20 (accessed 30.07.2021.)

outside the palace walls and, judging from the placement of the sound and lighting equipment, the audience was expected to look toward the palace. Xenakis indicated the location of 59 loudspeakers (plus 10 backups), the control center (poste de commanded), and once again in the ruins of the palace of the ancient Persian kings at Persepolis Gant celebration replete with fireworks.“[6]

The reactions to the religious and political impact

The performance of Polytope de Persépolis reminded parts of the Iranian audience~~Iranians~~ of their ’cultural memory‘, which had religious and political implications and conflicts. Joshua Jamsheed Charney said: „Regardless of Xenakis’ intention of meaning, the performance of *Persepolis* at Persepolis evoked a common history amongst the Iranian audience. Xenakis, as a Greek composer, played the part of the young Macedonian, Alexander the Great, in his conquering and subsequent rule of the Persian Empire, the first example of European imperialism in Persia. *Persepolis* was thus understood by some to represent what many in Iran were beginning to revolt against, the influence of an odd and unfamiliar part of Western culture that was forced on them from above.“[7]

Xenakis faced the greatest criticism not from those in Iran but from Iranians in Europe, particularly in Paris. The general criticism was that Xenakis was involved in a festival promoted by a repressive regime. On the 14th December 1971, Iannis Xenakis penned an open letter to Le Monde, defending his participation in the Shiraz Arts Festival and his political point of view: “What motivated me to go to Iran is this: a deep interest in this magnificent country, so rich with its superposed civilizations and such a hospitable population; the daring adventure of a few friends who founded the Shiraz-Persepolis Festival where all the various tendencies of contemporary, avant-garde art intermingle with the traditional arts of Asia and Africa; plus the warm reception my musical and visual propositions have encountered there by the young members of the general audience. [...] My philosophy, which I put into practice every day, consists of the freedom of speech, the right to total criticism. I am not an isolationist in a world as tangled and complicated as today’s. ... it is impossible to name one single country that is truly free and without multifaceted compromises, without any surrender of principles.”[8]

A combination of many factors, most notably his displeasure with the Pahlavi government, led to Xenakis ending his further involvement in the Shiraz Festival. He wrote to Farrokh Ghaffary, the festival's general director (addressed by Xenakis as P. Gaffray):

“You know how attached I am to Iran, her history, her people. You know my joy when I realized projects in your festival, open to everyone. You also know of my friendship and loyalty to those who, like yourself, have made the Shiraz- Persepolis Festival unique in the world. But, faced with inhuman and unnecessary police repression that the Shah and his government are inflicting on Iran’s youth, I am incapable of lending any moral guarantee, regardless of how fragile that may be, since it is a matter of artist creation. Therefore, I refuse to participate in the festival.”[9]

Between October the 12th and 16th 1971, a month after the premiere of Polytope de Persépolis and the fifth year of the Shiraz Arts Festival, the 2500th anniversary of the Persian Empire was celebrated. That year was announced as the year of Cyrus the Great. The Shah held a

6 Harley, Maria Anna: Music of Sound and Light: Xenakis's Polytopes, Leonardo, Vol. 31, No. 1 (1998), pp. 58.

7 Joshua Jamsheed Charney: The Shiraz Arts Festival: Cultural Democracy, National Identity, and Revolution in Iranian Performance, 1967-1977, University Of California San Diego, 2020, S.97.

8 Iannis Xenakis, Open letter to Le Monde, 14 December 1971. Translated in Robert Gluck, “The Shiraz Arts Festival: Western Avant-Garde Arts in 1970s Iran.” LEONARDO 40 (2007): 26.

9 Ibid.

state reception with heads of government and royals from all over the world in the ruins of the Achaemenid palace Persepolis to celebrate the anniversary of the Persian monarchy.[10] The Shah delivered a speech to link the glorious leadership of the ancient Iranian empire with the current leadership of the Pahlavi dynasty. He compared himself openly and enthusiastically with the Great Cyrus, whose affiliated with Zoroastrianism. On the one hand, the critics of the Shah's regime and the country's Islamist fanatics were provoked by the three days of celebration, on the other hand, international critics saw it as an act of political theater or a kitschy Hollywood staging.[11] About the Shah Festival, Shia cleric Ayatollah Ruhollah Khomeini, said from the exile: "Islam came in order to destroy these palaces of tyranny',[...] It is the kings of Iran who have constantly ordered massacres of their own people and had pyramids built with their skulls" [12] Eight years later, the Islamic Revolution occurred in Iran, a complex movement that led to the ousting of Shah Mohammad Reza and the end of the monarchy in Iran. [13]

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Levels of Multimedia Rhetoric in *Polytope de Persépolis* (1971). Defining Cyberworld Categories through Some Registers of Philosophy and Scientific Aesthetics

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Abstract

The multimedia topos *Polytope de Persépolis*, an architectural and cybernetic symbol-matrix conceived by Iannis Xenakis, overlaps rhetoric reiteration and the nature of *arche-trace* (Derrida). Dedicated to the Arts Festival in Shiraz[1] (Iran), the Persépolis polytope vibrates as a message of solidarity between cultures (nations), asserting that an ungoverned, de-politized culture will be capable to "always open to people the possibility of opposing options." (De Beauvoir 1966, 100-101) The trace borne by the ancient Persépolis in the Iranian desert – an atemporal attractor – has rewritten 'differences' by penetrating time windows in order to regulate the encounter of *Homo historicus* with *Homo algorithmicus* at the ruins of the temple built by Darius 3rd. Behind this trace, Xenakis, the visionary, architect, and composer, responded radiantly with a syncretic production, e.g., a dynamic model of conceptual installations reflected in points of bifurcation (e.g. specialized hypnosis) and asymptotic patterns. My paper focuses on defining the *cyber-rhetoric* which envelops the polytope; then, it suggests some hints to the "total semantic field" register (Henri Lefebvre[2]) (Turner 2012, 3) which favors the activation of several levels of lecture, orientated toward the built medial realm.

1. Introduction

Uniting his personal history with the "never completely constituted" (Ghideanu 1979, 116)[3] time of the being past, present, and future, Iannis Xenakis enlivens his thinking in an intermodal manner[4], which he provokes through alliances: music, architecture, history, philosophy, sciences. Through his polyvalent education, Xenakis acquired the freedom to define his artistic intentions by discovering – when he ponders on his personal history – archetype networks that are present in the history of mankind, in the eternity of the moment (*idem nunc*), as Meister Eckhart[5] saw it. This

[1] with its premiere on August 26th, 1971

[2] Philosopher whom Xenakis studied

[3] T. Ghideanu p. 116 apud. Merleau-Ponty: *Phénoménologie de la perception*, Gallimard, Paris, 1949, p. 474

[4] Intermodal links indicate the movement of the nerve trajectory connections, which register an abundance of sensory perceptions. Activating an intermodal connection is related to the readiness of the brain to make flexible and develop its competences'. In the case of Iannis Xenakis, these competences were exceedingly developed. Cf. Troge, A. Thomas 2013, 37

[5] Meister Eckhart reflects on the consistency of the moment in *Expositio libri Genesis* (dated from the beginning of the 14th century), asserting that "the beginning is the inaugural and simple moment of eternity […]" (Vieillard-Baron 2000, p. 124), what means that the onset of the first moment represents the onset of the creation of history, in the timeline of which lie all past, present, and future histories (regardless of the intensity of their accents; I also mean here, of course, the macro-dimensional, and the individual, intimate history of a human being).

eternal image-moment reproduces "a retention […] of differences, a spacing and a temporization, a game of traces" (Derrida 2015, 42) – noise of past civilizations – also containing the sacred-historical one, "where God renounces to be hidden, in order to reveal himself" (Vieillard-Baron 2000, 123) which breathes right next to Xenakis. Thus, the history of the deeds from the Greek Ancient Epoch – for instance – appears in reality as an abbreviation of a time gone through long ago, which manifests in a recurrent manner and alternates with the rumbling sound of a present and unabridged history, that of the composer. Therefore, a massive, macro-dimensional, volcanic history, being there as it wants to say something, is projected through subtle relays into an intimate, individual history. The symbolic spectacles: *Polytope de Persépolis*, *Polytope de Cluny*, *Polytope de Mycenes* reveal themselves to the mind's eye as its awakenings, after stasis conditioned by memory, which, when it does not shut itself off again (in order to return), narrates in a circle ('eternal return') the story of the dislocation of historic time. Putting aside threshold after threshold, Xenakis reinvented a model of learning history. Trained in this learning, he reunited skills of penetrating the atemporal cosmic program, testing its infrastructure, proving a clear manner of working, like a scientist. To follow the arrow of this time, dominated by contradictions – which we capture today rather through an ahistorical lens –, Xenakis boldly handled manifesto-gestures of creativity. Pondering on the idea that man does not need to take on his limits, his finiteness, attention-drawing statements could have burst out from someone like Bach, three hundred years ago: "I shall write a mass the like of which has never been heard before!"[6] (Johnson 2007, 127) – as he mastered the organ like no one else. (Idem, 123)[7] Xenakis manifests himself with equal mastery in a different register. Bach's organ is for Xenakis the computer, and the organ registers of the genius Kapellmaster[8](Ibid.,123) are close to the programming media Fortran and Basic, which the Greek composer knew to perfection. Technological intelligence surpasses musical epochs, and cyber programmes, specialized in composition algorithms, could successfully complete a project like GENDYN (1962)[9].

The aim of this paper is to launch comments knowing from the start that the audio-visual production *Persépolis* consummates a portion of mystery not contained in its composing design; as a knowledge object, it "[...] *reveals itself* through its signs on one hand, and hides *behind* its signs on the other." (Blaga, 2014, 142) However, taking over data from other papers that extend the argumentation on the matrix of Xenakian composing strategies, I had the impression that I was directly conditioned by the decency with which the composer's intermodal thinking[10], his ability to create the plurality of possible worlds within a real world is left to freeze and then to perform again; therefore, the conviction acquired after reading these papers was that almost everything is already given, expressed.

Recovering past times, de-obscuring them in order to redefine them, may be seen as a de-stratification of becoming patterns of civilizations and of their cosmological identity, and as a mirroring of macro-dimensional history within an intimate history of the composer. Through event sequences archived in the resource of history, archaeology, anthropology, myths that lie at the limit of erasing the archetypal trace, the historical distance elapsed from the premises of Darius 3rd's temple until modern times is reminded as a sensory re-writing. Reducing the encounter interval with the historical past and finding the premises to be far away from its presence (which would today help us understand its functional limitation from back then[11]), the architect-composer will translate,

[6] The author refers to the *Great Mass in B Minor* BWV 232 (1748-49).

[7] "No performer or composer from his century, and perhaps from all centuries, knew more about the organ than him. What concerned him was how to use the vast resources of the 18th-century organ in order to obtain the highest quality and flexibility of the sound in performance, and how to write organ music for such performances.").

[8] Carl Philipp Emanuel Bach wrote: "No one understood registration better than him. The organ builders were terrified when he sat down to play one of their organs and pushed the registers in his own way, for they feared that the effect would not be as good as they had planned it. Then they heard an effect that filled them with awe."

[9] Electroacoustic composition of Xenakis, designed in the Fortran programming medium.

[10] The composer's thinking formed a maximised intermodality: "Thus, Xenakis was – as it was to be assumed […] – a man in whom the intersection of various talents with experiences of his life enabled him to become a successful walker on and passer through boundaries in the musical and architectural domain." Troge, A. Thomas, quoted work, p. 39

[11] because it took on the coat of a functional ruin anyway, which fitted into the 20th-century landscape

through the syncretic performance space, the reverberation of a different, freshly inseminated, (post)modern political and social time. By this insemination, knotting the thread of historical behaviors will disappear, blocking a part of the archetypal and mythological functioning; the reverse will lie in the opening of another field of derivations: the culture that suffers a new super-organization that defends itself by deconstruction[12], fearing to return to itself again.

2. *Persépolis* as an Identity within a Cyberworld Rhetoric

The sharpness of the audio-visual display in *Persépolis* perforates steel plates, pierces the Persian premises museum[13] with laser rays, altering the familiar perception patterns to an extent above average. The information contained in the violent act, in the noise, in the phantasy with which foreign objects of sound with an 'absurd' medial physiognomy are combined, effects that bring to life the image built of shrapnel and dust, of the fact that it seems like the composer himself is throwing the explosives, leads to a form of comment meant to impress and persuade, to a different approach in encompassing the goal of the rhetoric.

Thus, the rhetoric categories Xenakis operates with surpass the normal boundaries; it does not adhere to the canon of language, since it does not require its support, and it refuses to integrate into any ambiance that might refer to the resource and connotations of traditional rhetoric (*inventio*, *dispositio*, *elocutio*, *pronunciatio* "the whole aiming to move *(movere),* instruct *(docere)*, and delight *(delectere*))."[14] Through their incandescent light, the reflections of the Xenakian algorithmized rhetoric – 'cyberworld rhetoric' – make a closure to the synthesis of museum conditioning, and send the human being to the edge of history in order to sink it into those cybernetic exploration possibilities, of evolution in the virtual space. Here, the idea of Xenakis that "musical thinking is a mystical (and yet atheist) ascesis"[15] is thus highlighted as well.

The world of classical rhetoric has always been completely intimist, thinking that it should dwell within and draw breath from within. Historically installed in the perception of the art maker and focused on understanding the syntactic relations of the sound structure agglutinated onto the *affect* associated with it, it seems to escape from artificiality, even if (for instance) the music *as a drama* breathes quite lightly: through an intimate air and deaf presence[16] (Kennedy 1994,155). The classical oratorical model, portrayed by a subject, the *orator* (Cicero)[17] – prisoner of the scene he is contemplating – and by an object-print, the *oratory (oratorio)*, acquiesces to its edge as a closed space (chapel, public square), and the emotional contact of the orator with other parties involved in transmitting the noema is immediately conformed to the place. Well established, this pattern will build poetic images or psycho-physiological states, like intuition and affectivity, to which the rapport with the subject's state will be added (which it will passively color). Therefore, the sensory space of self-affectation, already present in *Trivium* and then in *Quadrivium* was correlated with an even intelligence. As a determinist heritage, this will hold in check any attempt at a differentiated artistic exploration, resonating with only a certain education, and also with the control of *Auskomponierung*[18] technique belonging to musical developments, which, once

[12] in its sense as featured by Derrida

[13] keeper of the chronology of the contingent human deeds, layered through history, culture, and civilisation

[14] These concepts of rhetoric were not only present in the writings of Aristotle, Cicero, Quintilian, but they were studied and invoked by the theorists of music starting with the Middle Ages and continuing within the Baroque era (see Johann Mattheson: *Der vollkommene Capellmeister* (1739) cf. Latham, 2003, p.1055

[15] "Musical thinking is a mystical (however atheist) ascesis." See Troge, A. Thomas, quoted work, p. 38

[16] Sometimes, after large customised descriptions, the reader also (rhetorically) joins the more than expected, naïve question: "What does a piece 'say'?"

[17] "Cicero admits […] two kinds of good orators, "those speaking simply and succinctly, and those grandly and amply", but "that is better which is more splendid and magnificent."

[18] The notion *Auskomponierung* (unfolding) was introduced into the theoretic thinking of the classical musical episteme by Heinrich Schenker (1868-1935). Defining subcategories of techniques, like that of construction of the ciphered base, of the

embraced, has referentially contributed to the formation of musicians[19], but whom it conformed on a single level (by the pre-announced multiplication of a similar-subject). This project of the *subject imitation*[20] which has worked by means of Auskomponierung like a program[21] (software) – laid the same trap to the performances of classical rhetoric, which will not surpass its limit of only one direction. Thus, Auskomponierung structured the mental frame of composers in the historical music evolution; its autobiography bears the stigma of the slowly extinguished torch, − that of a past cultural time.

Returning to the substance of profound mutations in the intuition of the foreboding originator – and in this sense (for instance), the SF novel *The Hyperboloid of Engineer Garin*[22] represents a beacon that impresses extraordinarily –, we face a cyber-rhetoric; and him who will explore it: Xenakis. His vision was not crossed with another; hence his refusal[23] to get close to another trigger of the classical rhetoric gesture – see the serialism syndrome in the '50es – where the Auskomponierung tried, through anti-(hyper)stylism, to efface the symbolic of debilitated (obsolete) rhetoric figures. The practice in Xenakis's laboratory paralyzed the pathos, sterilized the impetus of metaphysics; in writing by deconstruction, it broke the rhetoric packaging, articulating a different aesthetic category: of 'non-musicality'; as Xenakis remained, par excellence, the composer who *did not compose*.[24] (Mahnkopf 2007, p. 106) If a Stockhausen or a Nono make the essence apparent, they still remain blocked in Auskomponierung[25] (in the 'never changing' composing typus); they compose while appealing to the convoy of climaxes, of interjections, of declamations, or they veer toward the outdated *elocutio* and *collatio*. But "*composing* is an idea completely foreign for Xenakis. His scores are overflowing with passages that no musician who grew up in the Central European tradition has ever been responsible for; these are sometimes simply stupid, unmusical in the most banal sense of the word." (Mahnkopf 2007, p. 107) The composition *as contradiction* to the 'never changing' composing manner made Xenakis to be a radical pathbreaker in musical thinking, an opponent of Auskomponierung-technique, of the serial-mechanism (e.g., what it produces as musical material).

In *Persépolis* – designed as a <Musical Land-ART> – the dissonances and accents of rhetoric figures are flattened, melted (through synthesis processes of sound), transformed into symbols cleansed of any semiosis (curves that generate a certain apparition probability), into sound clouds. The shadows of rhetoric figures (*climax, circulatio, hyperbole*) do not stop scintillating, they look for a derived narrative, a rebirth of the old, traditionally regarded skills, of the controlling-process in sharing and influencing the story. Even if the rhetoric's syntax enters here into hypnosis, is robotized, the figures turn into dual objects, come out of their opaqueness, and stir the deep layer of medial integration.

melody, harmony, and polyphony, of using music intervals by melodic diminutions (passing notes, arpeggios) and prolongations by structuring procedures of the type of the motet, fugue, theme with variations, the *Auskomponierung* determines thematic and rhetoric amplifications, and thus edifies musical forms like the rondo, the sonata. Cf. Forte and Steven: *Introduction to Schenkerian Analysis,1982*. Once the atonal grammar and the *Reihentechnik* were constituted, the *Auskomponierung* technique also remained enrolled for the serial music.

19 I refer to Schütz, Händel, Bach, Beethoven, Brahms, Schönberg, Webern, Boulez, Stockhausen, Nono (a.o.).

20 The delivering of composition technique from mentor to disciple (for instance, from Buxtehude to Bach) gives out a reflex of imitation.

21 Auskomponierung (e.g., including the skills of the traditional modality of writing music) is the compositional working system in the way of crocheting musical structures – from one tone to the next one – as by using a needle; thus, the distances between tones can be drawn as close steps (in gradual motion) or as skipping tones.

22 Where the projective form marked by Xenakis in his architectural designs is present. The novel was written in 1927 by A. N. Tolstoi (1883-1945).

23 "In 1954 I denounced linear thought (polyphony), and demonstrated the contradictions of serial music." (The composer published the comments concerning his position in *La crise de la musique sérielle* (*Gravesaner Blätter*, no. 1, 1955)) in Xenakis 1970, p.3

24 "One should also not define Xenakis up to a composer of traditional making, in the other way. In a strict sense, he does not compose, and this makes him a composer."

25 Xenakis considered the *Auskomponierung* technique as an instrument of torture.

Called together as newer and specialized rhetoric voices, in ”the archaic grandeur of the ruins of *Persépolis*” (Hartley 1998, 57), they exhibit the following technological devices in the cyberspace: 2 laser lights; 6 military beamers; 20 round fire containers; 5 oil-based fire systems; 2 giant bonfires installed on two hills (to burn randomly, for the audience’s pleasure); 6 listening stations provided with 8 independent loudspeakers[26] (idem, 58) marked from A to H (one for each track); 92 circuits for light effects[27] (ibid, , 58) ;150 children bearing torches.

A. M. Harley documents that, as compared to the mentioned display, “Xenakis indicated the location of 59 loudspeakers (plus 10 backups), the control centre”, which were scattered into clusters of 8 or 16, to surround the audience on an entire area formed of three domains (latifundia) close to each other. (Hartley 1998, 59) In the composer’s notebook is written that the production equipment also needs to include 5000 pieces of aluminium, 1500 metal goblets for fire, 170 mirrors, 4 fire-swallowing devices, and fireworks.[28]

We experience throughout the *Persépolis* performance an acute separation from the classical rhetoric which provided power to the functional metaphysics, intending to give the word to *cyber-rhetoric*. The latter will deconstruct the metaphysics, will annihilate its retentions, will shut down the writing, will interrupt the Auskomponierung.

3. The Honeycomb of Time in the Wire Net of Deconstruction. *Arche-writing* and *De-obscuring* in *Polytope de Persépolis*

The principle of the *Polytope de Persépolis* composition hosts two representations that breathe together: the sound-medium[29] (Luque 2009, p. 77) and the envelope of light, inserted as a *differance*[30] (*différance*) of the corpus of morphologies; by alchemizing the form, difference spreads the power “through which any system of differences is constituted”; and it also identifies itself as “the paradoxical figure of an original differentiation, [...] of a never fixed originality, which de-doubles and multiplies itself ceaselessly.” (Derrida 2009, 333) Seemingly sunken in a ‘fog’ room, the multi-timbral assemblage also emanates (through clarifications with different resolutions) an *arche-trace*[31] (*archi-écriture*) – a psyche agent which, when crossing the *form* read at sensory level, also keeps on moving toward the *imprint* (reflected as the unencountered difference between ‘appearing’ and ‘apparition’, between ‘world’ and ‘experienced’) (Derrida 2009, 84). In the ‘fog’ room – where the sounds crawl, wriggle[32] or toss around, and those in glissando crash at speeds with different delays, hardly maintaining their physical features – not only an acoustic-visual reality is hosted, but also “the eye with which the robot explores the environment it is in.” (Nicolau 1971, p. 68) Separating them, we rip them from their secret mounting; we kill the mirror which projects the bi-dimensional audio representation onto the 3D visual image – mediated by the mind’s eye. Polishing the ‘glass’ arcades one step at a time, this reactive music tries to recuperate the function of both the represented and the perceived space; thus, led by the syntax of perspective focused in one point, its indispensable subject “is projected as an image”; so, the gaze will bounce in the point of light from where not only the subject looks at the world,

[26] “[They were] arranged in an irregular semi-circular pattern around the audience.”
[27] “[They were] scattered throughout the ruins of the palace.”
[28] Cf. movie *Polytope de Persépolis* (www.youtube.com/results?search_query=Polytope+de+Persepolis)
[29] Stochastic synthesis at the level of micro-sonorities… The author documents that Xenakis used synthesis algorithms for the first time between 1967 and 1972. Even if Luque refers to the composer’s experiments for *Polytope de Cluny* (1972), we will deduce that the syntax of sounds created in *Persépolis* was the same.
[30] The notion belongs to Derrida. The differance (*différance*) represents the “environment, the generative element itself for the formation of temporal and spatial oppositions, and between “space” and “time”, of the apparition of non-identity and non-coincidence.” See Derrida 2009, 332
[31] The notion also belongs to Derrida.
[32] The texture of these sounds captures in a vague hint the acoustic nature determined by the known “rhythmic-sonic continuum”, which Henry Cowell used in his *The Banshee* (1925) – for piano strings

but also the world gazes at him.[33] (Holm 1992, 24) Placed on a vortex, *Persépolis* talks about exasperation; it doubles and reverses its mirrors, multiplies them – sometimes by crushing them – continuing to disrupt the image in a 'to and fro', to 'break' the corner of the eye, to stifle the place of perception, to evict any significance. Lighting certain corners from underground, it proliferates through patterns of 'temporal architecture'[34]; in this adverse world, the subject starts to hesitate, avoid his own glance, and understand his contradictory side, that "the subject, like the imaginary, is structured by signification and absence."[35] (Holm 1992, 24) The composer replies through a reaction, has an intuition of the human situation: the ruins of Darius's fortress are the ruins of modern man; but he celebrates the world, technology, launching spaceships into outer space (lasers, military beamers, fire-swallowing devices, the huge bonfires on hilltops). Somehow replacing his perceptions in order to inhabit two temporalities, two existential durations, Xenakis offers himself as a divided subject[36] (Idem, 25), who sometimes freezes history in order to admire the cybernetic man, and other times hides him in a time rift in order to nostalgically interrogate the past.

The pictural ambiguity of this music, which also enchains structures of hallucination, illusion, highlights the reflexion and perception of a 'there-body' which found its full signification in Xenakis's war experience; a horizon-conscience that sits on a single eye[37] (Estrada and Derfler 2001, 216), conjugated with a psychological dislocation, "passes as a place of clarity", being the very place of equivocalness. (Ghideanu 1979, 102) Xenakis, like Beethoven, struggled, with a rational mind, to prevent the failure caused by "auditory torture, converting it into the discovery of a new music […] made of inharmonic material that declares the beauty of imperfection." (Estrada and Derfler 2001, 216) But we can also discover the surprise element in this music of images: it programmatically insists on profiling the composer's portrait, expressing his voice, attitudes, the way he "is adamant to impose his own law (nomos) and his own will."[38](Iliescu 2014, 66-83)

From feeling the pulse of the *Persépolis* pattern, some questions would arise, derived from pursuing the trajectories that cross its narrative scheme; be the digressions, returns, freezing, trials 'by error', slowdowns some directing instructions through which the masses of sound, the amplified echo of the glissando[39] − viewed as a transgressive act of interrupting the affect establishments − seeks refuge in the discipline of deconstruction? Grant them a direction to strong or weak metaphors, to testing schemes of the movement of an unidentified language of hypothesis and predictions, of a repertoire of space releases with various erosions? Or do they launch hints at the latent structure of history, of the universe? By altering the perception angle, will it, the very pattern, not lead us to the *arche-trace*, to discern that it alters; it re-writes the archaic hieroglyph and "the process of its own degeneration" (Derrida 2009, 251) in the dust of glissandos, in the narrow slots of the arching of sound?

[33] This phenomenon of projection, where "the gaze is the point of light from which the world looks at me", is described by Lacan

[34] Le Corbusier had the intuition of this architecture, which reframes through the syntax of photography the structure of the optical perception space, separating it from its bi-dimensional representation.

[35] The author heads towards the analysis of operational montage, in the context of which he analyses the way in which Lacan re-brings into debate the experience of the imaginary register "and the disposition of the gaze as absence".

[36] "[…] Lacan's concept of the split subject – [has the meaning of] the displacement or alienation of the subject as site of perception from its own image […]".

[37] Julio Estrada discusses the effect grown in Xenakis understanding due to the psychological matter, the way in which noise emerged in his hearing (after he was hurt in Athens in 1945); that he found himself in this situation led him, through despair, to the attempt to represent it musically. Therefore, Xenakis insisted that the rupture in his conscience activate a fusion, trying to 'validate' the dislocation and to show through creation 'the discovery process of the path which repairs it'.

[38] Iliescu, Mihu: "[…] il imprime sa marque, en imposant ainsi sa loi (nomos) et son ordre."

[39] We refer to the "transgressive power of the musical glissando, [the] musical glide between and across tones. Because of its constant shifting, the glissando destabilizes the listener's perception of [an] harmonic grounding. These violations of the boundaries between individual tones and keys have, over the course of music history, been employed to signify different types of transgression. Moreover, the glissando's seemingly endless movements suggest that its possible ending point can only lie beyond the perceivable, in infinity or in nothing." (Van Elferen, 2013, 20.)

Located at the opposite end to domestication through musical notation[40], this opus manifests as a multitude of projections, transient manifestations of sound, roughness. Moving toward the virtual, it will remake the "past-preserved-sublimed present" (Derrida 2015, 63); and will vigilantly capture through a melting pot of "losing and mixing up the traces" (Derrida 2009, 5) an inscription that obsessively dismisses its own writing (precisely because this calls for an inter-subjective violence).[41] (Idem, 145) The impetus of the *Persépolis* performance emanates wild vitality, as it attempts to conciliate opposites; to deconstruct metaphysics from its source, to annihilate the writing (shut it off). The weakening (cancellation) of writing, the 'secondary rank of the sign', putting the 'victories' of metaphysics between parentheses, spacing (especially the "internal") (Ibid., 6-7) are attributes of this music which we capture like some traces of an ancestral gesture. Repeating the internal history of thinking the deconstruction (as a form of surpassing – like J. Derrida finds its meaning) will be the one that will dissolve the whirl of the hundreds of 'gaze-placings'[42] (Derrida 2015, 178) in order to proceed then to articulate the *historiality*[43] *of history*. (Derrida 2009, 9)

4. Conclusions

The ascetic ideal of Xenakis profiled itself through the "Promethean attitude of the hero who defies the gods, questions their supremacy and dares compete against them" (Iliescu 2014, 69), contaminating at a substantial scale the avant-garde musical thinking of the past decades. All over the *Polytope de Persépolis*, the abundance of a *Gesamtkunstwerk* as a polycentric broadening of the audio-visual complexity is maintained through new expansion links of the thinking activity, "the process itself implying both birth and perishing as a return of things to the place they started from." (Vlăduțescu 1987, 125)[44] In the gigantic labyrinth of the Achaemenid culture, surrounded by tombs, ruins, scattering[45] arrows of light in the Apadana reception hall of Emperors Xerxes and Darius, *Polytope de Persépolis*[46] maintained dominantly the legends of the Persian dynasty, electro-acoustically conveying a tragic background, deconstructed through the code of a *khôra.*[47] The means to decipher it will question a super-world (of meta-questions) sustained by "[the composer's] abstract and geometrical vocabulary (based on the axiomatic entities of point of line) to the sphere of light and sound [in order to realize] a global and parallel formalization in the space of architecture, light, and sound." (Sterken 2001, p. 267) They result from the super-arrangements of the *supplément*[48] spaces,

[40] which would curb it through the system of the omissions it allows for

[41] Connotating the writing as being untemperable, since it controls everything Derrida also captures other reverberations of it: "The conclusion [which the concepts] contain surpasses by far the limits of the field of what is here called "writing" (that is, writing with its common meaning). It also covers the field of the unwritten word. What is intended to mean that, if we need to connect violence to writing, writing emerges far before the writing with its strict meaning?"

[42] 'Placing in the gaze' = construct derived from what Husserl defines as live present (*lebendige Gegenwart*) – when he talks about the ultimate, universal, absolute "form" of transcendental experience; Husserl asserts that "the metaphysical domination of the concept of form cannot rule out an obedience to the gaze". So that the phenomenological field of the rapport with the exterior (form) involves the "placing in the gaze".

[43] Refers to discovering the perspective of history

[44] Cf. Vlăduțescu apud. Martin Heidegger, *Chemins*, Gallimard, Paris, 1962, p. 269.

[45] through translations (rotations) of images suggesting the cyberspace of an architectural ensemble

[46] "Persepolis was designed to host countless crowds of people and to serve as an immense theatre. On a huge rock corner, Darius built a large terrace, 450 m by 300 m, partly carved into the mountain; this gigantic foundation was above ground level and rested at its sides on the rocky walls. The ascension to the terrace was made over a double stairway, with steps so wide that they allowed the passing of ten horses standing side by side. During the reign of Xerxes, a monumental gate could be admired, called "of all countries", and enormous propylaea, resting on two pairs of winged bulls, carved in Assyrian style." (Cumont 1998, 199)

[47] The Greek word *khôra* designates a launching set up in J. Derrida's philosophy. Thus: "the discourse about the *khôra*, as it *presents itself*, does not stem from the natural or legitimate logos, but rather from a hybrid, bastard reasoning." (Derrida 1998, 20)

[48] This concept gets significations in the system of thinking by Derrida: "The supplement makes up, holds and takes the place [*le supplément supplée*]. It is only added in order to replace. It intervenes and insinuates itself *in-the-stead-of*;" (Derrida 2009, 160)

also perceivable in the electroacoustic sound of the works *Orient-Occident* (1960), *Bohor*[49] (1962), *Hibiki-Hana-Ma* (1970), and later in the cry of *Eer* (*La Legende D'Eer*, 1977-78).

In *Diamorphoses*[50] (1957-58) as in *Polytope de Persépolis*, designed to successively cohabit in the night-time performance of the Shiraz Festival (1971)[51], Xenakis once again experimented[52] the mix of "[...] 'pure' electronic sounds with 'concrete' sounds" (Luque 2009, 78) and, additionally (as John Rahn asserted), the *invasion* of the *visual* into the musical. The composer climbed the highest step of abstraction to reveal mysteries and set in motion the incantation medium of the glissando as a metaphor of the curved line[53], invading the space through multimedia counterpoints. The new rhetoric becomes not only a medium of persuasion (common in the classical rhetoric) but an overwhelmed tsunami of noise, light, alarming laser beams, motion of torches coming from everywhere. Slowing down time, the vortex of the *suppléments* allowed the archetype of historical nervousness to come out of the dark, its casting into a moulage enabling the composer's dialectic force to explode even more powerfully. Thus, a global workspace 'conquered', brought closer and mingled the histories of "the original organization of the forms of [his] ego" (Lynch, 2008, p. 209) inseminating the terrain of "the source of all [his] lived unities of experience" (Reeder 2010, 92). This has always given him power to breathe the omnipresence of the manifestation born in his *cosmic city* (Xenakis 1997, 139) and within the *polytopes* from where he scrutinizes the underlying meanings of the planet's dystopian pulsation.

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[49] Xenakis's ability in *Bohor* to turn "sounds into something entirely unrecognizable" suggested to the Parisian critics the sound substance of a "sonic cataclysm". (Harley 1998, 60)

[50] The first electroacoustic composition of Xenakis; it includes construction mechanisms of the *musique concrète*; duration approx. 7 minutes. The flexibility of the categories of recorded sounds (sound/ engine or exhaust pipe noise, plane take-off/ landing noise, glissandos) refers to the sonic environment of Pierre Schaeffer.

[51] "Iran in the 1970s […] provided a home for the flowering of electronic music and avant-garde arts." (Gluck 2006, 216)

[52] It is about pursuing the line of his vocation for electroacoustic music in *Polytope de Montréal* (1967). The design of his multimedia installation, placed in the French Pavilion of the International Exhibition in the Canadian city, surprised through its grandeur (intended for 4 identical instrumental ensembles, this design was replaced by the electroacoustic solution). Terre des Hommes (Man and His World) – topic proposed within the exhibition, propagated – in Xenakis's vision – the idea of de-territorialisation, of sympathising with the infinite expansion of space.

[53] Mihu Iliescu considers them "sonic traces – of motion, of gesture or of time itself." (Iliescu 2006, 1) Retrived from www.iannis-xenakis.org

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Persepolis Polytope: Resolving Fictitious Attributions from a Persianate Perspective

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Abstract

Iannis Xenakis's relations with Iran's royal family resulted in some political troubles in the artist's already troubled political life. Criticism and reports on the Shah's human rights violations increased in 1970s Europe while Xenakis, a leftist revolutionary, had a seemingly prosperous association with that aggressively hardline monarchy. What made the association more troublesome was *Persepolis Polytope* (1971). This paper concerns the polytope, Xenakis's most celebrated Iran-related work. It contributes to two understudied aspects of the polytope, i.e. how Iranians received and understood the polytope, and a historiographical conflation that exists in the field. The latter demonstrates that almost all the literature around Iran's Imperial Celebrations and a considerable share of the scholarship about Xenakis have conflated *Persepolis Polytope* with *Persepolis Son et Lumière*. This completely different audiovisual program was premiered during the Imperial Celebrations and had no connection with Xenakis whatsoever. Some scholars claim that Xenakis created *Persepolis son et Lumière* while some argue that Xenakis's *Persepolis Polytope* was premiered during the 2500th anniversary of the Persian Empire. However, Xenakis *Persepolis Polytope* was premiered during the August 1971 Shiraz Art Festival, not the October 1971 Imperial Celebrations that offered *Persepolis Son et Lumière*.

Undoubtedly, the location, similarity in names, and closeness in dates between the two events are innocent contributors to this conflation. However, scrutinising the conflation leads to more fundamental problems. For example, Empress Farah Pahlavi, the former queen of Iran and the primary patron of Xenakis's Iran-related activities, was still asserting on her official website that Xenakis was the composer of the October 1971 event. Such scandalous mistruths like Xenakis performing for royalties during the ultimate propaganda of the Shah, the Imperial Celebrations, made him seem more politically biased than in reality. Besides, Iranians' reaction to the polytope was very adverse. Not many works performed in Shiraz Art Festival, if any at all, received such critical feedback. Soon, the negative reactions extended to Iranians living in Paris, where the opponents of the Shah criticised Xenakis for collaborating with a human rights abuser. Reacting to critical remarks, Xenakis first wrote an open letter explaining he was solely interested in art and culture. A few years later, though, he wrote another letter and refused to take any further commission from the royal family or participate in the *Shiraz Art Festival*.

The paper begins by describing *Persepolis Son et Lumière*. Afterwards, it categorises the conflated arguments around *Persepolis Polytope* and *Persepolis son et Lumière* through reviewing the literature from 1998 to 2021. Then, the paper

builds on an interview to show how the conflation started. This section also proposes three scenarios about why the piece was attributed to Xenakis, among all artists. This research is an archival work and pivots around Archives Famille Xenakis, print media published in 1971, and an interview with Loris Tjeknavorian, the composer of *Persepolis son et Lumière.*

1. Introduction

Iannis Xenakis's *Persepolis Polytope* inaugurated the Fifth Shiraz Art Festival on August 26th, 1971. The fifth festival was already overshadowed by the upcoming 2500-year Celebration of the Persian Empire (Imperial Celebrations) scheduled for October 1971. However, what made *Persepolis Polytope* peculiar were its hostile reception among audiences and a historiographical misattribution that conflates *Persepolis Polytope* with *Persepolis son et Lumière*, a completely different audiovisual program that was premiered during the Imperial Celebrations and had no connection with Xenakis whatsoever. This paper examines these two understudied aspects of *Persepolis Polytope*. It uses Xenakis Famille Archive, print media published in 1971, and an interview with the composer of *Persepolis son et Lumière* to unpack how the conflation occurred and how Xenakis got involved in the Imperial Celebrations.[1]

In October 1971, Iran hosted a series of events to commemorate the 2500th anniversary of the founding of the Persian empire (Imperial Celebrations). The Celebrations had several diplomatic, cultural, economic, and political agendas that may be categorised under two overarching objectives. For a domestic audience, the event bolstered the ideological underpinning of the Pahlavi Monarchy (1933-1979) by promoting the idea that the country's successes had been, and always would be, dependent on the throne while to an international audience, the event signalled the beginning of a new period of prosperity and global influence for Iran (Steele 2021, 1). Addressing both audiences, the programs incorporated in the Celebrations demonstrated Iran's history, culture, and recent advancements. One of those programs was an audiovisual spectacle premiered on October 14th, 1971, on the Persepolis site, entitled *Persepolis son et Lumière*.

Son et lumière is the term given to a night-time outdoor entertainment where multicoloured lights of changing intensity are directed against the facade of a historical building in synchronisation with music and recorded narrative (Son et lumière 1998). *Son*, sound, usually consists of taped historical narrations, music, and sound effects, while *lumière*, light, refers to the changing-coloured lights. The narration encapsulates a nation's or location's history and significance, evokes past glories, and stimulates the audience's imagination. It is significant to highlight the popularised character of this form. The objective of the narration here deviates from a historical lesson. As a dramatised form of historical enactment, the primary object of the event was to entertain contemporary audiences. A son et lumière links the site to its past and spatialises the history (Azaryahu and Foote 2008).

Persepolis son et Lumière was a roughly 40-minute long show that concluded the October 14th ceremonies. It was performed in French while Iran National TV broadcasted the Persian translation. Iran commissioned Etude et Creations d'Ambiance (ECA) to prepare the scenario, light patterns, and the historical narrative. The composer of the pageant's music was Loris

1 *Persepolis son et Lumière* is examined extensively in my PhD dissertation. That research considers the design and production of the pageant as an intersection of propaganda and entertainment and discusses how the heritage, selective historical narration, and spectacle was deployed in political messaging and diplomacy. The broader project concerns architectural diplomacy and addresses how architecture and diplomacy interacted with each other in the 2500-year anniversary of founding of the Persian empire (Imperial Celebrations).

Tjeknavorian (1937-), a leading Armenian-Iranian composer and conductor of his generation. In 1971, Philips published the 33 and 45 rpm records of the music, covering the name of the contributors to the pageant (picture 1).

Figure 1 – Philips 33 and 45 RPM Records of Persepolis on et Lumière

2. The Historiographical Conflation

The history of *Persepolis son et Lumière* and its records leave no doubt that Iannis Xenakis had no involvement with the pageant whatsoever. However, almost all the literature around the 2500-year Imperial Celebrations and a considerable share of the scholarship about Xenakis's life and works have attributed the piece to Xenakis. For example, Robert Steele, the author of the most comprehensive and recent work on the Imperial Celebrations, writes that "following the royal banquet, the guests moved out to the ruins of Persepolis where they watched a son et lumière display and fireworks. Greek avant-garde composer Iannis Xenakis's latest work was premiered"(Steele 2021, 48). Steele, then, cites Maria Harley, one of the most prestigious Xenakis's scholars, and continues that "the [Persepolis] ruins were brought to life as actors dressed in a traditional Achaemenid dress walked solemnly around them, while projected luminous patterns evoked the Zoroastrian symbolism of Ancient Persia"(M.A. Harley 1998). This is indeed an accurate description of what occurred during the Celebrations as it describes *Persepolis son et Lumière*, but not *Persepolis Polytope*. Xenakis's *Persepolis Polytope* was performed in August 1971 during the fifth Shiraz Art Festival, while ECA's *Persepolis son et Lumière* was premiered in October 1971 for the Imperial Celebrations. The following table shows the differences between the two works.

Name	*Persepolis Polytope*	*Persepolis son et Lumière*

Venue	Persepolis historical site	Persepolis historical site
Form	Polytope	Son et lumière
Date	26 August 1971	14 October 1971
Event (Commissioner)	The 5th Shiraz Art Festival	Imperial Celebrations
Creator	Iannis Xenakis	- Loris Tjeknavorian (Composer) - Etude et Creations d'Ambiance

Table 1: differences between Persepolis Polytope and Persepolis son et Lumière

The fictitious attribution of *Persepolis Son et Lumière* to Xenakis has caused inaccurate interpretations of both the Celebrations and the artist's life. Steele's book concerns the Imperial Celebrations and was published in 2021; Harley's paper is about Xenakis's polytopes and was published in 1998. A review of the materials published in this nearly 2.5 decades reveals six sets of conflated arguments among scholars. The first set claims that the Polytope was performed twice. Harley is an instance of that set where she claims that *Persepolis Polytope* was performed "for the opening night of the 1971 Shiraz Festival" and "once again in the ruins of the palace of the ancient Persian kings at Persepolis on August 26th 1971, […] belonged to a series of events marking the 2,500th anniversary of the Persian monarchy" (M.A. Harley 1998). In reality, the piece only opened the fifth festival on August 26th.

The second category constitutes scholars who attribute *Persepolis son et Lumière* to Xenakis, without mentioning the polytope or Shiraz Art Festival. Researchers focusing on Iran's modern political history or solely on the Imperial Celebrations are usually of this category. An example is a book published to commemorate Michael Stevenson's exhibition reproducing Persepolis tents. The authors write, "the guests moved out into the ruins of Persepolis itself and were treated to a theatrical display of lights, music, and fireworks. The Greek avant-garde composer Iannis Xenakis had been commissioned to produce a major new work to be premiered that night" (Stevenson 2008, 24-25).

Scholars' attempts to explain the "murky" association of Xenakis, a "leftist revolutionary", with the "aggressively hardline monarchy" of the Shah (Stevenson 2008) is one of the outcomes of this issue. The fictitious attribution of Xenakis's Polytope in the Celebrations exaggerates his contribution to Shah's propaganda (Charney 2020). For example, Sinker notes that Xenakis, "a celebrated leftist who lost an eye fighting Nazis in World War II", hired himself as "court composer to deliver a massive son et lumière for the Celebrations" (Sinker 2002). The third conflated argument claims that "Xenakis's *Persepolis Polytope* rebranded to *Persepolis son et Lumière* and performed again during the Celebrations" (Chehabi 2018). Although this set has no more than one explicit representative, those who argue that the piece was premiered twice probably imply the renaming.

The literature has also partially confounded the objectives and ambience of Shiraz Art Festival with Imperial Celebrations. The former was an annual art festival, while the latter was a one-time highly political event that hosted the world's most influential individuals. Undoubtedly, Shiraz Art Festival had some political objectives too, but its propaganda and politically-charged agendas were not proportionate to those of the Celebrations (see Charney 2020). When Asphodel reissued *Persepolis Polytope* in 2002, its liner note explained that the Shiraz Art Festival was held the same year as the Imperial Celebrations and "in keeping with the 2500th national anniversary celebrations, the Shah commissioned [Xenakis] to write a piece of music

exalting ancient Persia's aristocratic religious culture". It continued that selecting Xenakis "could not have been more symbolically appropriate given the Shah's desire to modernise Iran" (Asphodel 2002). However, in words of Afkhami, "the shah probably had never heard of Xenakis before. He did not commission the work. Nor did he attend his program in Persepolis. Had he attended, he probably would not have liked it" (Afkhami 2009, 421).

Some scholars have conflated the Shiraz Art Festival with the Imperial Celebrations. For example, James Harley writes that Xenakis was "given free rein to create an even more ambitious work to celebrate the 2500th anniversary of the Persian monarchy. The invited audience was to include royalty and heads of states worldwide. If ever there was one, this was a prestigious commission" (J. Harley 2001; 2004, 62). The 5th Festival did not invite any royalty or heads of states. Instead, it was the Imperial Celebrations that hosted the delegates of over sixty countries.

And finally, standing on the opposite side are a few scholars who declare that *Persepolis Polytope* had absolutely no link with the Celebrations. Afkhami and Charney are of this category when the former asserts that *Persepolis Polytope* was "performed in the same year [of 1971], though not at the same time as or in relation to the Anniversary Celebrations" (Afkhami 2009, 421) while the latter writes "Xenakis had no part in the event whatsoever" (Charney 2020, 94). Nevertheless, *Persepolis Polytope* was commissioned by the Shiraz Art Festival as a prelude or tribute to the Imperial Celebrations. In fact, it was perhaps the only reason that gave Xenakis the opportunity to open the fifth Shiraz Art Festival (see section 3.3. for more information).

In summary, *Persepolis Polytope* was commissioned by Shiraz Art Festival and it was a tribute to the forthcoming Imperial Celebrations. In other words, *Persepolis Polytope* celebrated Iran's 2500-year history but it was not related to the "2500th Anniversary of Founding of the Persian Empire by Cyrus the Great" (Imperial Celebrations). It was premiered in August, a few months before the Imperial Celebrations. The polytope did not have Zoroastrian illuminations or soldiers dressing in Achaemenid costumes, royalties and heads of state were not among its audiences, and the Shah of Iran was not much involved with commissioning that piece. On the other hand, *Persepolis son et Lumière* was a political pageant, a form of propaganda, similar to many other son et lumière around the world (See McGrath 1992).

3. How and Why did the Conflation occur?

It could be assumed that the similarities between *Persepolis son et Lumière* and *Persepolis Polytope* are innocent contributors to the conflation. However, it is still valid to ask how Empress Farah Pahlavi, the principal patron of Xenakis's activities in Iran, was asserting on her website that "a son et lumière show, the *Polytope of Persepolis* designed by Iannis Xenakis and accompanied by the specially-commissioned electronic music piece Persepolis concluded the evening" until as late as September 2021 (Pahlavi 2021).[2] This remark amalgamates a few of the categories mentioned above, as it has confounded polytope with son et lumière and attributed that to Xenakis. This section explains why and how the conflation occurred.

2 When I contacted the website and advised them on this mistake, they brought the whole Imperial Celebrations webpage down. The address and screenshot cited here are retrieved from Web Archive and dates back to July 23rd, 2021.

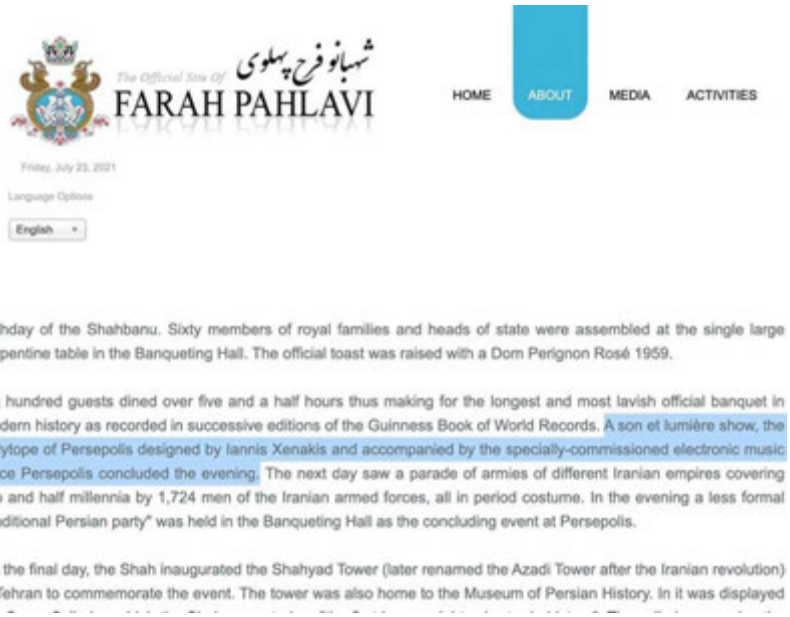

Figure 2- Imperial Celebrations on Empress Farah Pahlavi's Official Website

The Central Council of Imperial Celebrations, the primary organiser of the events, led by Javad Bushehri, was determined to select an "Iranian" composer for the son et lumière. However, the non-Muslim Iranian-Armenian Christian artist, Loris Tjeknavorian, was not registered as "Iranian" to Javad Bushehri. He tried to replace him, but Pierre Arnaud, ECA's art director, was already interested in Tjeknavorian's music draft and made Bushehri's plan obsolete. Tjeknavorian recalls that in a gathering before the Celebrations, Javad Bushehri lashed out, splashed a glass of beer on Tjeknavorian's face in front of his family and about fifty other guests, and yelled "you Armenian dog… you Armenians are janitors of hell… I will get SAVAK [Iran's intelligence organisation] arrest you…". No one arrested Tjeknavorian but it seems Bushehri succeeded in depriving the artist of taking credit for composing the music. He ordered print media and the national TV to avoid mentioning Tjeknavorian's name (Tjeknavorian 2021). He also tried to exclude Tjeknavorian's name from being mentioned after the show on October 14th, but Arnaud insisted that the composer's name should be proclaimed along with all other artists. Nevertheless, Bushehri prevented the distribution of 2000 copies of Philips's 33 RPM phonograph disc records (Tjeknavorian 2021). Only a few of them survived that were gifted to the guests (picture 1).

Except for the interview, no document is found that suggests such accusations though the absence of evidence is not evidence of absence. When the only source for this information is biased, though, it demands caution. In November 1971, only one month after the events, *Kayhan International* published an article about the composer with a bizarre title, "Persepolis Forgotten Man" (Kharazmi 1971). The report does not indicate racism, but it proves that Tjeknavorian did not receive much credit for his contribution.[3] Notwithstanding, although this oral history explains that religious discrimination and racism deprived Tjeknavorian from his rights as an artist, it does not explain why the piece was attributed to Xenakis, among all the other artists that could become misattributed. The following subsections propose three potential links between the misattribution and Xenakis.

3 Elsewhere, I have addressed this issue at length. It seems that the Shah and Empress had no involvement with such racial practices; in fact, they supported Tjeknavorian where they could. However, the influence of Bushehri Family and racial beliefs among a few Iranians sufficed the deprivation. For further information, see (Taheri 2022)

3.1. Xenakis's history with Iran

The decision to incorporate *Persepolis Son et Lumière* in the Imperial Celebrations was not an isolated decision but an extension of previous engagements with sound-and-light shows. The 1950s and 1960s saw increasing interest among mainly developed and wealthy countries in expos and international events to use advanced sound-and-light technology. Keeping in mind the overpowering influence of commerce and technology in twentieth-century society, it is not a coincidence that icons of its architecture contain projections, coloured lights, movement, images, music, and even smoke (Sterken 2001). Iran was aware of the easily accomplished diplomatic benefits of high-tech sound-and-light shows and had started harvesting them a few years before the Celebrations in expos and festivals. Iannis Xenakis, who had already gained a reputation as a creator of enormous audiovisual spectacles and a symbol of futuristic architecture (see J. Harley 2002, 2004; M.A. Harley 1998; Sikiaridi 2003; Sterken 2001), was the central figure in Iran's avant-garde sound-and-light programs. On top of the 1971 *Persepolis Polytope*, Iran had commissioned three more works to Xenakis that at least two of them could be conceived as audiovisual spectacles or spatialised music, i.e. Persephassa (1969) and AmeshaSpenta (1970). The Shiraz Art Centre (never realised) was also supposed to have or to support similar components and ideas (see Xenakis 2008, 173-175).

Therefore, Xenakis was the audiovisual spectacles incarnate to Iranians. Despite favouring his avant-garde, more advanced, and more sophisticated sound-and-light programs, Iran had to tailor the trend of creating high-tech audiovisual spectacles to meet the diplomatic objectives of the Celebrations. Eventually, Iran went with a more popular and more propaganda-friendly form of sound-and-light displays, i.e. son et lumière. One might conclude that given Xenakis's reputation in Iran as a deliverer of audiovisual spectacles, and in the absence of Tjeknavorian's name due to that racism, *Persepolis Son et Lumière* was inevitably attributed to the closest artist to such shows, i.e. Xenakis. If the actual composer could present himself, the conflation would have probably never occurred.

3.2. Personal Relations

Loris Tjeknavorian claims that Javad Bushehri, the head of the Central Council, ordered Reza Qotbi, the head of National TV, to leave Tjeknavorian's name out of the Persian version of *Persepolis Son et Lumiere* and instead proclaim Iannis Xenakis's name as the composer, hence Xenakis's involvement (Tjeknavorian 2021). Responding to that, Tjeknavorian wrote two letters to Qotbi, advising him on the misattribution; however, he never heard back from Qotbi. Unfortunately, I could not access the recordings of what Iran National TV showed in 1971. It is probable that Tjeknavorian's name was excluded. Had it been otherwise, the title of that paper mentioned above would not have been "Persepolis Forgotten Man", and the author of that paper would not have bothered to come to Tjeknavorian's house only to assess his claim (Tjeknavorian 2021). But if the national TV did attribute the piece to Xenakis, it requires further reflection.

In 1971 Javad Bushehri had already left his position in the Central Council of Imperial Celebrations to treat his cancer. The person who replaced him was his cousin, Mehdi Bushehri. Undoubtedly, Javad Bushehri retained his power and influence on not just the Celebrations but the whole government, and he was still able to exclude a name or misattribute something. However, the cases of Mehdi Bushehri and Reza Qotbi are notable because of their relations with Xenakis and his family.

In the 1960s, the cultural relations between Iran and France soared. Iran funded and built Maison de l'Iran (1967), a set of student accommodations for Cité Internationale Universitaire de Paris (Jeanroy 2020) and appointed Mehdi Bushehri as its manager. Over time and following

Iran's frequent commissions to Xenakis, his relationship with the artist deepened. For example, in a letter sent by Mehdi Bushehri to Iannis Xenakis in December 1971, Mehdi explains that he expects Iannis in Tehran around January 10th, where they would go to Shiraz together to inspect the land reserved for the Shiraz Art Centre. Mehdi concludes the letter with "A thousand thoughts for Françoise" (Bushehri 1971). In another example, a letter dated September 19th, Xenakis writes to Reza Qotbi, the head of the National Television. His letter ends with "Notre amitié à vous et à votre femme" (Xenakis 1969).

The impacts of Iranians individuals, especially Mehdi Bushehri, on Xenakis's engagement with Iran deserves a separate research project. But presumably, Mehdi was the primary mediator between Xenakis and Iran. It is too pessimistic and improbable, yet not impossible, to assume that when Javad Bushehri ordered on Tjeknavorian's boycott, they convinced him to proclaim Xenakis as the creator of *Persepolis Son et Lumière* simply because they liked him better and it was more believable. Nevertheless, this assumption presumes that the National TV of Iran attributed the *Son et Lumière* to Xenakis as early as 1971, as Tjeknavorian recalls, a claim that cannot be justified until more documents shed light on the misattribution.

3.3. Miscommunications and Misunderstandings

The third scenario on why Xenakis, among all artists, became the victim of that misattribution is likely to be the most plausible explanation. Hardly a 1971 Persian newspaper or magazine can be found that has linked *Persepolis Polytope* to the Imperial Celebrations. For example, Ayandegan, one of the most influential and popular daily newspapers in Iran, allocated a page to Xenakis on August 24th, 1971, to welcome the piece that would be performed soon. The majority of this article is translated from Maurice Fleuret's notes on Xenakis; however, the introduction, written by the newspaper, does not mention the Celebrations at all. It merely indicates that the *Persepolis Polytope* is commissioned by Shiraz Art Festival ("Xenakis: The Lonely Adventurer" 1971). Besides, none of the print media cited in the next section has linked Persepolis Polytope to Imperial Celebrations. As mentioned in section 2, at least two scholars assert that there was no connection between the polytope and the Celebrations, i.e. Afkhami (2009), a prestigious historian on modern Iran and Charney (2020), whose PhD dissertation is one of the most comprehensive contributions to Shiraz Art Festivals.

The official plan of the Fifth Festival that was given to artists and audiences does not indicate any connection between the polytope and the forthcoming event (Programs of the Fifth Shiraz Art Festival 1971). As will be explained in the next section, the post-performance roundtable did not put the polytope in the context of the Celebration. Besides, the artists performed in the festival, including Xenakis, were given a brochure on the Imperial Celebrations (Bunsel 1971) that does not take *Persepolis Polytope* as a prelude to the Celebrations. Keeping in mind that the Celebrations were overwhelmingly occupied the early 1970s media, if the linkage were clear or arguable, it would have been mentioned more.

There is no doubt that Xenakis created the piece to pay his tribute to the culture and history of Iran, as he has stated many times. However, at some point the festival organisers decided to introduce *Persepolis Polytope* as a especial commission in alignment with the Imperial Celebrations. It does not revolutionise our understanding of the piece because in the context of Iran's 1971, the Cyrus-the-Great Year, celebrating the 2500th anniversary and paying homage to the Shah, Cyrus, and the Imperial Celebrations were rather compulsory. The Central Council of the Imperial Celebrations had already wrote to all governmental entities to celebrate the event. Given that the event was the most significant and ambitious event ever hosted by Iran, the whole country was expected to support and promote that. Therefore, the festival acknowledged the Celebrations and celebrated the 2500th anniversary just like all organisations,

corporations, schools, offices, programmes, and media did.

However, the linkage was not communicated well; not many people were aware of that connection. As far as the findings of this research show, there is only one Persian print media that states *Persepolis Polytope* was commissioned by the Shiraz Art Festival as a prelude or tribute to the Imperial Celebrations ("Inauguration of the Fifth Shiraz Art Festival in the Presence of Her Imperial Majesty Shahbanu Farah Pahlavi"). Therefore, despite what Afkhami and Charney claim, the connection between Persepolis Polytope and Imperial Celebrations is not entirely fictitious. It may have been poorly communicated, but there was some connection.

Turning back to the conflation, Xenakis's *Music and Architecture*, under the *Polytope de Persepolis 1971 - SK* (p217), asserts that "the fifth edition of this festival celebrated the 2500th anniversary of the founding of the Persian empire". This statement, whether by Sharon Kanach or Iannix Xenakis, is misleading. The 1971 festival did not take place to celebrate the 2500th anniversary, it took place and also celebrated the 2500th anniversary. Even if the Celebrations had not happened, the Festival would still have been held at that time and invited Xenakis to perform, though probably they would not give him the opportunity to open the event.

The misleading statement in Xenakis's book has probably bolstered the conflation, at least among non-Iranian Xenakis scholars who have published their contributions after that book. Xenakis himself was definitely aware of the difference between the Imperial Celebrations and the Shiraz Art Festival; however, his scholars were not. As a result, they misunderstood Kanach's/Xenakis's "this festival celebrated the 2500th anniversary of the founding of the Persian empire" and thought the festival was the Imperial Celebrations.

This scenario, though, is only applicable to non-Iranians Xenakis scholars. To Iranians and scholars of modern Iran, familiar with the local context, the first two scenarios are more applicable.

4. Reception and Aftermath

Those who attended the Fifth Shiraz Art Festival did not like *Persepolis Polytope*. On the performance night, the guests were not notified about the details of the show. Audiences were not prepared. They arrived in Persepolis in their fine suits and dresses only to find out that no seat was arranged. They were expected to sit on the ground or walk within the palace, in that windy weather, to enjoy the spatialised music. "Had the audiences knew about it, some of them would never show up", wrote Javad Mojabi, an Iranian art critic whose article was titled "Xenakis's work was shallow and unsuccessful". According to him, many people started to talk with their peers and friends just a few minutes after the show began, as they could not engage with that. He also mentions that the text, we bear the light of the earth, was not easy to read. Mojabi concluded his article by saying that such ideas "had been implemented much better in the past, it is not acceptable to name this preliminary sound-and-light program avant-garde, in fact, it is disappointing". He cited another critic, Ahmad Shamlu, and stated that "the modernism of these people is nothing but complexes and marketing strategy" (Mojabi 1971). Similarly, Kayhan newspaper wrote that, except for being interesting, Xenakis's work did not have any value ("A Dialogue with Herald Tribune Journalist" 1971).

In another newspaper, someone named "Florence", probably a pseudonym, argues that "it was not the first time contemporary music confronted Persepolis. In 1969, Xenakis himself challenged these magnificent ruins and failed". Then the author counts a few problems in the design and execution of *Persepolis Polytope*. "They may say that the loudspeakers were not powerful enough; otherwise, it would have been more effective […] But it is a lie. […] It took

torch bearers one hour to reach the audiences in Persepolis site: a poor unoriginal mise en scène that had been implemented better in other works. […] The artist did not expect windy weather; as a result, the anti-aircraft projectors lost all their aesthetical purposes. […] the laser beams were making flint noises" (Florence 1971).

Criticising Xenakis's work reached its summit in a round table held after the performance at Pahlavi University. Someone asked Xenakis, "are you fully aware of Iran's ancient religion?" to which he responded, "no". The questioner continued, "that is why you are wrong about the concept of light and fire among Iranians". Hamind Samandarian, another Persian critic, boldly asked if Xenakis admits that his only incentive in creating that piece was money. Xenakis, clearly annoyed, responded, "if this gentleman thinks only money is valuable, he is wrong. My life shows that I have not worked for money" ("Where Mountains Serve Art: A Roundtable on *Persepolis Polytope*" 1971).

The roundtable was full of tension and got interrupted a few times due to the severity of disputes. The critics also interpreted the presence of fire as a reproduction of the Macedonian invaders, a further insult. Iranians conceived the Polytope as the Greek artist's attempt of reenacting the burning and destruction of Persepolis, which was first accomplished by Alexander. Other opponents pointed to the general artistic weakness of the music, stating that it "does not yet provide any means of evaluation, its meaning is the one arbitrarily chosen by its maker." Another person expressed a lack of meaning to the sounds, saying, "It could have been presented as a homage to a sausage factory" (Charney 2020, 91-93). The piece received very negative feedback to the degree that Xenakis left Shiraz and returned to France in the middle of the Festival. The headline of Tehran Mosavar, a popular magazine, reads "Xenakis Left Shiraz with a Broken Heart". Within the text, though, the author writes that "it was a relief that he left Shiraz broken-hearted; although we are hospitable, we should not let the fundamentals slide because of our emotions. If he is disappointed at us, so be it!" ("Is Xenakis Genius or Witch?" 1971).

The adverse reactions extended to Iranians living in Paris, where the opponents of the Shah criticised Xenakis for collaborating with a human rights abuser (Gluck 2007). Responding to them, Xenakis first wrote an open letter to Le Monde in December 1971. He acknowledged while "it is impossible to name one single country that is truly free and without multifaceted compromises, without any surrender of principle", his philosophy consists of the freedom of speech and the right to total criticism. A few years later, in February 1976, he wrote another letter to Farrokh Ghaffari, the festival deputy director-general, explaining that "faced with inhuman and unnecessary police repression that the Shah and his government are inflicting on Iran's youth", he is incapable of lending any moral guarantee and refused to participate in the festival (Gluck 2007).

It is not clear why it took Xenakis about four years to refuse further participation, given that the human rights challenges for the Shah had started much earlier. After Persepolis Polytope, he continued his works on the Shiraz Art Centre. It takes more than this paper to unpack all the incentives and disincentives Xenakis had in engaging with Iran's monarchy. Human rights were indeed a concern to Xenakis, as evidenced by his life and injury. Still, his 1971 open letter published in a popular public media cautiously mentioned that the Shah of Iran is not alone in abusing human rights, hence justifying his association, while his 1976 letter was blunt, but private. Had not it been for such hostile reception, would he continue collaborating with the monarchy? Is it possible that his critics residing in Europe were also under this misapprehension that Xenakis had contributed significantly to the Imperial Celebrations? This paper can only call for more research and contributions on one of the most controversial aspects of Xenakis's life, i.e. his association with the monarchy of Iran.

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The *Polytope de Cluny*: towards a reconstitution

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1. Introduction

During the 1960s and 1970s, Xenakis conceived several shows mixing music, architecture and performance called “Polytopes”. In the *Polytope de Cluny* (1972-1974) in particular, the most advanced technologies of the time were employed to imagine a new synergy between music, space and light. During this twenty five minutes long installation, concrete tape music flowed under the arches of the ancient roman therms of Cluny (Paris) while interacting with visual patterns created by an array of hundreds of flash lights and laser beams. In order to synchronise the diffusion of the different audio tracks among the many loudspeakers together with the luminous ballet, Xenakis had a custom technical apparatus designed, that relied at its core on a monotasking computer decoding in real time the digital data stored on a command tape. However, the technologically avant-garde nature of this work, together with the temporary character of the show and its prohibitive cost, was the very reason why it was never to be played again.

Due to the scarcity of the remaining original material, it was long thought that the *Polytope de Cluny* was lost. However, the digital command tape of the show was recently rediscovered, and its cross-examination against archival documentation available at the Archives Xenakis opened new perspectives for the reconstitution of the *Polytope*. An ongoing effort was able to recover most of the aspects of the show with great accuracy, and paves the way for possible reenactments and sustainability of this pioneer work. We give in this paper a summary of the technical apparatus for the show, and of the control equipments that synchronised all the devices. This is followed by a discussion on the command data recovery and the methodology behind its interpretation.

2. Technical apparatus

The technical apparatus for the *Polytope de Cluny* did combine state of the art technologies, all synchronised to create a unique sound and light show. This machinery, unseen at the time, is comprised of many different pieces of equipment, some of which were designed for the sole purpose of the show. This complex undertaking was achieved through the involvement of many actors and companies sharing the development and supply of the electrical, optical, mechanical, sound, electronic and other equipment.

2.1 Scaffolding

Since it was, for obvious preservation reasons, out of the question to attach anything to the ancient walls of the frigidarium, a scaffold was made to support all the equipment. Designed to fit a simplified version of the shape of the vault, it took up the maximum volume available. Its geometry served as a reference for the placement of flashes, lasers and mirrors.

2.2 Flashes

The vaulted ceiling was covered with a layer of six hundred flashes. As clearly appears in several sketches by Xenakis[1], the intention behind the placement of the flashes was that, seen from the centre of the room, the lights would appear to be arranged in an orthogonal grid, deploying an abstract array of light points which evoked a stylized stellar landscape. This treatment of the ancient firgidarium, plunged into darkness, seems to proceed from a form of neutralization of the references of this place steeped in history; only the characteristic "T" shape of the room remains, immersing the viewer in an virtual space.

2.3 Lasers

The second aspect of the light installation for the show consisted of several effects created by three lasers. The laser technology was rather new at this time, and its use in artistic performances even more. Xenakis had witnessed it in Osaka for the World Exhibition in 1970, in the Japanese steel industry pavilion, which was likely an inspiration for the use of lasers in the *Polytope de Cluny*. Since this recent technology was still confined to research laboratories, several pieces of equipment had to be designed and produced in order to make possible the manipulation of the laser beams as intended by Xenakis: this task was undertaken by Jean Colmant and its team at the JAF company.

2.3.1 Laser sources

The laser sources in themselves consisted in three ion lasers: one 1W krypton laser (appearing red), and two 2W argon lasers (appearing blue and green). Each source was situated in one of the ends of the T-shaped room, on a scaffold at 2.5 meters above the ground (for security reasons, it was an explicitly required that no laser beam went below this height[2]). Since the ion technology used to produce the laser beam was very power hungry, most of the energy was not transformed into light but dissipated as heat, which meant that the lasers had to be cooled down by a dedicated water cooling system while they where running.

2.3.2 First deviation of the laser beams ("tourelles")

To use the laser beam for artistic purpose, a special piece of equipment had to be made to control the direction of the beam and send it towards various optical devices. Indeed, the industrial machines producing the laser light generated a one directional beam, and provided no integrated mean to control the direction of the light. The custom devices, called "tourelles" (turret), were made by Jean Colmant and its team under the control of Xenakis. They were designed as a horizontal disk placed in front of the laser source. On the disk, several small mirrors were fixed, each pointing towards a precise direction. By rotating the wheel on its axis, it was possible to choose which mirror would be in front of the laser source, thus deflecting the beam at a predetermined angle. The movements of the wheel itself would be operated by the automation system controlling the whole show.

However, the device suffered from a number of limitations. It was quite heavy and large (about 50 centimeters), hence too slow to switch configurations rapidly: up to several seconds instead of the twenty-fifth of a second that Xenakis intended! Moreover, it was rather imprecise, and it often happened that the incremental deviations of positions became so large that the wheel was completely offset. In this case, the laser beam would miss the mirrors, at which point it would be completely inoperative for the remaining of the show. For these reasons, the device was severely criticised by Xenakis, and it was one of the main cause for breaking the contract with JAF after the first few weeks of operation[3]. Xenakis then obtained fundings to have a new device designed and produced for the second version of the show in fall 1973[4].

[1]See for example Archives Iannis Xenakis OM 22/1 p. 2 and 11, OM 22/7 p. 6-17.
[2]Archives Iannis Xenakis OM 22/3.
[3]Archives Iannis Xenakis OM 22/3.
[4]See the correspondence with J. Pervillé, Archives Iannis Xenakis OM 22/3.

The second version of the “tourette” was made by Jacques Pervillé, a young engineer form the Entreprise Téléphonique. The new approach solved the previous problems by creating a compact and rigid metal box hosting a series of mirrors in the shape of a toothed wheel that created four successions of deviations, for a total of sixteen combinations[5]. The mirrors where controlled internally by four independent step motors, that only made small rotations of one sixteenth of a turn and were thus very swift. According to Pervillé, they could change to any deviation in a tenth of a second, which contradicts the advertising made for the show, as well as the specifications of the control equipment, that all indicate changes of deviations at a rate of a twenty-fifth of a second[6].

2.3.3 Mirrors

The first usage of the lasers is to create three dimensional shapes by bouncing the beam of a network of mirrors. By changing the first mirror to be hit by the laser, the beam was reflected on different networks, creating configurations using from six to fifteen different mirrors[7].

The mirrors were mounted on micrometric screws. During the setup phase of the *Polytope*, once they had been attached to the scaffold, each mirror had to be calibrated manually, one by one in the order, to create the several configurations Xenakis had imagined. This calibration had to be so precise that even the slightest deformations of the structure, induced by the technicians calibrating the mirrors on a ladder pushed against the scaffold, distorting the whole calibration process[8]. For this reason, the setting up was halted until an load elevator was brought in. This piece of equipment had to be used regularly to recalibrate the mirrors and change dead lights, and could not be removed during the shows; it remained in place during the whole exploitation of the show.

The small circular mirrors bought for the show were made using a mainstream manufacturing process, that is, with a so-called silvering technique (a layer of reflective metal deposit on a glass plate); this choice later turned out to be disappointing. Indeed, the reflectivity of this type of mirrors is in the range of 90-95%, which meant that each time the laser beam was deviated by a mirror, it lost 5 to 10% of its luminosity. Even worse, this lost energy was dissipated on the mirror as heat, rising the temperature enough to create a small bulge on the metal coating. As a consequence, the reflected beam was slightly spread into a conical shape, and a portion of the light beam might then miss the next mirror. Added to the fact that the longer the path of the light, the more the laser was gradually attenuated, this meant that the beam faded out rapidly and only the first five or six reflection of most laser figures were really visible[9]. This problem could have been avoided by using dielectric coated mirrors, however this technology discarded because of its prohibitive cost.

2.3.4 Omega mirrors

The mirrors installed on the scaffold were fixed, and the resulting laser configurations static. To allow for more dynamic effects, mobile mirrors, called “omega” mirrors by Xenakis, were also installed. For each of the three laser sources, one mirror was mounted on a frame orientable along two axis and controlled automatically by small increments in either directions at a rate of a twenty-fifth of a second. With those devices, it was possible to move a laser beam across the room.

2.3.5 Deflectors

The optical devices discussed previously only allow for light figures formed by a single beam of light. In order to enlarge the possibilities of visual expression, deflectors were integrated to the show. Those instruments deviate an incoming beam of light with a rapidly changing angle on two axis. The rate of change is set as a specific frequency. When frequencies are high enough (above a

[5]Archives Iannis Xenakis OM 22/8.
[6]Personal interview with J. Pervillé, 17/03/2021.
[7]Archives Iannis Xenakis OM 24/3.
[8]Archives Iannis Xenakis OM 22/3.
[9]Personal interview with Pervillé, 17/03/2021.

few dozen hertz), an effect of retinal persistence transforms the beam into a volumetric halo of light. Moreover, due to the same physiological optic effect, when hitting a wall the beam draws shapes evoking Lissajous figures. Both these effects seem to have inspired Xenakis, who refers to the volumetric evanescent light shadows as “aurores boréales” (aurora borealis) and to the drawings of the beam with several descriptive terms[10]. Sketches by Xenakis, probably done during experimentations with the devices at JAF laboratories, seem to show that the sets of frequencies and amplitudes of deflections were mainly chose for the aesthetic qualities of the corresponding planar figures. For the *Polytope*, the deflector was itself mounted on an orientable chassis, so that it could perform actions similar to those of the omega mirrors, effectively changing its direction in space. It was controlled in the same manner as omega mirrors.

2.3.6 “Comptes-gouttes”

Another luminous effect is sometimes mentioned, but very poorly documented, so much so that we have not been able to determine their exact nature and function. It is generated from the laser beam by a device called by Xenakis “compte-gouttes” (dropper). An account given by Jean Colmant describes them as “devices that transform a thin horizontal beam into a horizontal plane of light” using the “tangential diffraction of a light beam on a glass tube[11]”. This description could correspond to some effects visible on several pictures, but additional elements would be needed to confirm this hypothesis. Since the devices were deemed unreliable by Xenakis, it is unclear whether or not they were still employed by the time he designed the second version of the show, for which he entirely rewrote the laser controls.

2.4 Sound system

The sound system consisted of twelve loudspeakers, distributed over two interlocking horizontal rings, one at a height of about 3 metres, the second at about 8 metres. The distribution chosen by Xenakis was not entirely symmetrical, but covered all the walls of the therms in a more or less uniform manner[12]. To limit the clutter and visual disturbance from the lights, the choice for the loudspeakers was a fifteen inch 2x2m Tannoy model, flat enough to fit between the scaffolding and the brick walls[13].

3. Control equipment

The entire light and sound show of the *Polytope de Cluny* were fully automated. This was achieved by synchronising all the equipment with state-of-the-art electronics. The digital equipment running the show was hosted in a cabin placed in a smaller room adjacent to the main hall, connected by a large opening in the eastern corner of the south wall. The wall shared between the cabin and the hall was made out of glass to let the operator visually inspect the show; we can speculate that is was also done to proudly offer to the view of the public the state-of-the-art digital equipment. This cabin contained the four main pieces of control equipment: and audio tape reader, a digital tape reader, power amplifiers, and a custom-made “armoire de commande”, which was a collection of custom-made electronic circuitry and high voltage relays that can best be described as a primitive monotasking computer (see figure 1).

[10]Archives Iannis Xenakis OM 22/1.

[11]“Appareils transformant un rayon horizontal fin en une nappe de lumière horizontale”, “diffraction tangentielle d’un rayon lumineux sur un tube de verre”, Archives Iannis Xenakis OM 22/3 p. 98.

[12]Archives Iannis Xenakis OM 22/2.

[13]Archives Iannis Xenakis OM 22/3.

Figure 1: The control equipment hosted in the cabin. On the left: the audio tape reader and the power amplifiers; on the right: the “armoire de commande” and the digital tape reader.

The audio for the show was read by an Ampex MM1000 from an eight tracks tape: seven tracks were used for the actual sound, and the eighth for a synchronising clock, which consisted in pulses of 1kHz emitted every twenty fifth of a second. The clock signal was used to synchronise the second tape reader, an Ampex TM-7 borrowed to the National Iranian Radio Television. The tape read by this machine was a digital nine tracks tape (an IBM standard meant to be decoded as a stream of 8-bits bytes with an additional parity bit stored on the last track), and contained all the control data for the flashes, laser equipments, and sound spatialization. To run the show, both tapes were therefore required.

In order to synchronise, on one hand the seven tracks of audio signal, and on the other the command information for the lights and the sound spatialisation emanating from the digital tape, the eigth track of the audio tape reader was used to store a clock signal triggering the digital tape reader, effectively creating a master/slave configuration between the two tape devices. A special circuitry was designed to create this connection, operating as follows[14] :

- the audio tape reader outputs a 1000 Hz pulse stored on track eight
- the signal of the eighth track is detected by a demodulator and triggers the start switch of the digital
  tape reader
- while the digital tape is being read, a byte counter is incremented
- once the byte counter reaches 150 (corresponding to the total length of a twenty-fifth of a second
  frame of data) a comparator triggers the stop button of the digital tape reader, which remains idle
  until the next clock pulse.

[14]See electronic diagrams in Archives Iannis Xenakis, OM 22/3 p. 15.

Another solution might have been employed as an alternative to the byte counter. Indeed, the digital tape has nine tracks, of which only eight are used to store the data as bytes (octets), leaving the ninth empty. Instead of using it for the parity check storage suggested by the IBM standard, a logical 1 was placed on this last track to indicate the end of a frame. This feature was used by us to separate the raw data of the recovered digital tape into 150 bytes frames.

In any case, the synchronisation system was never used, and it is unclear whether the synchronising circuit was even ever built or not. Moreover, the digital tape reader was already outputting its maximal amount of data, and possibly may not have had the time to pause and resume twenty five times per second. In any case, the improvised solution was to press play on the two tape readers at the beginning of the show and hope that they would not drift apart too much by the end of twenty three minutes of the performance[15].

Unfortunately, the electronics that transform the data on the tape into actual electronic commands for the various devices of the show has long been lost, and very little documentation is available describing its inner workings[16]. Therefore, the interpretation of the command data has to be performed without this piece of the puzzle. Our approach was to bypass the reconstitution of the electronic equipment to directly interpret the command data; this is the subject of the following section.

4. Control data recovery and forensics

The reconstruction of the work cannot be done without access to the original data. While the audio tape is preserved at the Éditions Salabert, it was considered for a long time that the command tape was lost. One possibility, in that case, would have been to work with second hand material, such as films, photographs, sketches and graphic scores, to try and rebuild the timeline of the show; but such a massive undertaking has little chance of success on the scale of the full work. It should be mentioned, however, that such work has made it possible to reconstitute several minutes of the sound spatialization of the *Diatope*, a show by Xenakis sharing a very similar technical apparatus with the *Polytope de Cluny*, and whose tape has not been found to date[17].

Fortunately, we were recently able to locate the original control tape of the second version of the show in the Xenakis collection at the audio department of the Bibliothèque Nationale de France. The tape was successfully digitised, and the data recovered with a few minor reading errors. Since all the show's electronic equipment (most of it custom made, as we have seen) has long since been dismantled, the control data must be interpreted in the light of the documentation available in the archives. This interpretation would be extremely difficult to perform — if possible at all — if some precious computer documentation of an intermediate stage of the first version of the *Polytope* had not been kept in the archives[18]. Those pages, typewritten by Robert Dupuy, the computer engineer in charge of writing the programs for composing the lights, describe the data layout on the tape, and served as a first guess to understand the data stored on the control tape.

[15]Personal interview with Bruce Rogers, 30/11/2021.

[16]According to Pervillé, the chief engineer for the "armoire de commande" at Entreprise Téléphonique designed the electronic circuits in his head and communicated them directly to the manufacturing team for completion, leaving few written documents.

[17]Elisavet Kiourtsoglou, "An architect draws sound and light: new perspectives on Iannis Xenakis's *Diatope* and *La légende d'Eer* (1978)" in *Computer Music Journal* 41 (4), 2018.

[18]Archives Iannis Xenakis OM 22/3 p. 221-227.

The data on the tape is organised in blocks of 150 octets (i.e. 1200 bits), each block commanding one twenty-fifth of a second of the show. Data is divided in three main categories: the first seventy-five octets trigger the flashes, the next thirty-six octets command the laser devices, and the last forty-two octets automate the spatialization of the seven tracks audio tape on the twelve loudspeakers. Each of these categories is detailed thereafter.

4.1 Flashes

The command of the flashes is rather straightforward. The first six hundred bits (seventy-five octets) of each frame independently trigger the flashes, that is, a digital one at the n-th bit triggers the n-th flash in ascending order. By implementing this solution directly, we were able to recover configurations of lights that matched drawings by Xenakis, giving confirmation of the validity of the description of the flash related data (see figure 2 for an example).

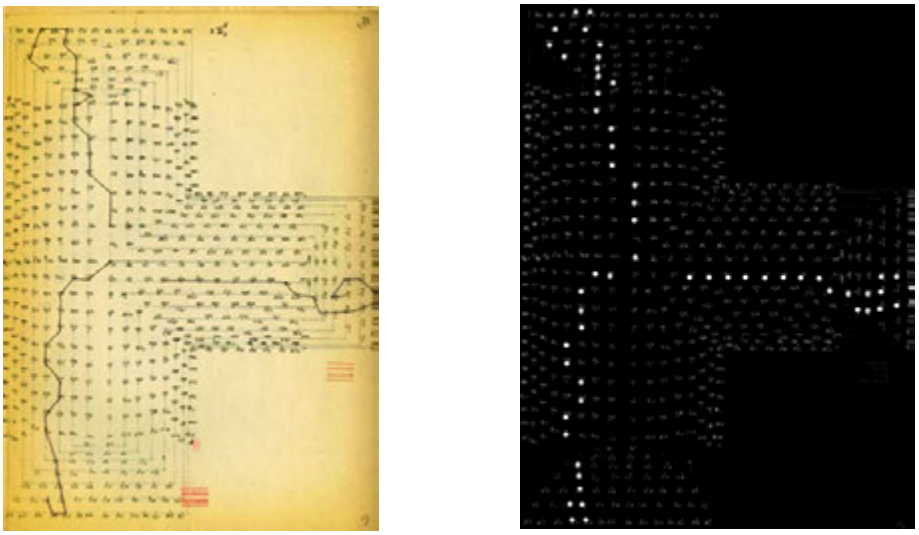

Figure 2 : Superimposition of archival documents OM 22/1 p. 2 and OM 22/4 p. 22 (left).
The simulation of flashes from frame 15364 to 15390 obtained from the tape (right) matches the drawing by Xenakis.

4.2 Sound spatialization

The documentation shows that any of the seven tracks can be outputted on one or several of the twelve loudspeakers on four different levels (0, -3, -7 and -12 dB). The diffusion is actuated by a digital routing matrix of 7 × 12 × 4 stored on the tape for each frame. Again, applying directly the description given in the documentation results in valid sound movements that confer this interpretation of the data a great credibility.

4.3 Laser devices

The command data for the lasers is by far the most challenging to interpret, for several reasons. Firstly, the data is routed towards different pieces of equipments (tourette, deflectors, omega mirrors), each having their own particularities. Besides, some aspects of the chain of command are integrated in the devices themselves, which makes it more difficult to understand what action does a command correspond to. The full documentation is not always available, nor are a lot of crucial artistic and technical decisions made along the way by Xenakis and his collaborators. Finally, as we have seen, the (mostly undocumented) changes between the first and second versions of the *Polytope* mainly affect aspects related to the lasers. In particular, since the number of mirrors was changed from one hundred to three hundred, the figures were dramatically reshaped for the second

version, and the “tourelles” devices were replaced altogether. To interpret the laser data, it is therefore needed to cross-examine all available sources and make successive inferences to sort out the most likely scenario; we will outline those assumptions as we go.

For each laser “tourelle”, a configuration identifier is given on the first four bits of the command data, which commands towards which device the laser beam will be deviated. Those four bits can therefore encode sixteen unique values. This information is sent directly to the “tourelle”, whose internal command circuitry sets a specific deviation according to the value. This original deviation then hits another external mirror, which in turns sends the beam towards a network of mirrors, an omega mirror or a deflector. However, the correspondence between a configuration number on the tape, on one hand, and the actual optical device the beam is send towards, on the other hand, is not documented, and therefore has to be guessed based on several assumptions.

Firstly, examining all the configurations values for each laser shows that some values are never used during the entire show, and thus can be safely ignored. Secondly, according to the documentation, some regions of the laser data encode the change of orientation of the omega mirrors. When data is written in these regions, the configuration of the lasers is always set to the same constant value. The same is true for the region of data actuating the orientation and frequencies of the deflectors. Hence, we can for each laser attribute the actuation of the omega mirror or the deflector to a given configuration number; this is summed up in table 1.

Laser	I	II	III
Unused configuration numbers	4	5, 15	14
Omega configuration number	0	1	6
Deflector configuration number	13	13	13

Table 1 : Unused configurations and attribution of configuration numbers for the omega and deflectors.

From the analysis of the archives, our assumption was that the remaining configuration numbers were associated with laser figures created by the networks of mirrors. Gathering all the available material gives a total of forty figures, divided into two types of drawings[19]. The first correspond to the figures of the first version of the show. Since no positional measurements are given on those drawings for the location of the reflections, this might suggest that those were copied after the conception of the *Polytope I* based on the existing hanging plan for mirrors[20]. For the second type of drawings, precise mirror coordinates are given, suggesting that these were working drawings. Two of the drawings of the first version of the show (the figures called AR and ECLAIR) were placed in a separate folder by Xenakis[21]. Since the aesthetic of those figures is redundant with a more elaborate version designed for the second show (called ARC), we assumed that they were put aside in the second version. With this assumption, this gives a total of thirty-eight figures which also happens to correspond to the total number of laser configurations on the tape that remain yet unattributed. The remaining of this section discusses the association of these selected figures and the configuration numbers.

The most striking difference between the two versions of the mirror networks design for the *Polytope* is that, apart from having more different configurations, some of them are designed as ensembles of figures that share similarities: namely, ANEMONE A, B, C and ARC A, B, C. When cycled through rapidly, those series of figures create kinetic patterns that give an illusion of movement under the ceiling of the therms. Since the new “tourelles” precisely allowed this type of rapid changes, it is highly probable that Xenakis intended to use those configurations this way.

[19]Drawings present in folders OM 24/3, OM 4/3 and OM 24/4.
[20]See document OM 22/7 p. 18.
[21]Folder OM 24/4 instead of OM 24/3.

Each laser has three Anemone figures, which makes up a total of nine. The ARC figures are slightly different: laser I and II each have three of them, one being the symmetric of the other. The beams of all the ARC I and II figures ends up its path on the laser source III, so it is possible to light those figures in reverse using the laser III and finish at laser I or II. When lit by laser III, the figures ARC I are called ARC III, and ARC II figures become ARC IV[22].

Such rapid cycles of groups of three configurations do indeed appear on the tape at numerous occasions. The configuration numbers for these groups are given in table 2; in all probability, these have to be attributed to either ANEMONE or ARC figures. Since ARC I and ARC IV are symmetrical to each other, as are ARC II and ARC III, we assume that those figures are likely to be found paired this way on the data tape, since it seems to make more sense from an aesthetic standpoint. The examination of the correlation coefficients for the on/off signals of each configuration helps to determine the most statistically credible matches (see table 6). This leads us to conclude that the figures are numbered as shown in table 3.

Laser	I	II	III
Configuration numbers	(1,9,5), (10,6,14)	(0,8,4), (12,2,10)	(3,11,7), (8,4,12), (9,5,1)

Table 2 :Configuration numbers that often appear as rapid cycles on the command tape.

Laser	I	II	III	IV (= laser III)
ANEMONE A,B,C	10, 6, 14	0, 8, 4	3, 11, 7	
ARC A,B,C	1, 9, 5	12, 2, 10	8, 4, 12	9, 5, 1

Table 3 : Attribution of configuration numbers for the kinetic laser figures.

All the remaining unattributed configurations are static figures, meaning that they are not intended to produce kinetic effects. Some only involve one laser at a time (ATAH and ARAW for laser I, UHINE for laser II, PAPPUS and ATTL for laser III), some involve both lasers I and II (DESARGUES, FICELLE and LOTUS), and others all lasers (PYRAMIDE and ROSACE). By computing the correlation coefficients between the configuration numbers, we can establish which ones are likely to work as pairs or triplets. Given the values in tables 7, we worked out the combinations of configuration numbers given in table 4.

Figure \ Laser	I	II	III
Triplet 1	8	11	2
Triplet 2	2	9	15
Duet 1	3	7	
Duet 2	11	3	
Duet 3	15	6	
Solos	7, 12	14	0, 10

Table 4 : Attribution of configuration numbers to static laser figures.

The configuration 14 of laser II necessarily corresponds to figure UHINE, which is the only solo figure for laser II. However at this stage, it is not possible to attribute the other anonymous

[22]This is the only occurrence of possible use of networks of mirrors by several laser sources.

configuration numbers, and making inferences based on the tape data alone does not seem to allow us to make further progress. To overcome this difficulty, the hypothesis made so far have to be confronted with other material evidence. In particular, photographs can reveal much precious information. Since in the low light conditions of the show, most pictures were taken with a long exposure time (typically more than a second), several frames might have been captured, during which flashes are triggered, and several laser configurations are used. Cross examining all the information about the on/off state of the optical devices gives sometimes enough information to determine when (and for how long) the shot was taken. It is then possible to deduce new information about the attribution of configuration numbers to laser figures. An example of such a process is given in figure 3.

Similar analysis of other pictures confronted with previously made assumptions about the attribution of configuration numbers confirmed our choices and revealed new attributions, which ultimately resulted in the identifications given in table 5. Further investigation is still needed to solve the remaining uncertainties, and the calibration of deflector frequencies and omega mirrors offsets; this will be the subject of future work.

Figure 3 : By analysing the photograph from the laser and flash data, it is possible to determine the date and duration of the shot, as well as to make assumptions about the assignment of configuration numbers to anonymous laser figures. Here, knowing the configuration number for deflectors and omega mirrors, it was possible to determine that the ATTL figure of laser III is associated with the number 0.

	I	II	III
0	Omega	ANEMONE II.A	ATTL
1	ARC I.A	Omega	ARC IV.C
2	ROSACE A	ARC II.B	PYRAMIDE 1
3	[Duet 1]	[Duet 2]	ANEMONE III.A
4	Unused	ANEMONE II.C	ARC III.B
5	ARC I.C	Unused	ARC IV.B
6	ANEMONE I.B	[Duet 3]	Omega
7	ATAH / ARAW	[Duet 1]	ANEMONE III.C
8	PYRAMIDE 3	ANEMONE II.B	ARC III.A
9	ARC I.B	ROSACE C	ARC IV.A
10	ANEMONE I.A	ARC II.C	PAPPUS
11	[Duet 2]	PYRAMIDE 2	ANEMONE III.B
12	ARAW / ATAH	ARC II.A	ARC III.C
13	Deflector	Deflector	Deflector
14	ANEMONE I.C	UHINE	Unused
15	[Duet 3]	Unused	ROSACE B

Table 5 : Attribution of tape configuration numbers with laser devices and figures.

5. Conclusion

The rediscovery of the command tape of the *Polytope de Cluny* was the starting point of an investigation into the reconstitution of the show. This was made possible by cross examining

sources of documentation coming from the Archives Iannis Xenakis, the Bibliothèque Nationale de France and testimonies from witnesses. Although still incomplete, this work makes it possible today to reconstitute the *Polytope de Cluny* in its original form with great fidelity. This allows us to take a new look at a multimedia work that we long thought was lost, and to put it into the wider context of the musical and visual work of Xenakis; but most importantly, to experience it. Similar approaches and methodologies could well allow the restoration of other Polytopes such as the *Diatope* or the *Montreal Polytope*, the major problem being to obtain the control data in one form or another.

II \ I	1	9	5	10	6	14
0	-0.088	-0.036	-0.134	0.012	0.020	-0.013
8	-0.022	-0.017	-0.005	0.078	0.248	0.126
4	0.014	0.009	0.031	0.085	0.095	0.220
12	0.220	0.034	0.024	0.016	-0.017	-0.016
2	0.049	0.271	0.043	0.098	-0.033	-0.022
10	0.076	0.060	0.110	0.029	-0.023	-0.014

I \ III	3	11	7	8	4	12	9	5	1
1	-0.031	-0.022	0.018	0.098	0.072	0.039	0.175	0.036	-0.003
9	0.027	0.038	0.003	0.022	0.128	0.072	0.021	0.151	0.020
5	-0.045	-0.033	-0.033	0.025	0.029	0.140	-0.004	0.011	0.279
10	0.258	0.039	0.016	0.025	-0.018	0.040	-0.016	-0.019	-0.035
6	0.027	0.306	0.017	-0.038	-0.018	0.048	-0.028	-0.017	-0.033
14	0.035	0.064	0.318	-0.036	-0.011	-0.013	-0.021	0.022	-0.027

II \ III	3	11	7	8	4	12	9	5	1
0	-0.005	-0.038	-0.082	0.007	-0.070	-0.031	-0.069	-0.051	-0.115
8	0.040	0.323	0.056	-0.024	-0.013	-0.007	-0.015	-0.016	0.011
4	0.038	0.061	0.245	0.027	0.047	0.052	-0.007	0.022	-0.017
12	-0.028	-0.004	-0.021	0.130	0.095	0.062	0.127	0.039	0.047
2	-0.031	0.046	-0.031	0.067	0.169	0.132	0.046	0.016	0.038
10	-0.022	-0.006	0.004	0.057	0.095	0.153	0.049	0.063	0.060

Table 6 : Correlation between on/off signals of kinetic configuration numbers among the different lasers. Correlations above 0.1 are highlighted.

II \ I	2	3	7	8	11	12	15
3	-0.046	-0.010	-0.025	-0.068	0.270	-0.064	-0.023
6	-0.049	-0.037	-0.028	0.040	0.252	-0.052	0.328
7	-0.048	0.511	-0.028	-0.047	-0.060	0.001	-0.033
9	0.479	-0.038	-0.050	-0.054	-0.033	0.315	-0.039
11	-0.051	-0.022	0.052	0.149	-0.053	-0.061	-0.020
14	-0.039	-0.029	-0.023	-0.043	-0.047	-0.042	-0.015

III \ I	2	3	7	8	11	12	15
0	-0.181	0.107	0.057	-0.151	0.102	-0.101	-0.030
2	-0.070	-0.031	0.032	0.419	-0.069	-0.075	0.035
10	-0.003	-0.003	0.008	-0.009	0.014	-0.014	-0.014
15	0.489	-0.031	-0.015	-0.053	-0.067	0.273	-0.021

III \ II	3	6	7	9	11	14
0	0.048	0.001	0.057	-0.168	-0.131	-0.002
2	-0.083	0.099	-0.044	-0.075	0.371	-0.050
10	0.004	-0.011	-0.015	-0.011	0.011	-0.007
15	-0.059	-0.045	-0.043	0.651	-0.030	-0.040

Table 7 : Correlation between on/off signals of static configuration numbers among the different lasers. Correlations above 0.1 are highlighted.

The Narrative of the Mycenae Polytope

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Abstract

Iannis Xenakis' last realised polytope, *Polytope de Mycènes*, is often described as a synthesis of his previous interdisciplinary works. As an artist and engineer who acted under the influence of arts and sciences of the time but was also inspired by Greek cultural heritage, Xenakis approached this project as an assemblage of various sensorial elements. These elements consist of musical compositions, narrations, light shows, performances, and processions. To comprehend the spectacle as a whole, it is necessary to consider what each of its elements represents. In doing so, we look at instances from ancient Greek history, mythology, and literature to which Xenakis referred and used as a metaphor to transmit a humanistic message.

Although large-scale polytopes like *Persépolis* and *Mycènes* are inseparable from the political dynamics of the time, the purpose of this paper is to primarily focus on the formal design instead of a socio-political context. We take a glimpse at the contents of various literary sources Xenakis either set to music or deployed in narrations. These include the fragments of Mycenaean tablets, Homer's *Iliad*, and the plays by tragedians Aeschylus, Sophocles, and Euripides. We also look at the instrumental pieces incorporated in the performance and their symbolic role in the spectacle. In the research, we use archival materials at our disposal, such as manuscripts, interviews, and sound recordings of the performance. Upon analysing all key elements of the Polytope, we place the event in the broader context of cybernetic art and uncover the way Xenakis applied its aesthetic features to formalise an unconventional narrative. Such features include fragmentation, non-linearity, and circularity. In the end, we will see that *Polytope de Mycènes* – in contrast to previous more abstract multimedia works – is the most narrational of all Xenakis' polytopes, and all of its elements are carefully chosen and mindfully organised to form a unified plot.

1. Introduction

In 1974, after the collapse of the Fascist military dictatorship in Greece, Iannis Xenakis returned to his homeland after 27 years of political exile. Four years later, he created what was to become his last and most ambitious multimedia project in the series of so-called polytopes: *Polytope de Mycènes*. The performance took place in the evening hours from 2 to 5 September 1978 at the ancient acropolis of Mycenae and its surroundings. The composer utilised a large number of performers and visual effects, such as anti-aircraft searchlights, video projections, torches, bonfires, fireworks, even the herds of sheep and goats carrying lights and bells. Apart from professional musicians, many amateur performers and locals from the surrounding areas participated in the production of the event. The monumental celebration at the historic site was meant to serve as a retrospective of Xenakis' music and an homage to one of the oldest European civilizations (Harley, M. A. 1998; Sterken 2004).

To structure the spectacle, Xenakis reached out for five existing compositions in his catalogue of works. These include percussion and vocal incidental music: *Persephassa* (1969), for six percussionists; *Psappha* (1975), for one percussionist; *Oresteïa*, for children's choir, mixed choir, and

ensemble; *À Hélène* (1977), for female soloists, or female or male choir; and *À Colone* (1977), for male or female choir and ensemble. The only music composed specifically for the Polytope was a series of electroacoustic interpolations created by Xenakis on his newly developed UPIC system[1] and played back through a number of loudspeakers. The collection of these interpolations would soon become known as an electroacoustic piece *Mycènes alpha* (1978). In addition to music, Xenakis included narrations of excerpts from Homer's *Iliad* and some surviving fragments of Mycenaean hieroglyphics, known as Linear B script. Each one of these pieces and texts were used for their symbolism with which the composer was able to formalise an overall "libretto" of the spectacle. Together with the event diagram that Xenakis created to organise the event,[2] the publication of the program catalogue, and the sound recordings of the performance,[3] we are able to reconstruct how the individual parts form a unified whole. By taking a closer look at their contents, we begin to unveil the narrative *Polytope de Mycènes* aims to communicate with its audience.

2. Performance timeline[4]

1st sound interpolation (UPIC I)[5]
Narration in Mycenaean language
Helen (Euripides); lines 1107-1136
2nd sound interpolation (UPIC II)
Narration in Homeric language; *Iliad*, book XII, lines 1-5
Psappha
3rd sound interpolation (UPIC III)
Narration in Homeric language; *Iliad*, book XII, lines 241-244
Oedipus at Colonus (Sophocles); lines 668-719
4th sound interpolation (UPIC IV+V)
Narration in Homeric language; *Iliad*, book V,[6] lines 855-864
Persephassa
Narration in Homeric language; *Iliad*, book XVI (excerpts)
5th sound interpolation (UPIC VI)
Helen (Euripides); lines 1137-1164
Narration in Homeric language; *Iliad*, book XX and XXII (excerpts)
6th sound interpolation (UPIC VIII)
Helen (Euripides); lines 1495-1511
Narration in Mycenaean language (I-XVI)
7th sound interpolation (UPIC VII)[7]
Oresteia (Aeschylus); *Agamemnon*
The Libation Bearers
The Eumenides

[1] The abbreviation of "Unité Polyagogique Informatique CEMAMu", a computerised musical composition tool, devised by Xenakis.
[2] In Iannis Xenakis archives (folder OM 19).
[3] In KSYME (Contemporary Music Research Centre) archives.
[4] This timeline is an overview based on the event catalogue, Xenakis' own event diagram, and archival recordings.
[5] In the event diagram, Xenakis assigns lowercase letters of the Greek alphabet to each of the UPIC interpolations and second appearance of the Mycenaean fragments. They represent Ancient Greek numerals: α (alpha) = 1; β (beta) = 2; γ (gamma) = 3; δ (delta) = 4; ε (epsilon) = 5; ϛ (digamma) = 6; ζ (zeta) = 7; η (eta) = 8; θ (theta) = 9; ι (iota) = 10. The combination of iota (ι = 10) and digamma (ϛ = 6) give 16 (ιϛ), as used for the second narration in Mycenaean language. For the fourth sound interpolation, Xenakis merges delta (δ = 4) and epsilon (ε = 5). The last two interpolations, zeta (ζ = 7) and eta (η = 8), are swapped. In transliteration to Latin alphabet, these values are traditionally romanised as Roman numerals.
[6] In the program catalogue, the fifth book of *Iliad* is coincidentally printed as canto E (epsilon).
[7] In the program catalogue, the last electroacoustic interpolation precedes the last narration in the Mycenaean language, but in the archival recordings, it takes place between the narration and the beginning of *Oresteïa*.

Narration in Mycenaean language and final procession[8]

Xenakis' hand-written two-page event diagram is divided into ten columns with the following inscriptions: *Chronology*, *Recited poem*, *Music*, *Light Danalis*, *Light Laskaraios*, *Light Antreas*, *Film*, *Children acropolis*, *Children valley*, and *Other*.[9] In the *Chronology* column, the composer predicts the duration of each segment; *Recited poem* deploys Mycenaean fragments and quotations from *Iliad*; *Music* lists the separate musical pieces; *Light Danalis*, *Laskaraios*, and *Antreas* define the assignments of the team of lightning technician, Gregory Danalis; *Film* shows at which point of the performance the video segments are to be projected; *Children acropolis* and *Children valley* describe the movements and tasks by children in their respective locations at the site, and *Other* includes miscellaneous commentary. Although one can notice a slight difference between the program catalogue, event diagram, and the performance recordings, they are insignificant as the general order of Polytope segments does not change.

2.1. Mycenaean fragments

Xenakis uses texts in the Mycenaean language on three different occasions in the Polytope. The first time it occurs is at the beginning of the event, invoking a procession in honour of the god Zeus. The second time, we hear it before the last electroacoustic intermission and the performance of *Oresteïa*. This time, the text includes "enumeration of furniture items, objects, and chariots, that formed part of the booty of Troy's conquerors". These texts, although merely a list of objects, sparked an interest in Xenakis not only because of their content but also because of their sonic aspects, including their accent and pronunciation. The composer consulted various linguists, but the final decision on how these fragments would be recited was left to him alone. He may have used his artistic instinct, the advice of the experts, or a combination of both, but in any case, he wanted to remain faithful to the original phonetics and personally gave precise instructions to the performers (Tsagkarakis 2013). Finally, a variation of the first invocation appears at the end of the Polytope, only this time Zeus is replaced with Poseidon. Both first and last fragments appear in five versions in the program catalogue: the original in Linear B script, syllabic transliteration to Latin alphabet (i-je-to-ge di-u-jo do-ra-ge pe-re po-re-na-ge a-ke di-we), transliteration to the Greek alphabet, Xenakis' own translation to Katharevousa,[10] and the translation to English. The English text reads: he sets in movement a procession in the sanctuary of Zeus, brings presents, carries(?) for Zeus…

The sentence fragment invoking ancient sacred rituals comes from the Mycenaean clay tablet PY 172=Tn 316. In the 1953 book and its expanded 1973 second edition, *Documents in Mycenaean Greek*, authors Michael Ventris and John Chadwick demonstrated that the previously mysterious Linear B script was, in fact, a syllabic form of written Greek. The authors translate this fragment as: Pylos [Puro] sacrifices at the shrine of Zeus [ijetoge Diujo dorage] and brings gifts [pere porenage] and leads victims [ake diwe]. The further text on the tablet includes descriptions of offerings, such as golden bowls, men, and women. It is not fully clear whether the inclusion of human beings indicates a sacrificial victim or merely libation bearers, but it must be noted that the Mycenaeans did practice human sacrifice (Ventris & Chadwick 1973; Darbon 2014). The translation included in the program catalogue leaves out the ancient Mycenaean city of Pylos, replaces the word "sacrifice" with a phrase "sets in movement a procession", and finally, the implemented question mark (?) actually corresponds to "victims". It is not clear what was Xenakis' reason for this. Darbon (2014) proposes two hypotheses: either he struggled with translation, or he wished to delete the reference to the sacrificial ceremony. If latter, it would be possible that Xenakis removed the reference deliberately, not intending

[8] The last narration occurs before the end of the performance of *The Eumenides*. After bar 305, the ensemble takes a break, and we hear once more the voices of narrators. The music resumes with bar 306, and the spectacle ends in full volume.

[9] Translation by the author with the help of the native speaker.

[10] Conservative form of Modern Greek language which was still in use in official and formal purposes in the 1970s.

to hide the gruesome historical fact, but rather to leave space for different, more positive readings and interpretations of the ritual. Instead of completing the fragment discovered on the ancient tablet, the narration stops after "for Zeus…", upon which the music performances follow. Xenakis thus replaced the listing of offerings with artistic content, as if he wished to exchange destruction for creation.

2.2. Homer's Iliad

The war between Achaeans – a coalition of Mycenaean Greek states, led by brothers Agamemnon and Menelaus – and Troy is fictionalised in Homer's epic poem *Iliad*. Dating from c. 8th century BCE, it is written in Homeric Greek and divided into 24 books. It tells of events during the few weeks of the final year of the war but indirectly covers the earlier and later events as well, making it a more or less complete tale of the ten-year-long conflict.

Xenakis quotes *Iliad* on five different occasions in the Polytope: the first narration includes the first five lines of the first book; the second, lines 241-244 from the book XII; the third, lines 855-864 from the book V; the fourth, various excerpts from the book XVI; and fifth, excerpts from the books XX and XXII. The first narration invokes the Muses to sing about "the wrath of Achilles", the legendary warrior who fought for the Greeks and "sent many brave souls to the underworld". For the next narration, Xenakis jumps on to book XII, only to return to book V in the third narration. As the quote from the book XII merely expresses the loyalty to the god Zeus and idolises fearless defence of one's own country, the chronology remains preserved. The third narration depicts the duel between the Achaean hero Diomedes and Ares, the god of war. As Diomedes wounds Ares, the fear began to spread among the Greeks. The next duel, between the god Apollo and Achilles' friend Patroclus, is the subject of the fourth narration. Upon Apollo's strike, the Trojan prince and Paris' brother, Hector, kills Patroclus. The final narration depicts Achilles' revenge, duel between him and Hector, and Hector's death and dishonouring of his body by Achilles, who dragged it behind his chariot. *Iliad* ends with Hector's funeral, and his loss signifies the final breakdown of Troy.

2.3. Euripides' Helen

Euripides' play premiered in 412 BCE in Athens, and it describes an alternative version of events preceding the Trojan War. In contrast to the Helen of Troy, who fell in love with Paris and abandoned her husband Menelaus and her country, Euripides' Helen never even met Paris, let alone left her husband. Instead, the prince of Troy was confronted by a phantom look-like whom goddess Hera sent by emissary Hermes to replace the real Helen. While Paris took her body double to Troy, the actual Helen was abducted to Egypt, where she was held captive for the entire duration of the war. On his return from Troy, Menelaus survived a shipwreck and ended up in Egypt. He reunited with his wife, and they planned the escape together. Helen's reputation is thus restored, as she remained faithful to her husband all those years – even though the Egyptian king's son Theoclymenus intended to take her as a wife – and never turned her back to her people. The alternative assertion has also been made by Herodotus and Stesichorus before Euripides would write the play. By replacing the tragic Helen with a romantic one, the plot not only adopts a feminist dimension, but a profoundly pacifist as well. The great Trojan War was ironically fought over a phantom and took many lives in vain (Arrowsmith & Golder 1981).

Xenakis composed music for two fragments of this play for its staged revival at the ancient theatre of Epidaurus in 1977. The chantlike arrangement is scored for (preferably) female voices in two parts (Harley, J. 2004). The fragments Xenakis set to music are two choruses from the play, namely the lines 1107-1164 and 1494-1511. The first chorus consists of two interchanging strophes (lines 1107-1121 and 1137-1150) and antistrophes (lines 1122-1136 and 1151-1164).[11] Although the second chorus also consists of two interchanging strophes (lines 1451-1464 and 1479-1494) and two antistrophes (lines 1465-1478 and 1495-1511), Xenakis set to music only the second antistrophe

[11] Strophes and antistrophes, together with epode, were stanzas in Ancient Greek tragedy.

(lines 1494-1511). In the Polytope, Xenakis divided the two choruses. He also split the first strophe and antistrophe of the first chorus from the second strophe and antistrophe of the same chorus, separating thus the performances of *À Hélène* into three independent parts. The text of all choruses is a commentary and lamentation on Helen's ill fate and the Trojan War.

2.4. Sophocles' Oedipus at Colonus

Originally composed for the Contemporary Music Festival of Metz, Xenakis chose an extract from Sophocles' last drama as the basis for his 1977 choral work, *À Colone*. Unlike *À Hélène*, a purely vocal work, the piece includes brass and string instruments (Harley, J. 2004). With a reference to Sophocles' play, Xenakis introduces Athens – one of Agamemnon's coalition partner states – to the plot for the first time. The story of Sophocles' play takes place after the infamous incest and blinding of Oedipus. As he left Thebes[12] with his daughter and sister Antigone, they took refuge at Colonus, right outside Athens, on the ground that is sacred to the Eumenides.[13] The chthonic deities were bringing punishment to humans who commit the most basic and intense of crimes: violation of the natural, unalienable bonds between members of a family. The locals were in fear that Oedipus' cursed presence would bring plague to their city and wanted him to leave. After the purification rites to appease the Eumenides, Oedipus stayed at Colonus and died a peaceful death (Grennan & Kitzinger 2005).

Similar to *À Hélène*, the chorus of *À Colone* is divided into two strophes (lines 668-680 and 694-707) and antistrophes (lines 681-693 and 708-719). In Xenakis' own words, "It is a prayer-chant for Athens, just before it lost its independence (404 BCE) after a war that had lasted 27 years, a chant therefore full of melancholic piety (…)". The war in question is the Peloponnesian War between the Delian League, led by Athens, and Peloponnesian League, led by Sparta. The latter claimed the victory, which marked the dramatic end to the golden age of Athens.

2.5. Aeschylus' Oresteia

Xenakis chose to conclude the Polytope with Aeschylus' tragic trilogy. It is divided into three parts, corresponding to the titles of the three successive plays: *Agamemnon*, *The Libation Bearers*, and *The Eumenides*. Composed between 1965 and 1966, *Oresteïa* remains the only work in the composer's catalogue to which he would return for revisions over the span of three decades.[14] One of Xenakis' most celebrated works was first performed in the English language in 1966 in Ypsilanti, Michigan, under the direction of Alexis Solomos. Within the Polytope, however, the piece was sung in Greek (Harley, M. A. 1998; Harley, J. 2004; Vagopoulou 2005).

Xenakis again does not use the entirety of the tragic texts but a selection that emphasises on the significance of the chorus. Although he displaces certain lines, he pays attention not to affect the continuity of the narration. The trilogy covers the final events of the curse of the Mycenaean royal bloodline. Clytemnestra – the wife of the Mycenaean king Agamemnon who led the war on Troy – was enraged by the murder of her daughter Iphigenia and had an affair with Aegisthus, Agamemnon's nephew. When the victorious king returned to Mycenae, Clytemnestra drew a bath for him and stabbed him to death with the help of Aegisthus. Agamemnon's only son, Orestes – after whom the trilogy is titled – was sent to exile. In the second part, *The Libation Bearers*, he needed to bring justice upon his own mother for killing his father. This put him in an impossible position to end the curse because the revenge would make him a murderer of his kin, too. Advised by the god Apollo, he decides to carry out the plot. Upon killing both his mother and her lover Aegisthus, he wandered the land for many years, disturbed by his actions and tracked by the Eumenides. The third part concludes

[12] The city of Thebes was also a Mycenaean settlement where clay tablets written in Linear B script were excavated.
[13] Female goddesses of vengeance, also known as Erinyes and Furies.
[14] *Kassandra* (1987) and *La Déesse Athéna* (1992) – which incorporated solo voices rather than focused on choruses like the original version – were added years after the *Polytope de Mycènes*.

with his trial in Athens, where Athena, the goddess of wisdom, decides he should be released from the guilt, which ultimately ended the curse on his bloodline (Hayes & Nimis 2017).

2.6. Instrumental music: Psappha, Persephassa, *and* Mycènes alpha

Besides vocal music, Xenakis included more abstract instrumental works in the spectacle. The first among such is a 1975-piece *Psappha*, for solo percussionist. In the event catalogue, he explains it is dedicated to Sappho[15] whose language, Aeolic, is a direct parent of Mycenaean. Sappho, a celebrated Greek poet from the island of Lesbos, was famous for her lyric poetry. Alongside epic and drama, lyric poetry was the third great literary genre of ancient Greece that flourished between the 7th and 5th century BCE. Xenakis credited Sappho with introducing "metabolae" (changes) into the rhythmic patterns of her poetry, a notion of which he incorporated in his own systematic organisation of the rhythmic material (Harley, J. 2004).

Persephassa, for six percussionists surrounding the audience in a hexagonal formation, originally premiered in 1969 at the Shiraz Arts Festival at the ancient site of Persepolis, Iran, where Xenakis realised a similar open-air spectacle, *Polytope de Persépolis* (1971). The piece is dedicated to a chthonian goddess Persephone,[16] the cult of which played an important role to the ancient Mycenaeans (Harley, M. A. 1998; Tsagkarakis 2013; Kotzamani 2014).

The electroacoustic sound interpolations, known today as *Mycènes alpha*, are the only musical implementation without a clear reference to Greek history. With their introduction to the spectacle, Xenakis superimposed the notions of historical and modern, intentionally bridging the ancient forms of communication with that of the new computational age (Touloumi 2015).

3. Narrative analysis

Xenakis belongs to a group of composers who wrote music for the production of ancient dramas, blending Eastern musical tradition with contemporary trends of art music (Siopsi 2013).[17] *Polytope de Mycènes* is closely affiliated with the project of Delphic Festivals of 1927 and 1930.[18] They intersect the specific historical site, environment, and performance, encouraging communality and participation of the locals (Siopsi 2013; Kotzamani 2014). *Polytope de Mycènes* is also the most narrational of all Xenakis' polytopes. At the very beginning of his experimentation with multimedia,[19] the composer favoured abstract expression over the figurative one. His first multimedia project with an insinuation of the programmatic content was *Polytope de Persépolis*, within which the torch-bearing children waved the inscription "we carry the light of the earth" in Persian language (Harley, M. A. 1998).

3.1. Overview and interpretation

At Mycenae, Xenakis tells the historical and mythological story of the Bronze age civilisation by referencing various literary genres spanning three historical periods of ancient Greece: Mycenaean (approximately 1800-1100 BCE), Archaic (800-500 BCE), and Classical (500-323 BCE). To represent the first, Xenakis used the narrations of fragments in Mycenaean language and a percussion piece dedicated to the goddess Persephone worshipped at the time. The Archaic period included Homer's epic *Illiad* and Sapphic lyric poetry that inspired the rhythms of *Psappha*. Finally, the Classical period was represented by three great Athenian tragedians: Aeschylus, Sophocles, and Euripides. Although

[15] "Psappha" is an archaic form of "Sappho".
[16] "Persephassa" is a variant of "Persephone". It also refers to Persepolis, where the piece was first performed.
[17] Other composers include Jani Christou, Mihalis Adamis, Theodore Antoniou, Dimitris Dragatakis, and George Couroupos.
[18] Envisioned and organised by poet Angelos Sikelianos and his wife Eva Palmer at Delphi.
[19] Namely, a collaboration with Le Corbusier and Edgard Varèse on the Philips Pavilion (1958).

the Mycenaean glory was long gone by the time of classical Greek drama, Xenakis justified the use of tragic plays as an artistic revival that would unite the "high summits of the Achaeans as seen by the Athenians of the fifth-century BCE".[20] The ancient legends are also revived through the prism of various historical and ideological perspectives, ranging from Homer, who sees warfare as a stage on which the highest virtues are manifested in tragic heroism, to Euripides, who enforces an anti-war vision. The problematic nature of justice is based on a simple revenge ethic that fails to resolve the curse but only deepens it by responding to each crime with a new one. This problem expands from the inner circles of the royal family to the broad Greek society. To understand why Orestes deserves to be declared innocent, it is necessary to attend the difference between his motives and those who came before him. He was the first in the long line willing to stand the trial and abide by the verdict. It is ultimately Athena who sees through it all and creates room for human communities to rule themselves justly (Hayes & Nimis 2017).

It is safe to assume that *Polytope de Mycènes* was of personal value to its creator. Just as Alexander Scriabin identified with the legendary ancient musician Orpheus, Xenakis could have easily had a similar sentiment towards Orestes and his role in the ancient myth: a tragic hero who fought for the right cause but suffered immensely for it and spent a lifetime in exile. Indeed, *Oresteia* represents both the climax and the suspense of the plot. Touloumi's reading (2015) of the Polytope and how it reinvented the origins of democracy from Athens to preceding Mycenae is backed by Xenakis, as stated in an interview recorded during Polytope's realisation in September 1978.[21] According to Xenakis, the European culture is a projection of Minoan and Mycenaean civilisations, but this culture is not present in Greece anymore. Instead, it has moved further away, leaving a void behind it. Xenakis' artistic contribution serves as an attempt to reconnect with these origins and place modern Greece back into a multicultural context.

3.2. Aesthetics and structure

Xenakis' aesthetics were influenced by the dawn of information theory and cybernetics in scientific studies. He was acquainted with French electrical and acoustic engineer Abraham Moles, who introduced Claude Shannon's information theory to the field of aesthetics. In 1960, together with Michel Philippot and Alain de Chambure, they founded a study group for mathematics and music MIAM (Touloumi 2015).[22] Cybernetics with which the group curiously engaged can generally refer to any self-regulating system that is set up by a stimulus and response through continuous feedback. It is a developing construct applicable to many disciplines and areas, arts included. Cybernetic art, and subsequently the cyberculture that followed, place equal significance to the medium as to the message it occupies. The meaning is not only created by the artist and received by the observer but also a product of an interaction between the observer and the system. This notion pushed artists to try to find new ways of narrating. As the sense of reality is structured from a collection of information, the traditional narration is replaced by interactive narration. Cybernetics break down the linear narrative structure and regenerate a non-linear one together with its modes of operation: circularity (as a real-time network communication), feedback (real-time action), and perception (the output) (Selen 2015).

There are a few elements to tackle concerning *Polytope de Mycènes*. The interactivity is established between performers – that is, the artwork – and the audience. The Polytope was a creative effort not only by Xenakis and professional musicians but also by the amateurs and volunteers who directly contributed to its organisation and production. Xenakis' intention was not to alienate the locals from the site but to bring them closer together, bridging the millennia-long cultural gap. Another feature is the open-air public execution. The boundless performance space is regarded as an open territory, accompanied by the gradual rejection of the architectural barrier present in the Western indoor

[20] In the program catalogue.
[21] Archival recording number 1024.
[22] Also: MYAM (labelled after the initials of its four members: *M*oles, *Y*annis, *A*lain, and *M*ichel).

performance tradition since the Renaissance. At the same time, the articulation of the performance became more open to randomness and unpredictability, as it inevitably included the influence of the weather and the constant transformations of the outdoor soundscapes. By incorporating the surrounding environment, the landscape directly affects the perception of the audience (Konomis 2015; Vovolis 2015). Finally, Xenakis reoriented the site's historical narrative around formal repetitions of sensorial stimuli. With the use of technology, the Polytope transcended the chronological time and acted as a transference between two parallel perceptive realities. The old myths, full of sex and violence, are transcribed into modern-day warfare with the use of anti-aircraft searchlights and loudspeakers that immersed the audience in noisy environment (Bailey 2019).

Xenakis stated that the location, light, and texts constitute the focal elements of the Polytope. He wanted to create a happening in a non-traditional way and combine different forms of art instead of music or theatre alone. He intended to bring the Mycenaean culture closer to the public using texts that are our only connection to the lost civilisation.[23] He utilised extinct languages incomprehensible to the audience but included the translations to Modern Greek as well,[24] exhibiting the sonic magic of the linguistic continuity. The combination of all these components together contributes to a better understanding of the plot. However, if one is to read *Polytope de Mycènes* as a cybernetic event, one must not only take the meanings of its elements into account but the overall structure, too. Xenakis' arrangement of events within the performance includes both traditional linear narrative as well as cybernetic one coloured by the notions of fragmentation, non-linearity, and circularity. While the composer jumps back and forth from one point in time and place to another – from the battles of Troy, over Helen's captivity in Egypt, to laments about the future at Colonus – he inten-tionally and uncompromisingly navigates the plot in the direction of tragic resolutions that took place in Mycenae after the war.

The notion of circularity may be found in the symmetry of the Aristotelian tragic plot structure. Zeus and Poseidon – the gods to whom the processions were included in the performance – were both sons of Cronus and Rhea. Together with the third brother, Hades, they ruled the Greek pantheon. Upon defeating the Titans, the Olympian gods split the power between themselves: Zeus ruled the sky, Poseidon the sea, and Hades the underworld. *Polytope de Mycènes* begins with a procession in honour of Zeus and ends with a procession in honour of Poseidon. Hades is not present, but around the middle of the spectacle, at the 40-minute mark, the performance of *Persephassa* takes place. It occupies approximately 23 minutes of total spectacle duration, as predicted by Xenakis in the event diagram. Persephone, after whom the piece is titled, was the wife of Hades and the queen of the underworld. One could argue that all three gods and their respective realms are thus present in the plot. With such a formal gesture – marking the beginning, the mid-point, and the end – the Polytope insinuates the totality of the ancient mythological world. The tripartite arrangement is also evident in narrations in the Mycenaean language, in which the middle one occurs just before the procession of animals and the performance of *Oresteïa*. The same procession of animals, together with the other two processions at the beginning and the end, adds up to the number three as well.

4. Final remarks

The established circular form which begins and ends in a similar fashion can be interpreted as a grand resolution in which the curse of the Mycenaeans is finally abolished, and life goes back to normal as the people continue to honour their old gods. But just as the circle does not have the beginning or the end, or the beginning is one and the same as the end, the Polytope's narrative can be read as an indefinitely repeating model. It ends the way it begins, and so does the history of Mycenae, and to a further extent, the history of humankind. Such an interpretation leaves us both pessimistic and

[23] Archival recording number 1023.

[24] In the performance recordings, one can hear the Modern Greek narrations following the ones in original dialects. The exception is, of course, the music performances where vocal parts are sung uninterruptedly.

optimistic at the same time. While the story ends on a positive note with the salvation people always hoped for, the curses that inflicted our society in the past could indeed burden us again. In the aforementioned interview, Xenakis stated that art has only one way, and whatever existed in the past exists today, and what there is today will be again in the future.[25] The turbulent history of 20th century Greece and Xenakis' own life experience seem to prove this to be the case. The implemented bracketed question mark (?) in the program catalogue – the one which replaces the word "victims" – can be understood as the key question we are left to answer for ourselves.

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[25] Archival recording number 1023.

Xenakis' *Oresteia*: a reconstructed theatre

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Abstract

This paper aims to demonstrate the theatrical side of Xenakis' *Oresteia*, an a priori autonomous musical work, whose roots lie in the collaboration between the composer and the director Alexis Solomos, for a purely theatrical performance of Aeschylus' trilogy in 1966. It can be noticed that the theatre, in the final form of *Oresteia*, is inherent in his essence, either as dramatic text, or as scenic actions or even as theatricality in the music itself. *Oresteia* is a multidisciplinary work that opens in multiple directions, weaves multidimensional relationships and interdisciplinary dialogues that are the fruits of an attempt to illuminate a distant myth. For the analysis of the genetics of this work, we will rely on - apart from the examination of existing published researches - on the correspondence between the composer and the stage director, seeing that the director had a profound influence on the composer and vice versa, in a mutual exchange of ideas about drama, the dramaturgy of sound, the use of space and the relationship between text and music. We will carry out an analysis of the composer's sources of inspiration, and his relationship with the text, trying to understand why he was interested in it and how in the end he put it to music respecting the dramatic sense. Lastly, we will focus on theatrical elements that have remained in the score of the concert version as an inherent part, even outside of a stage context.

1. Introduction

Oresteia is a musical work from the contemporary repertoire based on the dramatic text of Aeschylus. Originally written as incidental music for a theatrical production of director Alexis Solomos' entire trilogy, Xenakis transformed it, after its' premiere, in Ypsilanti, Michigan, into a stand-alone work that naturally retains many elements of its original form (Xenakis 1996, 49-48,54). Xenakis is a composer who, throughout his career, has often approached music in relation to other arts or sciences, always carrying out deep philosophical and scientific research before writing a musical work. Therefore, for the composition of *Oresteia*, the composer approached the Aeschylus work by conducting an in-depth study of the text, the characteristics and essence of Greek tragedy, ancient Greek music, but also other cultures, such as Japanese Noh theatre. In this work, the theatre hides itself in an unobtrusive way, but emerges through the music, being present in each note in a more intimate way; as dramatic text, as stage actions or even as theatricality in the music itself, the essence and logic of the theatre remaining in this musical work in an abstract and concrete way. In order to define the result of this special aesthetic and practical collaboration of these two genres, we cannot simply use the term "opera" as it is marked several times or "musical theatre", but prefer to opt for another term that of "theatricalized music", which we will analyze further below.

2. The *Oresteia*: An abstract reconstruction of tragedy

2.1. The influence of theatre on music

Iannis Xenakis' collaboration with Alexis Solomos, one of the most important, prolific and innovative directors in post-war Greece, began in 1964 with the production of Aeschylus' *Suppliants* at the Theatre of Epidaurus (Soulele 2011,1). At the time, Xenakis was a political refugee in France; sentenced to death in 1947, while still a student in Athens. Xenakis took part in the fight against fascism and Nazism during the Second World War, as well as in the Greek civil war. Wounded and sentenced to death, he was forced to flee his country, for his militant involvement during the British occupation, forbidden to return to Greece (Solomos 2008, 20-21) and the opportunity to write music for an Aeschylus work performed in Epidaurus was a way for him to get closer to his native country and its traditions, and to experiment in an artistic genre he had never before encountered (Solomos 2008, 54). For Xenakis, Solomos was the ideal collaborator for this project, as the director had already been carrying out in-depth research into the substance of tragedy and its original characteristics for some years, and his ambition was to overturn the conventional and academic approaches to staging that prevailed at the time, which he still considered to be cliché, banal and not at all in keeping with the ancient spirit.

It was therefore within a framework of profound research into Greek tragedy that they sought the most suitable chant and wanted to integrate music into the theatrical action, not to write music that had no apparent connection with the stage, but music that satisfied the needs of tragedy. He refers to this in his text 'Notice on the *Oresteia*', by saying that tonal or serial music was incapable of expressing the sonic 'sensibility' of tragedy and that other functions had to be found in order to achieve this, based more on the functions of tragedy itself (Xenakis 1996-1967, 3). Xenakis, being inspired by the theatre, enriched his music by integrating theatrical characteristics to express the stage action and the dramatic story, which should be in constant interaction with the drama. The result of all this was that the two artists agreed on the musical functions that would be practised in their creation, functions that, at the same time, wanted to come closer to antiquity, namely the "kataloghe", recitative in recto tono, a technique used in Byzantine music, the "instruments of worship", played by the choir to enrich its scenic aspect as well as the spatiality of sound, the "sound commentary" where the music itself expresses a dramatic situation, and the "symbol of events" among others (Xenakis 1996-1967, 1-2).

Already in the theatrical production of the work we can underline that theatre and music were in a situation of complementarity, both artists made an effort to incorporate music in the drama and not to put a musical carpet, distant from the scenic action. Furthermore, we can underline the importance of music in Ypsilanti's production by taking into account that Xenakis wrote music for almost the entire duration of the performance, i.e. 110 minutes, of which the choral parts were strictly sung and the rest was accompanying music, music that was "reasonable, measured, in a way symbolic, in order to respect the spirit of Aeschylus' contemporaries" as Xenakis describes in his text *Aeschylus, a total theatre* (Xenakis 1996, 54). On the other hand, although the performance in the United States was in English and the director sent the composer the translation, Xenakis initially wrote his music for this performance in the original language of Aeschylus (Xenakis 1996). This shows Xenakis' attachment to the ancient Greek language, which carries the tradition of tragedy within itself, being the element that allows us to approach the theatre of antiquity in the best possible way, as a very well preserved monument that offers us a deep insight into the spirit of the time. Furthermore, we can see that, from the very beginning of the writing process, the composer intended to have this score performed as an autonomous work.

2.2. From autonomous musical work to theatricalized music

What remains of the creation in Ypsilanti is the musical work of Xenakis as we know it today. We can therefore already state that the existence of this work is due to a perfectly theatrical process. The exchange between composer and director considerably enriched the composer's ideas about the theatre and we shall see that several theatrical elements remained in the score of the concert version as an inherent part, even outside a stage context. *Oresteia*, in its original concert version, was 36 minutes long. Its first performance took place at the 'Sigma' festival in Bordeaux on 14 November 1967, one year after the production of Ypsilanti. It is a work for twelve musicians, a children's choir (20 children) and two choirs (18 women and 18 men) equipped with some musical accessories. Xenakis thus created an autonomous musical work with a few stage interventions, transforming each piece of the Aeschylus trilogy into a piece of music. Originally, the work was divided into three parts: *Agamemnon, Choéphores and Euménides;* in 1987 Xenakis added to the score of *Agamemnon* the part of *Kassandra*, for baritone and percussionist after a commission for the performance of the *Oresteia*, staged by Yannis Kokkos among the ruins of the city of Gibelina, in Sicily. In 1992, the composer added the part of the *Goddess Athena*, for baritone soloist and instrumental ensemble, to the third part of the *Oresteia*, for the performance at the Megaron in Athens, bringing the work to a definitive end (Aggelikopoulos 2005, 25).

We see that Xenakis revisited the score several times in his life, which was very rare for the composer who almost never revised his works. This was due to the fact that the composer had always been interested in the Greek tradition and in particular in the main subject of the Aeschylus trilogy which was the meaning of justice and the that of democracy. More specifically, from his earliest youth, Xenakis had shown a keen interest in ancient Greek culture, including philosophy, mathematics, music and theatre (Xenakis 1996, 51). The ancient Greece is omnipresent in his work, either in the titles, or as an abstract source of inspiration, or even in the Dorian, even austere, character that is the hallmark of his music. Moreover, his struggles against oppression show a strong love for the notions of justice and democracy, which explains his attachment to Aeschylus' trilogy, where, after an endless circle of blood, justice is done by the Athenian people.

This autonomous work was composed of choral parts and certain key moments of the dramatic action. The narrative of the drama now existed in the score, expressed purely through the music. The text, even in its absence, remains important, as it is the basis for all the music, and thus continues to carry the meaning and guide the development of the drama. Xenakis keeps the text that was set to music for the theatrical performance though, the dominant presence of almost all the protagonists no longer exists finding only the chorus as the main 'character' of the work as well as Orestes and Electra, played by 3 men and 3 women respectively from each chorus. Some key roles in the work such as Clytemnestra and Agamemnon are mentioned, but their presence is only expressed through music. Solomos asked Xenakis to focus his music on the chorus, as it was the chorus that sang in Greek tragedy, meanwhile being the representative of the audience, i.e. the people, so by using it as a 'protagonist', it creates a notion of communion with the audience. The added parts of *Kassandra* and the *Goddess Athena* are not main roles in relation to the original text, but represent the two fundamental notions of the work,: Kassandra represents barbarism, fatalism and vengeance, and on the other hand Athena represents logic, justice and democracy. The two additional parts enrich the work considerably from a dramaturgical point of view and we can now see that Xenakis' reading of the tragedy is very legitimate, given that the main notion of Aeschylus' work is 'the victory of justice, through democracy, against the law of vengeance'.

Through *Oresteia*, the composer wanted to convey the Aeschylus drama in its entirety, its text and its main notions as well as the spirit of tragedy, which is defined as a "total spectacle" according to Xenakis' idea, i.e., it is a "synthesis of the major arts" that includes text, myth, music, theatrical performance, and all of these elements must interpenetrate each other (Xenakis 1966-1976, 1). Already, since the performance of Ypsilanti, tragedy represents for him a new and unexplored territory that deserves consideration in its entirety because it is a research possibility that opens up towards all

the new possibilities that result from musical composition and we can say that the characteristics of tragedy, its theatricality and its essence, in the concert version, remain ever present. In his score, Xenakis indicates certain stage directions, namely the position and some movements of the choir in space, as well as the distribution to the audience of small metal flags to be shaken at the end of the work (Xenakis 1996, unnumbered page). We find phrases in the score that indicate where is the beginning of each section in relation to the drama, even when the text is not included, which shows that it is important for the composer to guide the musicians in this way. Consequently, we can easily deduce that this musical work by Xenakis has kept its theatrical character for which it was originally written, as shown by its 6th scenic note which states that 'in general, a sober and austere animation could be admitted (Xenakis 1996, unnumbered page). In this way, there is freedom in the performance of this work to create theatrical actions that intervene in the musical interpretation.

Indeed, *Oresteia* is not just a musical work, nor even a simple theatrical work; it is an autonomous work that could not legitimately be characterised in a way that is already known. The theatre exists within this work in a delicate way, unburdened by common clichés and codes; the music derives from the theatre and vice versa, mixing these two genres in an even tighter way. In any case, it is remarkable that Xenakis did not like theatre, and, we claim, that is why he appropriated this genre, adapting it to his own style, creating something unique. It is exactly this indefinable aspect that led us to search for a relevant definition to characterise this work, concluding that the term "theatricalized music" would be the most appropriate to define it. Theatricalized music in the sense that the music becomes a stage to express the drama; the dramatic text becomes music and the sound in its absurdity takes shape to express the dramatic situations. The musicians and choristers, for their part, not only have a sonic role but, at the same time, they have a scenic role by interpreting, in a more or less abstract way, the characters, in expressing the drama. Moreover, in order for this scenic reality to be evident, there is little room for the passive spectator but must immerse himself in this new approach to drama, accepting this redefinition of the stage space and the spectator's space, which now exist on an equal footing, in order to feel the event as an experience that unites both worlds.

3. Analysis of the work

We could detect the essence of theatricalized music from the very first moments of the *Oresteia*. The work begins with the instruments playing for a few bars and the chorus of the elders of Argos entering the stage shortly afterwards, singing in ancient Greek about Agamemnon's return to Mycenae (Xenakis 1996, measures 1-17). The fact that the chorus enters the stage during the musical performance at this point has a double function: firstly, the music serves as an invitation, a call to the chorus to make its appearance, while at the same time giving its entrance a dimension of grandeur and gravity, the chorus not being, from the very beginning of its appearance on the stage, a mere performer among others, but asserting from the outset its dominant and dramatic role. The choir then begins to sing, and the choir's corypheus sings in "kataloghe", the technique mentioned earlier, which is a prose reading without intonation (recto tono), with isochronous syllables, which comes to us from the Byzantine period, a reading technique found in the convents of the time and which aimed, according to the composer, at a detached, non-subjective reading of the text (Xenakis 1966-76, 3). This singing technique is the result of a joint decision between the composer and the director during their collaboration: Solomos wanted to create the illusion of a prayer in order to have a ritual atmosphere, and Xenakis proposed this technique from the Byzantine period, which, according to the composer, could be a link with ancient Greek tragedy (Solomos 1964).

Within a purely musical framework, Xenakis relies on ancient Greek music, also through Byzantine music, which is its historical continuation, without aiming at an absolute reconstruction or at exploiting any folklorism. As he wrote to Alexis Solomos, the music comes directly from the "sacred bones of the Hellenes" (Xenakis 1966), quoting the Greek national anthem, which underlines his need

to discover the music of his country in its roots. But it is not ancient music that he is aiming for. Everything is done in a rather abstract way, but which remains obvious, either to underline dramatically an important moment of the piece, or to create a solemn, Dorian or even imposing atmosphere, always in accordance with the text which even guides the composition. Looking at the score, we realise that the changes of measure are almost always dictated by the metrics of the language, so that even the proportions between the different parts are directly influenced by the structure of the text used. It should be noted here, a purely musicological remark, but important nonetheless, that in Xenakis's music changes of time signature are rather rare, the majority of his scores being in strict 4/4 time. This testifies to the respect with which he approached Aeschylus' text and that in this work he did not proceed at all in his usual way.

Xenakis uses music as a carrier of the story, representing the tragic text in some parts of the work only through sound. A good example of this is to be found in bars 59-95 of *Agamemnon*, where, even in the complete absence of stage action and text, the music describes the sacrifice of Iphigenia, the young girl being embodied by a solo oboe playing an extrovert descending melody, before being joined by the other lower instruments. This passage, in Aeschylus' text, is given to the chorus and tells of past events, not part of the linear development of the story. In the next scene, the oboe is absent, thus accentuating the previous symbolism. Another way in which Xenakis describes the drama through music is what he calls the 'event symbol', a more illustrative and classical way in which what is happening, or was going to happen, on stage has to be presented through sound or music. At the end of *Agamemnon*, bars 203-213, a fanfare is heard announcing the king's entrance on stage, in an almost clichéd way, which nevertheless works very well, serving its intended function perfectly. On the other hand, another way of anticipating the entrance of a main character on stage, in this case *Kassandra*, is the use of a recurring motif on the bongos that creates a sense of expectation and imminent danger, while at the same time establishing a rather primitive atmosphere, in keeping with Aeschylus' idea of her as a barbarian.

Our first observation for *Kassandra* is that the baritone has to play both the role of the chorus and that of Kassandra through various changes in his voice, singing low notes for the chorus and in a high range, using the falsetto technique, for Kassandra, Xenakis choosing here to tune everything to a person, giving this time a more abstract air to this scene, contrary to the descriptive use of the music earlier in the work. The composer's choice to have a man play a woman might seem modern to a viewer of his time, but it is perfectly consistent with what was done in antiquity, where all the roles were played by men, Xenakis finding here a point of reference that satisfies both his desire to get closer to tradition and his desire not to follow certain neo-classical trends of his time. Moreover, the heterophony that the composer creates in this work is reminiscent of elements of Japanese culture, particularly Noh theatre. Once again he sought inspiration in the theatre and, according to the composer, Noh is aesthetically and stylistically closer to the original Greek tragedy than our current Western approach to the genre, since in this type of theatre music and stage action are on an equal footing. In general, Xenakis believed that traces of ancient tragedy can no longer be found in Western civilisation and that it is in other non-European cultures that one must seek its essence.

Continuing with the score of *Kassandra*, Xenakis notes that 'the interpretation must avoid any expression of sentiment. For there is a great danger of superimposing current clichés on Aeschylus' text. At first sight, one might think that this suggestion takes away the theatricality of the work, but one must also take into consideration that today's theatre is not only a theatre of feelings or a psychological theatre, but a theatre of 'situations' where it is these situations that create the feelings. The interpretation of *Kassandra* requires a high degree of physical application on the part of both performers and therefore the theatrical dimension, or even the creation of drama, must be done only through the musical interpretation. In our opinion, this approach is perfectly legitimate because the tension that arises from the score, as well as the strength required to perform it faithfully, are more than enough to describe the grief, agony and fear of this character, condemned to be able to foresee the future without anyone ever believing him. Once again, the music carries the theatre and the spirit of the text within it, showing itself capable of projecting situations that *a priori* would need more

descriptive stage actions to be truly apprehended.

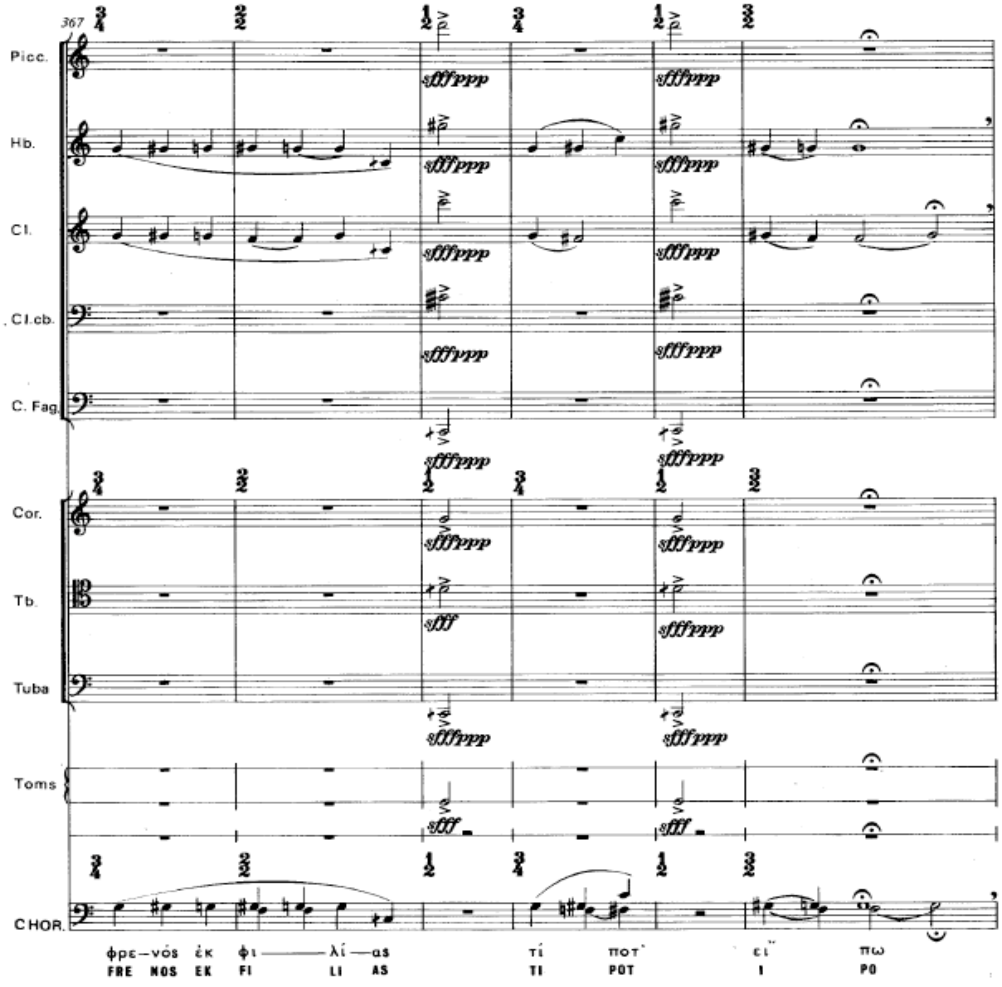

Figure 1: © Copyright 1996 by Boosey & Hawkens Music Publishers Ltd, Revised version, mesures 367- 372.

We continue with *Agamemnon II*. At the moment of the king's murder by his wife, Xenakis applies the function he calls 'sound commentary' where the men's choir on stage, accompanied by the women's choir backstage, shout the text of Aeschylus where Agamemnon shouts his last words. The fact that the female voices are also used from backstage symbolise the voice of Kassandra, who was also murdered by Clytemnestra, or/and it refers to the logic of tragedy, where the murders are not supposed to take place on stage in front of the audience.

Immediately after this scene, the old men of Argos mourn their dead king and we return to the collaboration between composer and director because Solomos asked Xenakis to write expressive music for this passage, in order to better support the drama and thus touch the audience. Solomos asked for a music that would be moving, that would create a feeling not too alien to the audience, and to achieve this, Xenakis combined elements from two different cultures in an abstract way, namely the melismas of Byzantine music with the heterophony of Noh theatre, resulting in a result that was both touching and grandiose. The text is set to music with careful respect for the prosody, the time signatures in the score is strongly linked to the text and evolves in accordance with it. The text sung almost in unison by the male choir in microtonal writing creates a ceremonial atmosphere from the outset, which refers, at first, to the Greek Orthodox church, which is amplified by the choice of orchestrating the voices with two instruments playing in octaves. The choir's singing is interrupted by a violent chord played by the orchestra, a chord that is repeated each time in the same way, like a fixed sound object, we might even say a Dorian column (see example 1). The juxtaposition of these two sonorities, which hardly touch each other, reminds us, once again, of the dramaturgy of Noh theatre, where music and text are in a complementary relationship, but not of accompaniment in the

classical sense of the term.

In both cultures the choir is often given dark and austere actions, as Xenakis also writes at the beginning of his score. In *Oresteia*, however, he gives the choir an extra dimension, namely position and movement in space, with the sonic results that this brings. At the end of Agamemnon the chorus leaves the stage, descends among the audience and forms two semi-circles behind it, making way for the women's chorus, which arrives at the same time in a slow and imposing procession, like a ritual. These movements underline that the choir in this work has a double function, sonic and visual, no longer being simply an accompanying choir waiting its turn to sing. It should not be forgotten that in Greek tragedy the chorus represents the people and the fact that in the *Oresteia* the roles of almost all the protagonists are removed, means that the 'protagonist' is the chorus, for not only is it responsible for singing, it is also the narrator of the story.

In the *Choéphores*, this is best illustrated in the recognition dialogue between Orestes and Electra, both performed by groups of choristers, where the stichomythia takes place with the audience in the middle. The two roles are thus no longer individual, Xenakis gives them a collective character, thus amplifying the symbolic aspect of the work, since for him it is not a performance centred around characters, but above all around symbols. According to Spyros Sakkas, Xenakis liked this passage very much because the frontal relationship between the stage and the audience was broken, thus integrating the spectators into the performance itself, in a situation of communion (Sakkas 2014). We can argue that Xenakis is here reappropriating the substance of ancient Greek theatre, since in Aeschylus' time, theatre was a perfect opportunity for people to gather and share a common experience, strongly linked to the political events of the city.

During the last part of the *Oresteia*, the Erinyes are transformed into the Eumenides, a choir of children enters the stage and slowly groups in the middle of the stage, symbolising this transformation. After the part of the goddess Athena and the institution of democracy, the men's choir also comes on stage forming a semi-circle behind the women's choir before starting a jubilant collective singing. Moreover, 200 small metal flag leaves are to be distributed to the audience at the end of the work, so that they "...shake them in joy, thus uniting with the spirit of the choir". The spectators must play these instruments at the end, thus joining the choir and becoming part of the performance by their contribution to the jubilation of the victory of democracy, thus amplifying the notion of communion between performance and spectator, in a relationship of equality and trust, accentuating in passing the democratic spirit that runs through the work and the thought of Xenakis[1].

Conclusion

The composer uses an element of ancient drama that is not technical, but rather refers to the relationship between the theatre and the people, which is the basis of all forms of theatricality. With his own means, he tries to reconstruct this relationship on other terms in the circumstances of today's society, with the aim of strengthening the links between the two parties. This work was a field of experimentation for Xenakis and marks a turning point in his output, for there is a "before and after" *Oresteia*, with Xenakis' music taking a considerably more expressive direction after 1967. Similarly, it can be used by musicians to enrich their practice with the theatre, and it can also help the theatre to unite with musical sound and its concerns.

Xenakis' sixth stage note, namely that "animation could be admitted", gives the freedom to choose

[1] Xenakis, Iannis, « Eschyle, un théâtre total », *op. cit.*, p. 58

the aesthetics and the means necessary for the desired representation of the work, whether with actors, dancers, projections or lights. What has not yet been taken into account, however, is that it is not only the sixth performance note that makes this piece potentially theatrical, but that Xenakis' other notes can also serve as a basis for a stage result. This music, which is already theatrical in itself, can support the drama without the need for an explanation of the story. In our opinion, an overly theatrical and descriptive approach diminishes this inherent theatricality of the music itself. We strongly believe that this work offers the opportunity to bring out the notion of theatricalized music, that is, music that highlights the theatricality that emerges.

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Xenakis and Revolution: A Critique of Aesthetic Autonomy

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Abstract

In this contribution I aim to point towards a not too much explored way in which we can trace significant aspects beyond aesthetics in the musical and theoretical works of Iannis Xenakis. The historical and political frameworks of Athens during World War II, and of Paris during the May ’68 revolts and the subsequent years, will be considered, but trying to transcend both contexts, in which Xenakis was directly involved. To do so, I will begin by posing some general reflections on the question of aesthetic autonomy and the relations between music and society, relying, above all, on the works of Theodor W. Adorno, Martin Jay, Fredric Jameson, and Jacques Attali, through which I will outline three major positions in this regard. Afterwards, I will discuss Xenakis' position regarding the debate on the notion of aesthetic autonomy. For this purpose, I will take into consideration several statements made by the Greek-Romanian composer in various interviews, as well as some of the critical comments regarding the kind of link that can be established between Xenakis' music and the revolution. For this entire section I will pay special attention to the materials recently published in the catalog of the exhibition *Révolutions Xenakis* (Cité de la Musique - Philharmonie de Paris, 2022). In addition, I will analyze some theoretical fragments contained in Xenakis’ *Musiques Formelles*, and I also will draw on two publications that have reflected in detail on Xenakis’ particular relationship to the revolutionary spirit of May '68: the article ‘*Xenakis, not Gounod’: Xenakis, the avant garde, and May' 68,* by Alannah Marie Halay, and Michael D. Atkinson, and Eric Drott's monographic study, *Music and the Elusive Revolution. Cultural Politics and Political Culture in France, 1968-1981*. From all this examination will result a bivalent but justified position of Xenakis with respect to the relations between his artistic practice and the revolution in the political and historical spheres. In the last section of this contribution, I will point towards a line of flight that – in a theoretical spirit akin to that of Jacques Attali’s hypothesized reading (namely, that we can interpret certain innovations in musical forms as an anticipation of future economic transformations) – could encourage an original analysis of Iannis Xenakis’ aesthetic revolution. That line of flight would be the bioeconomic revolution proposed by the Romanian economist Nicholas Georgescu-Roegen, especially since the publication in 1971 of his most relevant work, *The entropy law and the economic process*.

I.

The main question hovering over the approach to Xenakis’ work that I would like to present here is: how can we read political, economic, social, or historical meanings in a piece, and understand such a work, at the same time, as something that exceeds the formalization of a series of more or less explicit contents? In my view, the first problem that must be addressed in this regard is to clarify and calibrate the meaning of the very relationship implied in the binomial "music and society", for it is far from obvious how sounds and their meanings relate to the world and its history, and vice versa. Is it a

semantic relationship? Is it a reciprocal relationship? And if it is reciprocal, are both spheres equally determined by the other, or can we establish different degrees of determination? These are just some of the questions we should ask ourselves in this regard. The most immediate intuition seems to point to the idea that the type of link between music and society shares the features of the nexus between continent and content: the totality of the social would be the space in which music takes place, in such a way that every musical instance would necessarily have a historical, social, psychological, etc., meaning. However, as Adorno defended with regard to lyric poetry in his *On Lyric Poetry and Society* (Adorno: 1968), this correlation should not be identified with a social interpretation of musical works, or with the social interest of the latter or their authors, but should rather specify how the whole of a society, as a unity in itself full of contradictions, appears in the work of art, and in what way the work of art submits to its will and in what way it transcends it, all this taking into account that social concepts should not be added from outside the works, but should be extracted from the precise examination of these. A different way of affirming the same would be to state that the relationship between music and society is of a semantic type, in such a way that music could be understood as a language, its elements as signifiers and its socio-cultural contents as meanings or, in other words, as aesthetic reflections of that social totality. Of course, this conception leads us to the study of the relations between sounds and meanings developed by linguistics and to the Marxist theory of reflex.

A second type of position leads us to the notion of aesthetic autonomy, which we can associate without going into too much detail with a sort of ideal history of forms[1]. In this sense, it is useful to bring up here the contribution made by Martin Jay in "Modernism and the retreat from form", where we read that the history of aesthetic modernism has usually been formulated as the triumph of form over content (Jay: 1993). This preeminence of form, in turn, acquired diverse forms, such as the prominence of self-referentiality as opposed to the expression of something external to the work itself, the prevalence of abstraction as opposed to concreteness, etc. But, regardless of the conception of modernism we adopt - and in this regard it is important to bear in mind that Jay himself dedicated his essay to reworking the above definition, lowering the degree of formalism usually implied when defining the modernist aesthetic pattern - it is clear that what intuitively follows from formalism is its autonomy with respect to the expression of social, political, historical contents, etc., or, in a broad way for the case at hand: its autonomy with respect to extra-musical senses. This does not mean that, the formal dimension itself does not lend itself to nuances, and may involve a diverse variability. In fact, in his essay Jay brings up to five fundamental concepts of form observed by aesthetic modernism[2], which may be useful later on to assess not only the greater or lesser aesthetic autonomy of the work of Iannis Xenakis, but also the concrete variant of such autonomy: first, form has been defined as the composition or organized set of distinct elements, so that good form would be that in accordance with the principle of proportion, order or harmony between the component parts. Secondly, form has been assimilated as that which is directly perceived by the senses, its value residing in the pleasure sensibly aroused rather than in the meaning conveyed. Thirdly, form can be understood as figure, silhouette, or outline. In a fourth sense, we find the idea of form as the substratum, the essence of something, its ultimate truth. Finally, form has also meant the elaboration of intellectual structures and categories of the world we experience. Now, does this preeminence of form over content lead to the total disconnection of aesthetics from any other possibility of meaning?

The truth is that it does not. In this sense, we can affirm that the reading strategy that identifies formalism with aesthetic autonomy would find its reverse in the inversion that we associate with the Russian formalists: understanding the political, social, historical, etc. content of the work as the result of formal innovation. In the singular example of music, this hypothesis would be like saying that if the music of a given period is capable of being formally innovative, then also new kinds of content

[1] For a further discussion of the polysemy of the expression "aesthetic autonomy" we recommend Richard Taruskin's essay "Is There a Baby in the Bathwater? On aesthetic autonomy", in Taruskin, R. (2020), *Cursed Questions: On Music and Its Social Practices*, University of California Press, Berkeley.

[2] This analysis follows W. Tatarkiewicz's "Form in the history of aesthetics", in Weiner, P. P. (1973). *Dictionary of the History of Ideas*, Charles Scribner's Sons, New York.

can begin to emerge and be expressed by it, or that if musical language expands historically and culturally in a certain way, we will also be able to think and articulate a new musical semantics. This perspective, as Fredric Jameson has pointed out in his preface to the Jacques Attali's major book *Noise* (Jameson: 2008), is particularly promising because the readings to which we are accustomed, whether we move within the paradigm of aesthetic autonomy or not, and believe in the relations between works of art and political, social, historical, etc., meanings fall under the category of what can call musical historicism. That is, they are all strangely retrospective with respect to their objects of study and, at best, understand that a consummated work reflects, manifests or expresses the dynamics of the social system of which it was contemporary. This historicism - in accordance with the Marxist tradition - is articulated following the classic model of the relations between base and superstructure, even if, as Jameson has also pointed out, Engels himself, in his important late letters on historical materialism, tried to insist on a reciprocal interaction between the economic, a typically base dimension, and the superstructure. On the contrary, it has been understood that the superstructures (and when we speak of aesthetic forms, when we speak of music, we are speaking of superstructures) reflect or correspond in one way or another to the economic, or at best lag behind the concrete social development. Thus, Beethoven splendidly expresses the bourgeois revolutionary ideology, but after the implantation of that ideology, in the manner of an internalization of more objective, collective and ideological values. Herein lies for Jameson, then, the originality of Attali's book: he was the first to have arrived at the other possible logical consequence of the model of reciprocal interaction, namely, the possibility for a superstructure to anticipate historical developments, to announce new social formations in a prophetic manner. The argument of *Noise*, thus synthesized, would be that music has precisely this prophetic vocation, and that current music presents itself both as the promise of a new and liberating mode of production; and as the threat of a dystopian possibility that is the dire mirror image of that mode of production.

Finally, before analyzing the specific case of Xenakis, I would like to insist on the possibilities of the interpretative vein inaugurated by Attali, which, in my view, have been too easily denigrated, sometimes even branded as "mere political propaganda" (Drott: 2011, p. 263). For the relevance of music for the preservation and reproduction of the social order, it is well known: we can easily affirm that music makes people sing or play harmoniously, dance in time and discover their affinity around a shared way of vibrating. Moreover, it is not difficult for us to observe how music is an essential element in our rites and shows, setting the official code of weddings, funerals, military parades, or political speeches. However, the reverse side of this idea has been less frequently emphasized: the capacity of music to bring about change, reordering and insurrection in societies (Denning: 2015). Along these lines, an alternative tradition, which can be traced from Plato to the present day, has presented the history of music as a succession of prophetic noises and subversive sounds, out of tune and undesirable to the powers that be. Now, in what qualities does the disruptive effect of these music reside? What relations can we trace between their sounds and the historical framework in which they burst forth? How does the revolutionary potential of these works combine with our listening, can these aesthetic forms help to imagine, prefigure, or nourish, the expectation of future modes of social organization, and to what extent do they offer alternative ways of facing reality? To address such questions, the case of Iannis Xenakis constitutes an itinerary of particular interest, not only because of the specific cultural context in which it is framed, but also because of the peculiarity of his aesthetic contribution. In what follows, then, we must attend to the details of this case study.

II.

In his book *The Autonomy of Sound*, Gunnar Hindrichs states that the question about the frontier of musical sound comes to our attention when we analyze the case of the so-called *musique formelle*. Iannis Xenakis reduced sounds to their logical structure and formalized them by means of mathematical procedures. In contrast to concrete music, Xenakis' intention was to compose an "abstract" music, as he himself called it (Xenakis: 1981, p. 9). From here Xenakis drew the conclusion that the serial determination of music had to be replaced by an order that included, in addition to the

determinate, the indeterminate. The stochastic laws, with which the probabilistic calculus works, offered him such an order. The stochastic algebra of musique formelle manages to pass from determined sound relations to sound masses, sound events and sound clouds regulated based on their density, degree of order and level of randomness. And the fact is that "abstract music" sounds, certainly, quite un-abstract. If we look, for example, at the famous and prolonged glissando of *Metastaseis* (1953-1954), we perceive how it is stochastically structured, but despite its algebraic structure it is not abstract in the manner of numerical instances, but a concrete sound mass. In this sense, it can be affirmed that from the clouds and sound swarms emerges a bruitism that fits, as Hindrichs says, in the tradition of Stravinsky's *The Rite of Spring* or Varèse's noise compositions, an ascription that in itself shows how little musical formalization and noise can really be separated: when stochastically calculated sound masses end up sounding like noise, they too are calling into question the boundary between musical sound and extra-musical sound, and that is why we can say that the mathematical construction of musical sounds gives way to an experience of an extra-musical order. Xenakis left evidence of this blurred boundary also on the theoretical level, something that is perhaps better illustrated than any other quotation by this famous fragment of his 1961 essay *La musique stochastique: éléments sur les procédés probabilistes de composition musicale*:

> Everyone has observed the sound phenomena of a large politicized crowd of tens or hundreds of thousands of people. The human river chants a watchword in an unanimous rhythm. Then another slogan is launched at the head of the demonstration and spreads to the tail, replacing the first one. The clamor fills the city, the inhibiting force of the voice and the rhythm is culminating. It is a highly powerful and beautiful event in its ferocity. Then the clash of the demonstrators and the enemy occurs. The perfect rhythm of the last word of order breaks into a huge mass of chaotic shouts, which also spreads to the tail. Let's further imagine the crackling of dozens of machine guns and the whistling of bullets that add their punctuation to this total disorder. Then, quickly, the crowd is dispersed and, to the sonic and visual hell, follows a detonating calm, full of despair, death and dust. The statistical laws of these events emptied of their political or moral content are those of the cicadas or the rain. They are laws of passage from perfect order to total disorder in a continuous or explosive way. They are stochastic laws (Xenakis: 1981, p. 19).

Now, how do we interpret this homology of stochastic laws between natural events, political events and musical events? It is striking that when Xenakis speaks of "revolutionary art" (in *Art et Révolution*, a 1978 interview) he points not to the artistic manifestations of a revolutionary social or political movement, but rather to the revolutionary processes immanent to art itself: "Revolution, what we call revolution, has to do not only with political and social issues, but with all ideas in general, with all expressions of the human being" (Solomos: 2022, p. 21). In this sense, the Greek-Romanian composer has a conception of art that does not limit it to a mere function of reflecting the social context, but characterizes it as possessing its own ends, thus making art, to a certain extent, independent of external events. Moreover, in that same 1978 interview, Xenakis is reluctant to express that art can be identified with a seed of the society to come, and he is also skeptical about the possibility of the world revolution triumphing to the point of implanting socialism over the entire face of the earth, ending inequality and injustice. All these testimonies tend to suggest Xenakis' defense of a certain autonomy of art, a position that is reinforced if we take into account, as Makis Solomos has pointed out (Solomos: 2022, p. 160), that the Greek-Romanian composer's contribution is connected with one of the greatest formal revolutions of the 20th and 21st centuries, namely, that which constitutes the appearance of sound, the transition from composition with sounds to the composition of sounds (a revolution that, however, was not theorized in these terms by Xenakis himself[3]). However, as Makis Solomos has likewise emphasized, this time in his postface to the *Révolutions Xenakis* catalog, the Greek-Romanian composer, in an interview on *Nuits* (1967-1968), answered the question "Do you think music can have a political function?" as follows: "something

[3] For a further discussion on this topic, see Solomos, M. (2021), *From Music to Sound. The Emergence of Sound in 20th- and 21st-Century Music,* Routledge, New York.

becomes political when it is given a political meaning. Music in itself is not political. [...] A work can also be political if you decide to make it so. [...] Did political roots make me write this work the way I wrote it? Maybe. Almost all my works are linked in this way to all the great international movements and conflicts, which are no different (I. Xenakis in F. Séloron: 1970). In this regard, Solomos states that Xenakis, on the one hand, maintains that music is not political in itself, but that it must be specified that he probably means by this the restricted sense of the word "politics", i.e., manifest, ideological commitment, intention. When Xenakis then goes on to state that his compositions are linked "to all the great international movements and conflicts" he is arguing that his music is, in a certain sense, political, in the more general sense of a relationship with the polis, with the City, with the humanly organized world, with the historical events that derive from it, with wars and civil wars, with politically organized demonstrations, and so on.

Later in his essay, Solomos links the sonic events of *Metastaseis* with the fragment from *La musique stochastique* quoted above, illustrating very convincingly the fit between the musical form of the work and the extra-musical events narrated by Xenakis (Solomos: 2022, p. 302). And, further on, Xenakis' own explicit statement is provided in which a connection is made between *Metastaseis* and his experience of the war in Greece: "*Metastaseis*, the starting point of my life as a composer, was not inspired by music, but by the impressions I received during the Nazi occupation of Greece. The Germans were trying to bring the Greek workers into the Third Reich, and we organized big demonstrations and managed to stop them. You heard the sound of the masses marching towards the center of Athens, the shouting of slogans, and then, when we came across the Nazi tanks, the intermittent firing of machine guns, the chaos. I will never forget the transformation of the regular and rhythmic noise of a hundred thousand people into a fantastic disorder (I. Xenakis in B. A. Varga: 1996, p. 52). So here we have an interesting example of how such an abstract musical form as Xenakis' can lend itself to readings that decode historical and political meanings in it. Another interpretation along these lines, equally valuable, is deployed in the essay *'Xenakis, not Gounod': Xenakis, the avant garde, and May' 68*, where Alannah Marie Halay and Michael D. Atkinson link Xenakis' formal innovations with spirit of '68, capturing, for example, in the slogan of the Situationist International "it is not about putting poetry at the service of revolution, but about putting revolution at the service of poetry" (Situationist International: 2006) or in the "Xenakis, not Gounod," one of the graffiti found on the walls of the Conservatoire National Supérieur de Musique in Paris (Halay and Atkinson in Nakipbekova: 2019, p. 3), but also one of the chants sung by young Parisian students in their demonstrations (Drott: 2011, p. 28). The young people who participated in these protests rejected the so-called "ritual of the concert" and preferred to submit to "perceptual and aesthetic experimentation" (Harley: 2005, p. 64), something that is evident in the ephemeral success enjoyed by the figure of Xenakis during the year of the revolt and the subsequent moments: "For a few years you could read profiles of composers like Henry and Xenakis in the pages of Rock & Folk [...] and for Xenakis' concert on October 26 [at the 1968 Journées de musique contemporaine], the auditorium of the Théâtre de la Musique (ex-Gaîté-Lyrique) proved insufficient in the face of great public interest, which turned away more than a thousand people at the door. Even the public debates managed to attract a considerable number of spectators" (Drott: 2011, p. 206-7). It would be interesting to delve into the tensions between aesthetic autonomy and the gentrification of art, as Halay and Atkinson do in their article, and it would also be worthwhile to dwell on a study of the relations between aesthetics and politics with regard to the decline that ensued in France in the mid-1970s, when, according to statistics compiled by Pierre-Michel Menger, even the most successful recordings of contemporary classical music, those featuring renowned figures such as Henri Dutilleux, Olivier Messiaen, or Iannis Xenakis, sold only between a thousand and three thousand copies a year, a tiny fraction of total annual record sales. However, at this point, we can now move on to the last section of our proposal, in which we would like to point towards a critique of aesthetic autonomy still to be developed and which, in the spirit of Attali's proposal, situates Xenakis' musical revolution in connection with an economic revolution which succeeded the Xenakian contribution in time, and which is connected with it in a profound way, by the same formal homology of the "stochastic laws" that the Greek-Romanian composer invoked in his 1961 essay.

III.

If we think of revolution from the perspective of large-scale economic programs, there is no doubt that the most relevant event in this respect in the last century is the failed bioeconomic revolution (Riechmann: 2021). In the genealogy of this unparalleled revolution, we find a fundamental milestone in 1971, with the publication of the Romanian-American economist Nicholas Georgescu-Roegen's major work, *The Law of Entropy and the Economic Process*. It denounces the widespread ignorance, still valid fifty years later, that economic systems are embedded in the ecosystems of the biosphere and depend on them, as well as on a limited stock of finite mineral resources; and that the entire economic process is marked by entropy and subject to the second law of thermodynamics. Georgescu-Roegen incorporates in his work a detailed critique of mechanistic epistemology and its limitations, carrying out an extensive discussion on the concept of entropy and its difficult connection with the mechanistic worldview, given its association with notions such as change, quality and randomness, and, based on the law of entropy, he vindicates the concept of evolution as opposed to locomotion as a key element in the scientific reflection on the world, applying the consequences of this philosophical shift to the field of economics. Through this application, Georgescu-Roegen obtains an alternative analytical representation of the production process, which goes beyond the mechanical analogy of neoclassical economics and incorporates the teachings of the laws of thermodynamics, laying the foundations for a theoretical earthquake that would lead, if taken seriously enough, to the design and large-scale implementation of policies for the reintegration of human systems into the biosphere. In this sense, the line of flight to which I would like to point is the connection, in terms of the political economy of music, that could be established between the incorporation of entropy in Xenakis' stochastic music and the assimilation of thermodynamics in Georgescu-Roegen's bioeconomic proposal. And it is that, resorting once again to the studies of Solomos: "For the composition, he used various mathematical formulas. However, the underlying scientific vision is one: it is the one developed by the new physics of the 19th century, thermodynamics. Xenakis said it many times. Thus, when he explains that the first conclusion leading to the massive sound phenomena was based on the human and natural experiments already mentioned, he adds that the second conclusion was to think of the equations used by thermodynamics" (Solomos: 2003, p. 70).

Therefore, it is important to draw the attention to the fact that the "nature" Xenakis speaks of in his various writings is that of the imaginary of modern science, his naturalism having to do with the law of entropy and probabilistic calculus, not with the romantic concept of nature[4]. In the words of critic Alex Ross, Xenakis employed rarefied methods to release primordial energies, and Milan Kundera, who listened obsessively to recordings of Xenakis' works in Soviet-controlled Czechoslovakia, heard in them a "noise of the world, a 'sonorous mass,' which, instead of gushing from the heart, comes to us from the outside, like the steps of the rain or the voice of the wind."[5] This rejection of a romanticized nature can also be traced in many of Xenakis' theoretical writings, such as *Vers une Métamusique* (1967), where natural images, such as those of clouds and galaxies, are employed without implying the acceptance of any kind of pre-established universal harmony: "In 1954 I denounced linear thought (poliphony), and demonstrated the contradictions of serial music. In its place I proposed a world of sound-masses, vast groups of sound-events, clouds, and galaxies governed by new characteristics such as density, degree of order, and rate of change, which required definitions and realizations using probability theory. Thus, stochastic music was born. In fact, this new, mass-conception with large numbers was more general than linear polyphony, for it could

[4] Useful in this regard is the contribution of Pierre Carré, "Bibliothèque Scientifique" (Solomos: 2022, p. 53-4), where several influences appear that were also fundamental in the formation of Georgescu-Roegen's thought, such as Émile Borel. Also useful in this regard is the article Solomos, M. (2019), *Xenakis et la nature: des sciences de la nature à une musique environnementale*, hal-02055017f, where we break down three different levels that we can distinguish when addressing the question of the meaning of the notion of nature in Xenakis' work.

[5] Ross, A. (2010), "Waveforms", The New Yorker, March 1 (Accessed 1 April 2022).

embrace it as a particular instance (by reducing the density of the clouds). General harmony? No, not yet" (Xenakis: 1992, p. 182).

In this article we cannot take care of all the homologies that can be detected between Georgescu-Roegen's bioeconomics and Xenakis' stochastic music. However, with these brief notes we hope to have taken the first steps in a new direction in the investigation of the Xenakian contribution. To this end, Jacques Attali's reading hypothesis in *Noise* (namely, that we can interpret certain innovations in musical forms as an anticipation of future economic transformations) might encourage an original analysis of Iannis Xenakis' aesthetic revolution, considering it more broadly than as if it were a reflection of the author's political biography or his historical context, and, rather, to interpret the incorporation of stochastic laws in his compositional practice and his understanding of nature as a gesture deeply related to the paradigm shift that Georgescu-Roegen proposed in his 1971 masterpiece and in his later writings. Our intuition is supported by the fact that the presence and relevance of nature and stochastic laws is central to the Greek-Romanian composer's conception of music and to the Romanian economist's bioeconomics, but also by the ecological sensibility that runs through the writings of both and their shared references. However, the exercise of systematically showing how the incorporation of thermodynamics and a non-teleological conception of nature can allow us to link the proposals of Xenakis and Georgescu-Roegen will have to be carried out on another occasion. For the time being, we trust that we have pointed, even tentatively, in an original direction in which we scholars of Xenakis' work can find a new possibility of interpretation of Attali's words, when he stated, quoting Xenakis himself, that the parallel between music and science is total:

> "Music is unified with the sciences in thought. Thus, there is no break between the sciences and the arts… Henceforth, a musician should be a manufacturer of philosophical theses and global systems of architecture, of combinations of structures (forms) and different kinds of sound matter" (Xenakis). The parallel to science is total. Like science, music has broken out of its codes. Since the abandonment of tonality, there has been no criterion for truth or common reference for those who compose and those who hear. Explicitly wishing to create a style at the same time as the individual work, music today is led to elaborate the criterion of truth at the same time as the discovery, the language (*langue*) at the same time as speech (*parole*). (Attali: 1985, p. 113)

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The Xenakis case under international law:

Aspects of nationality, transnationality, vulnerability and international responsibility

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Abstract

This contribution aims to explore Iannis Xenakis' particular trajectory under the light of international law norms, both as a citizen – a political and historical actor of his generation – and as an object of international legal protection.

The experience of Xenakis' early years, especially in the capacity of resistance and fight against fascist and Nazi regimes and their collaborators during the World War II, offers a rich canvas for studying multiple figures of nationality and State's responsibility.

This "child of the century" confronted in a very short period of time with the most cruel part of Greek modern history. His participation in several armed conflicts, especially during the so called "December events" in the centre of Athens (1944), led to his serious injury and consecutive clandestinity and exile. The facts as described by Xenakis himself and other contemporary actors in various texts are meant to question international law and politics theories about possible violations of international legal rules in that particular case, as well as about the failure of the aforementioned rules to provide a full and effective protection of a young political actor in a state of vulnerability.

Even if it is difficult to assume the existence of a Xenakis case in the proper sense of the term – as his case never came before international judicial or non judicial mechanisms – we can though consider that his qualification as a "freedom fighter" could offer him an enforced protection under international and humanitarian law. Was Xenakis a freedom fighter? A series of characteristics in the classical definition given by international legal scholars argue for this hypothesis. In any case, whether he is considered as a freedom fighter or (simply) as a civil victim of a civil war, Xenakis had to benefit from full protection within the framework of international humanitarian norms. As wounded in an armed conflict, Xenakis had received instead only partial assistance, in contradiction to customary humanitarian principles recognizing full assistance to all former fighters. Tried in absentia and sentenced to death in 1947, Xenakis confronted with the rude situation of statelessness and asylum seeking, in violation of the most elementary rules of international refugee law. He will not be reinstated until 1974, when a change of regime came to recognize the absurdity of maintaining such a sentence: a late and partial rehabilitation – almost unnecessary, as Xenakis had adopted therefore a new transnational identity, naturalized as a French citizen, living and creating in France.

From the point of view of the international legal doctrine, these facts may challenge

researchers in the fields of State's responsibility for flagrant violation of international obligation to protect and consecutive impunity for that behaviour.

In the case of Xenakis, vulnerability and trauma were experienced gradually as parts of a creative and evolving identity. Therefore, in his search for new artistic and theoretical standards, this *homo universalis*, a Greek *ánthropos* beyond borders, seemed to explore the concept of transnationality, unknowingly joining the cosmopolitan doctrine in international law, when he affirmed that "*one must constantly be an immigrant*".

1. Introduction

The "Xenakis case" seems very intriguing from the point of view of an international legal scholar. Even if it is difficult to assume the existence of a "case" in the proper sense of the term – as the constituent facts of Xenakis' personal and political adventure have never been presented before a national or international, judicial or non-judicial, body – we can though consider that many aspects of his singular trajectory deserve to be analyzed and assessed in the light of international norms.

Why the Xenakis case can be considered of great interest from the angle of international law? The first reason is that it reveals the shortcomings and flaws of a normative regime that was built after the war over the new figures of intergovernmental organizations, in order to preserve peace, security and human rights both in the large sphere of international relations and in the small, private sphere of individuals. The second reason is that this case highlights in a characteristic way the evolution of this system of rules throughout the decades, leading us to wonder how the international community would have handled a similar case nowadays.

This short study aspires to contribute to the current renewed interest in a forgotten or ignored part of the history of some of the most emblematic figures of the 20th century who lived as exiles and suffered the troubles of their condition as foreigners – the Picasso's case is probably the most unexpected one.[1] Furthermore, the particularity of Xenakis' case consists in the importance of the artist's public and political action which was intrinsically linked, at least in his outset, to the definition of his creative path. The transition from the heroism of his early political action to the vulnerability of his post-traumatic condition and consecutive exile was experienced gradually as a conscious or unconscious multiple constitution of the creator's evolving identity.

For the purposes of this analysis, we will focus on Xenakis' personality, political action and public status rather than on his works, using the methodology and conceptual tools of our discipline, international law. We will successively apprehend Xenakis as a *subject* of international law – in his capacity of being an active citizen, a political and historical actor of a generation marked by the scourge of war (2) – and as an *object* of the protection offered by international legal rules, including its branches of international humanitarian law and international human rights law (3).[2] From the use of revolutionary violence to the position of victim of the "legitimate violence" of the State – described by Max Weber as the State's monopole – Xenakis turned towards a universal and holistic perception for art, science and politics, thinking and acting as a modern *homo universalis*, a Greek *ánthropos* beyond borders, unknowingly joining the cosmopolitan doctrine in international law, when he affirmed that "*one must constantly be an immigrant*" (4).[3]

[1] See Annie Cohen-Solal, *Un étranger nommé Picasso* (Paris: Fayard, 2021). See also the composer George Aperghis' recent interview in the Greek newspaper *I Efimerida ton Syntakton*, entitled "The Last Great Greek *Ápatris* (Stateless)", March 15, 2022: https://www.efsyn.gr/tehnes/moysiki-horos/335813_o-teleytaios-megalos-ellinas-apatris.

[2] According to the traditional positivist doctrine of international law, a *subject* of international law is a legal entity possessing rights and obligations at an international level. This involves the capacity to bring international claims for the recognition of these rights and to bear the responsibility for breaches of international obligations. States as well as international organizations are undisputed subjects of international law, while individuals are traditionally considered rather as objects of international law. Nevertheless, the consecration of rules for the protection of human rights has contributed to a progressive recognition of a certain status of subject for the benefit of individuals.

[3] Cf. François Delalande, *"Il faut être constamment un immigré". Entretiens avec Xenakis* (Paris: Buchet-Chastel/INA-

2. Xenakis as a subject of international law: from "freedom fighter" to potential claimer for international protection

The story is well known and exposed in various sources. Born in Romania in 1921 or 1922, in a wealthy Greek family, the young Xenakis emigrated in Greece in 1932, where he continued his studies in a renowned school. The outbreak of the World War II and the involvement of Greece in that war on October 28, 1940 brutally interrupted the beginning of Xenakis' studies on civil engineering at the famous Technical University of Athens (*Polytechneion*); the studies would not be completed before 1946. Xenakis' contact with the harsh political reality of Nazi occupation and regime determined his choice to join the ranks of the young communist resistance, transforming him into an emblematic figure of revolutionary action. Xenakis' participation in the resistance against the Germans has been documented since 1941, in the ranks of EAM-ELAS, the National Liberation Front and its armed branch. The end of the German occupation in 1944 coincided with the beginning of another, very strange situation, where the former British allies came to consolidate by the armed force their sphere of influence on a country devastated by war. The so-called "December events" of the same year led to a series of bloody battles in the streets of Athens between the British forces and their governmental allies on the one hand and the majority of the population supporting the communist resistance, on the other hand.[4] Xenakis, who had excelled as a leading figure in the famous student battalion "Lord Byron", ended up seriously injured on his face from fragments of a British shell causing the loss of one eye during the battle of Exarchia, on New Year's Eve 1945. Saved by his father who found him half-dead, he spent a long period of convalescence before resuming the fight during the civil law that followed the December battles. Arrested several times as a dissident, then called to enlist in the national army, he managed to escape avoiding an imminent deportation. Tried *in absentia* and sentenced to death "for political terrorism" by a military court in 1947 – his sentence would be commuted in 1951 to ten years in prison– he managed to sail for Italy with the help of his father and with a fake passport, before arriving in Paris, on December 25, 1947, where he would finally settle.[5]

The situation faced by Xenakis, as described in the lines above, can be analysed in many ways from the angle of international law. As mentioned *supra*,[6] the capacity of being a subject or an object of international law is often confused as regards to individuals. Physical and moral persons were not traditionally considered as full subjects of international law – i.e. as entities that have the capacity to dispose of rights and to fulfil obligations under international law – but rather as objects or only as partial subjects, for the cases involving claims before judicial and non-judicial international bodies (courts or equivalent mechanisms). Things are about to change under the influence of human rights protection standards, particularly since 1945; in that field, persons and peoples have been progressively granted full legal personality. Moreover, the contemporary legal system recognizes the role of actors that are not necessary subjects but are identified by their power and means of action instead of their legal status.[7]

GRM, 1997).

[4] For a detailed presentation of the historical context of the December 1944 events, see: Tassos Kostopoulos, *Red December: The Question of Revolutionary Violence [Κόκκινος Δεκέμβρης: Το ζήτημα της επαναστατικής βίας]* (Athens: Bibliorama, 2016) (in Greek). Also: Menelaos Charalambides, *The December 1944 Events: The Athens Battle [Δεκεμβριανά 1944: Η Μάχη της Αθήνας]* (Athens: Alexandria, 2014) (in Greek).

[5] For the biographical elements, see in particular: Makis Solomos, *Iannis Xenakis: The Universe of an Original Creator [Ιάννης Ξενάκης: Το σύμπαν ενός ιδιότυπου δημιουργού]* (Athens: Alexandria, 2008) (in Greek); Makis Solomos, "Des combats de décembre 1944 à *Metastaseis* : d'une révolution à l'autre", in *Révolutions Xenakis*, exhibition catalog, ed. Makis Solomos (Paris: Philharmonie de Paris, 2022), 297-299. Also Mâkhi Xenakis, *Iannis Xenakis, un père bouleversant*. Expanded edition (Paris: Actes Sud, 2022), 16-35. The episode of Xenakis' injury is narrated in detail by Spyros Tzouvelis, *Days and Nights of December. Testimonies [Μέρες και νύχτες του Δεκέμβρη. Μαρτυρίες]* (Athens: Kastaniotis, 2003), 101-102 (in Greek).

[6] *Supra*, note 2.

[7] Cf. Emmanuel Roucounas, *A Landscape of Contemporary Theories of International Law* (Leiden: Brill/Nijhoff, 2019, 513.

Why is this important for the Xenakis case? First, it is important for Xenakis' qualification not only as a sole political actor but, moreover, either as part of the "belligerents" during a conflict (the war against the Nazi occupation and the consecutive civil war) or as a "freedom fighter" – a status that could offer him an enforced protection under international and humanitarian law. Whether we consider Xenakis as a member of the armed forces led by a non-state actor (in the present case, the battalion "Lord Byron", linked to the revolutionary army) or as a civilian, the Geneva Conventions of 1949 that form the corpus of humanitarian law in force and, even before that, the customary humanitarian principles, known since the first and the second Geneva Conventions of 1864 and 1929 – Henry Dunant's heritage –, agree on the obligation to give assistance to wounded persons immediately and to treat them humanely. This fundamental obligation has been ignored with respect to Xenakis by the Greek governmental and the British forces.

Was Xenakis a freedom fighter? In fact, the recognition of a legal status for the so-called "freedom fighters" under international law seems to be rather controversial. Although the term was used to glorify the forces of resistance during the Nazi attacks and occupation in World War II, or the struggle of "national liberation movements" during the decolonisation era, the same term suffered from negative connotations during the last years, under the influence of the counter-terrorist doctrines. Nevertheless, international legal scholars seem to agree on the existence of a right to popular resistance to aggression and illegal occupation that could lead to "resistance or partisan wars" or "liberation wars". According to Frédéric Mégret, "*if armed action by non-state actors is specifically geared, explicitly or implicitly, to remedying the consequences of an illegal occupation, then it is possible, within certain limits, to see "insurgents" as the agents of a peculiar form of highly decentralized enforcement of international law*".[8]

Therefore, the difference between freedom fighters' activities and terrorism tends to be very slight and lies mainly on the respect usually shown by freedom fighters towards civilians, who are protected from becoming targets, contrary to what is customary in terrorist practice. On this subject, Kalliopi Koufa, former United Nations Special Rapporteur on Terrorism and Human Rights, notices "*the tendency of some States to obstruct international purview of the true internal situation by use of the 'terrorist' rhetoric.*"[9] That is the reason why modern international law doctrine and instruments progressively abandoned the qualification of "freedom fighters" for individuals or groups acting in resistance to a foreign occupation or a dictatorship, preferring to qualify relevant acts on a case-by-case basis.

The way Iannis Xenakis was treated by the Greek military justice during civil war reveals some other problematic aspects under international law. Tried *in absentia* and sentenced to death, then to a ten years' imprisonment, by two military courts, Xenakis could not benefit from any of the fundamental guarantees which were then provided for under customary international law, such as the guarantee of *habeas corpus*, the right to a competent, independent and impartial tribunal, the rights of the defense, the right to a just and fair trial, and the non-imposition of the death penalty. These rights and guarantees are now enshrined in the text codifying the Principles Governing the Administration of Justice Through Military Tribunals, more commonly known as the "Decaux Principles" – from the name of the former United Nations Rapporteur on the question of administration of justice by the military tribunals, Emmanuel Decaux. This text, adopted by consensus by the United Nations Human Rights Council in 2006, sought to establish a legal framework for the proper administration of justice by military tribunals through the enumeration of twenty principles and constitutes from now on the authoritative international norms on this matter.[10]

[8] Cf. Frédéric Mégret, "Beyond 'Freedom Fighters' and 'Terrorists': When, if Ever, is Non-State Violence Legitimate in International Law?", (6 April 2009), SSRN Electronic Journal. Available at: https://ssrn.com/abstract=1373590, 8-10.

[9] See Final Report of the UN Special Rapporteur on Terrorism and Human Rights, Kalliopi K. Koufa, *Terrorism and Human Rights*, *Specific Human Rights Issues: New Priorities, in Particular Terrorism and Counter Terrorism*, UN Doc. E/CN.4/Sub.2/2004/40, 25 June 2004.

[10] See Final Report of the UN Special Rapporteur on the Administration of Justice Through Military Tribunals, Emmanuel Decaux, *Draft Principles Governing the Administration of Justice Through Military Tribunals*, UN Doc.

Finally, an episode that is rather unknown from the history of Xenakis as a political dissident is the fact that he has been a victim of a long time persecution by the Greek police secret services that literally spied every single of the composer's movements, even having kept an administrative secret file in his name for a very long period, from his early years of political action until the end of the 1970s!

All the aforementioned elements plead for the recognition of serious breaches of States' international obligations under international and humanitarian rules, both during the civil conflict and in the post-conflict period.

3. Xenakis as an object of international law: the non-recognition of a victim status and the consequent lack of protection

In the same line of thinking, the history of international law can also be read as a history of struggles against States' impunity for breaches of their obligations to protect people from injuries or violations of their rights. In such context, the apprehension of the Xenakis case under international law raises issues of human vulnerability in post-conflict situations. Although international humanitarian law recognizes the category of former fighters – and *a fortiori* the wounded ones – as vulnerable people who require particular attention and assistance, States systematically fail to guarantee effective protection for the rights of these persons or groups, partly because of the lack of binding and enforceable instruments, as well as because of the flaws in the mechanisms of transitional justice that may be established in the countries concerned.[11] It is interesting to note that, apart from the Xenakis case, numerous violations, acts of torture, exactions, even murders were ordered by the Greek State after the civil war, during the dictatorship from 1967 to 1974 and even following the restoration of the democracy – crimes that have enjoyed complete impunity.

Eventually, the Xenakis case questions the issue of statelessness and the consequent failure of international law to remedy what is considered as a legal and political anomaly. In fact, Xenakis was stripped of his Greek nationality following his conviction to death for "political terrorism". Then, his exile in France coincided with the unusual and uncomfortable condition of a stateless person – an *ápatris* – meaning literally an individual who is deprived of the fundamental link a person can have with a State, this of nationality. As his daughter Mâkhi Xenakis recounts in her autobiographical tribute to her father *Iannis Xenakis, un père bouleversant*, Xenakis remained stateless until 1964, when President Georges Pompidou granted him French nationality; he will have spent eighteen years without legal status, despite the fact that he was a political refugee, risking the death penalty or the imprisonment should he decided to go back to his country. To avoid this fate, he will have spent twenty-seven years in exile, before deciding to cross the Greek borders after the fall of the military dictatorship in 1974.[12]

Indeed, statelessness is a condition that modern international law tries to avoid at all costs. Various international treaties, such as the Convention relating to the Status of Stateless Persons (1954), the Convention on the Reduction of Statelessness (1961), as well as international human rights treaties aim to prevent or reduce statelessness, establishing an international framework to ensure the right of every person to a nationality. Moreover, the Universal Declaration of Human Rights (1948) and the

E/CN.4/2006/58, 13 January 2006. Also: Claire Callejon, "Les principes des Nations Unies sur l'administration de la justice par les tribunaux militaires : pour une justice militaire conforme au droit international", *Droits fondamentaux*, no 6 (2007). Available at: https://www.crdh.fr?p=5045. Sharon Weill and Mitch Robinson, "The Decaux Principles on the Administration of Justice by Military Tribunals and the Guantanamo Bay Trials", in *Réciprocité et universalité : Sources et régimes du droit international des droits de l'homme, Mélanges en l'honneur du Professeur Emmanuel Decaux*, collective ed. (Paris: Pedone, 2017), 533.

[11] Cf. Stelios Perrakis, *La protection internationale au profit des personnes vulnérables en droit international des droits de l'homme.* Collected Courses of The Hague" Academy of International Law, vol. 40 (Leiden/Boston: Brill/Nijhoff, 2021, 114-115.

[12] Mâkhi Xenakis, *op. cit.*, 35.

Convention relating to the Status of Refugees (1951), that codify previous customary law, recognize a right for persons to seek asylum from persecution in others countries. In the light of these texts, States should be able to propose a status to persons who became stateless after a conflict, as well as to fully protect the rights of refugees and asylum seekers.

The legal and political approach of statelessness and asylum in France is even more generous: refugee status can be granted in France either on the basis of the 1951 Geneva Convention (conventional asylum), or on the basis of the French Constitution, under paragraph 4 of the Preamble of the 1946 Constitution that still remains into force (constitutional asylum). This second option was historically considered as the best way to grant asylum to freedom fighters.[13]

Under these provisions, it is certain that Xenakis, whose reputation of freedom fighter had crossed the French borders, could have benefited much earlier than in 1964 from this constitutional refugee status; the reasons of this negligence of the French State remain uncertain. One could also argue that, if the system of the European Convention and the European Court of Human Rights had existed at the time of the facts in Xenakis case, the outcome would have been different, in particular with regard to his situation as a stateless person and asylum seeker.

The persecuted artist will eventually prevail when returning to his native land, by the force of his genius, involving thousands of soldiers of the Greek army as performers in the majestic concert of Mycenae. As his wife Françoise recounts, Xenakis has been received by the people, in his return to Greece, as a hero or as a modern saint. Nevertheless, this unexpected popularity did not prevent him from fearing an arrest as soon as he arrived in Greece, since the amnesty granted after the fall of the dictatorship did not yet concern those sentenced by military tribunals.[14]

4. Xenakis and the future of international normativity: towards a new cosmopolitan humanism through a holistic approach of art, science and world politics

From a psycho-analytical point of view, Xenakis seems to have been intrinsically identified by his family name, literally meaning “little stranger” in Greek. Leaving progressively behind him the condition of victim, of the illegal or stateless person, Xenakis emancipates as an intellectual and a “citizen of the world”, forging a new cross-border identity as his artistic notoriety asserts and consolidates. As Sokratis Georgiadis remarkably states, what resumes some artists’ singularity and *grandeur* is the power with which they transform the trauma into creation and the scope with which their example is projected in the future. Xenakis rightfully holds a prominent position among these figures, as the contact with his free spirit unleashes a dynamics towards the restatement of the permanent quest for a social and human utopia that remains absolutely relevant in the current situation.[15]

Xenakis embodies, as few artists and intellectual do, the universal figure of exile and immigration. He defends throughout his life and creations this philosophy of no-border, free from conventions, that is resumed in his famous aphorism “*one must constantly be an immigrant.*” As Mihu Iliescu reminds us, the universality of Xenakis could find its deepest explanation in the fundamental *alterity* of the creator linked to his condition of foreigner and uprooted. From that perspective,

[13] On this debate, see Alexis Marie and Thibaut Fleury Graff, “La jurisprudence du Conseil constitutionnel relative au droit d’asile mise en perspective avec celle du Conseil d’État : l’art de l’ouroboros”, *Publications du Conseil constitutionnel*, Titre VII, n° 6, *Le droit des étrangers*, (April 2021). Available at: https://www.conseil-constitutionnel.fr/publications/titre-vii/la-jurisprudence-du-conseil-constitutionnel-relative-au-droit-d-asile-mise-en-perspective-avec-celle.

[14] See press article in the newspaper *L’Aurore*, August 16, 1978: “3.000 soldats grecs à Mycènes sous les ordres de l’ex-condamné à mort Iannis Xenakis”.

[15] Sokratis Georgiadis, “Iannis Xenakis, penseur en exil : réflexions sur la dynamique du trauma”, in *Penser en exil : les intellectuels grecs en France (1945-1980)*, ed. Eric Desmons and Despina Sinou (*Revue française de l’histoire des idées politiques*, no 2 (2022), publication forthcoming).

"*breaking down barriers in music and art*" – that was a frequent Xenakis' statement – is one way among others to defend a unitary vision of the world.[16]

The words used by the composer are not fortuitous; they reveal a political and social philosophy that joins both the cosmopolitan theory of international law and the humanist spirit of human rights defenders and scholars,[17] including the *internationale situationniste* and the May 68 philosophical heritage.[18] In this sense, Xenakis appears throughout his writings and public interventions as a *penseur* in his own right – in the line of the Renaissance humanist philosophers. Adopting a holistic approach that places the concept of *humankind* at the centre of the artistic and creative *praxis*, Xenakis unconsciously joins the most visionary international legal scholarship that considers humankind as a global addressee of international norms,[19] predicting in a certain way the future of a discipline that was predestined by the United Nations to a progressive development.

5. Epilogue

Iannis Xenakis, the "little stranger", "*managed to escape from Greece*", as he writes in his late years *Autobiography* (1980).[20] The words used to describe this exodus reveal a feeling of salvation yet imbued with regret, possibly with nostalgia. In that sense, Xenakis incarnates in a certain way the prototype of Ulysses' eternal return, not exempted from this archaic sense of anxiety as described in Mimika Kranaki's novel *Philhellenes* – perhaps the only novel written by an immigrant of the same period. Kranaki was of the same generation as Xenakis and one of the passengers of the legendary ship Mataroa – this post-war Noah's ark for the most talented part of the Greek revolutionary youth emigrating to France. As for the Xenakis case, this eternal return to the motherland can be accomplished in many ways: "*What do you still want Greece for? – It's been nailed inside me and when I try to take it out, a piece of flesh is always left alive on the hook.*"[21]

That "piece of flesh" that Xenakis literally left on the hook of Greece's modern history has become the artist's singular inner eye in the process of transforming through Art the historical and political *momentum* of one's life into the *continuum* of our humankind's destiny[22].

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[16] Mihu Iliescu, "Un éclaireur d'abîmes", exhibition catalog, ed. Makis Solomos (Paris: Philharmonie de Paris, 2022), 51.

[17] On the main characteristics of the cosmopolitan current in international law and its humanist origins and perspectives, see in particular: Olivier de Frouville, *From Cosmopolitanism to Human Rights* (London: Hart/Bloomsbury, 2022). *Idem*, "Qu'est-ce que le cosmopolitisme juridique ?", in *Le cosmopolitisme juridique*, ed. Olivier de Frouville (Paris: Pedone, 2015), 11. Catherine Wihtol de Wenden, "La gouvernance mondiale des migrations : un processus cosmopolitique ?", in *Le cosmopolitisme juridique*, *op. cit.*, 377. Demelemestre, Gaëlle, "Le droit cosmopolitique : un droit à la migration ?", *op. cit.*, 397.

[18] Cf. Alannah Marie Haley and Michael D. Atkinson, "Xenakis, not Gounod": Xenakis, the avant-garde, and May 68", in *Exploring Xenakis. Performance, Practice, Philosophy*, ed. Alfia Nakipbekova (Delaware, Vernon Press, 2019), 4.

[19] Cf. Emmanuel Roucounas, *op. cit.*

[20] Iannis Xenakis, "Une auto-biographie", 1980, reproduced in *Révolutions Xenakis*, exhibition catalog, ed. Makis Solomos (Paris: Philharmonie de Paris, 2022), 13.

[21] Mimika Kranaki, *Philhellenes [Φιλέλληνες]* (Athens: MIET, 1998), 204 (in Greek).

[22] Cf. one of the last letters that Xenakis has written, including the following statement addressed to Bob Wilson: "*Originality is an absolute necessity for the survival of the human species*". In Mâkhi Xenakis, *Iannis Xenakis, un père bouleversant*, extended edition (Paris: Actes Sud, 2022), 242-243.

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Connecting Xenakis' work to cyberphysical performance in dance education and artistic practice

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Abstract

In his writings as well as in his interviews, Iannis Xenakis delineates an expansive visionary aesthetic that connects musical composition not just to mathematics and philosophical thought, but also to many other social, technological, cultural, and scientific endeavours. Both his compositions and his theoretical writings seem to be firmly focused on musical composition within the tradition of the western performed score, his polytopes show that he was in fact actively interested in exploring performative domains adjacent to classical western musical tradition, and several works include forays into dance through collaborations (Kraanerg, Antikhthon, Pléïades). Here we intend to explore how Xenakis' work and thought can impact the practices of dance and live coding in the contexts of cyberphysical computing / performance which developed predominantly in the decades after Xenakis' active career. To this purpose, we revisit his aesthetics and approach to music in order to provide a hands-on view on interpreting Xenakis' thought, aesthetics and work methods from the perspective of contemporary embodied or cyberphysical / live-coding performance practices in education. We propose a workshop of up to 3 hours duration which will present the results of our work with undergraduate students at the Department of Digital Performing Arts of the University of Peloponnese and the Department of Audiovisual Arts of the Ionian University during the course of the academic year of 2021-2022. Our work will be based on the study of selected writings and works of Iannis Xenakis, as well as studies about him. Our objective is to see how Xenakis' work resounds today in the teaching of performance - both in computer music and dance, using the notion of cyberphysical performance as object of inquiry. By cyberphysical performance we mean the use of sensors and network technologies to connect the processes which generate the sonic (or other) elements of the performance with the bodies of the performers through measurements of physical properties such as motion or other physical magnitudes. By extension, this may include non-human sources, such as any other measurements from the environment, or of the collective behavior or events in groups of persons. As a starting point, we

use chapter 4 of "Formalized Music", because it describes a variable performance scenario using a selection of distinct textures whose sonic characteristics can be deduced from the textual description in conjunction with the score of the piece they refer to ("Duel"). Both the description and the score will be subjected to analysis in order to translate these into choreographic scores on the one hand and code for the synthesis of event structures (score-like equivalents) or sonic textures corresponding to the sonic events described by Xenakis. Further documents and scores provide additional support for the project. Finally, we compare this educational work with performances produced by our research group, in order to show how this relates to actual artistic practices.

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Mapping materialities: Digital embodied interactions with Iannis Xenakis' work

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The proposed workshop aims at a collective investigation of potential applications of third wave Human-Computer Interaction (HCI) in the reception of Iannis Xenakis' work. The technologies in question include eXtended Reality (XR), motion capture and sonification methods and tools (especially techniques originally devised by Xenakis), whereas the theoretical background extends into ecological psychology, phenomenology, embodied cognition and performance studies.

Multimodality is inherent in Xenakis' work, including the general structural correspondences between music, mathematics and architecture, the exemplary site-specific cross-mappings of distinct modalities such as visuals, audio and movement in his ambitious *Polytopes* [16][17][25][26], the incompatibilities between his notation and its embodiment in performance ([1][2][3][4][5][6][7][9][10][11][27]). In addition, in the third wave HCI, where the participants' experience and the socio-cultural becomes centric for designing digital interactions [15], Xenakis vision about participation[17] and artists role in society can become very relevant in digital artistic creations and communications of the future.

Driven by:

a) The project ARIA, which has thus far focused on the work of Nikos Skalkottas (Augmenting the Reception of music through Innovative solutions and Archives" https://aria-project.gr) which explores among other, the connection between embodied interactions with virtual material objects and visual metaphors [23] for audience's reaction to music in virtual environments through embodied interactions with abstract shapes [13], as well as baseline work on embodied interactions [14][18][10].
b) the project GesTCom (Gesture Cutting through Textual Complexity), which develops concepts and tools for technology-enhanced learning and performance of Xenakis' solo piano work ([3][4][5][6]):
    i) visualization, documentation and analysis of multimodal recordings of performance: https://youtu.be/io9iGpVUAkI (*Mists,* 1980), https://youtu.be/L8pAjnAiQ9E (*Herma*, 1961)
    ii) technology-enhanced learning: https://youtu.be/55tuHhRU-EM , https://youtu.be/eNQsusviPIg , https://youtu.be/VTdBlyV6qVE https://youtu.be/GnLKPmu36kQ, https://youtu.be/Rql732JUm5M (*Mists,* 1980)
c) augmented and virtual reality applications for enhancing the concert experience of Xenakis' works piano performance ([5][6])https://youtu.be/ZM1lEqseta4, https://youtu.be/7uM26Vpz3qU, https://youtu.be/jgi3beIlT_o, https://youtu.be/whmWSoxOBEs, https://youtu.be/D-vhOX88NfM (*Evryali*, 1973)
d) Telematic dance project focussing on embodied performance with motion sensors and live coding [27]

e) Multimodal performances that combine techniques pioneered by Xenakis like stochastic models and contemporary AI (https://youtu.be/M_s3aXvbtfk),
   i) Extended Interactive stochastic sound synthesis (https://vimeo.com/462730171) (https://vimeo.com/52934332)[20]
   ii) Immersive stochastic sound synthesis (https://vimeo.com/31259554)
   iii) Interactive arborescences (https://vimeo.com/148920133
   iv) Real time control of Stochastic functions and sieves for interactive disklavier piano performance (https://vimeo.com/191080304)[21]

We aim to consider means of representing and communicating information in an immersive and interactive manner. The information in question may range from archival-historic and analytical-systematic elements about the composer and his work, to the sheer materialities of bodies, instruments and musical scores, that usually remain in the sphere of the performer's private experience or in the realm of their inter-subjective communication with the composer. Drawing on James J. Gibson's ecological psychology [13], we will consider the affordances and constraints of visualizations and digital interfaces for the exploration and communication of actions and meanings to the participants.

The workshop will form a working group and session for hands-on activities, exchange of ideas and will report the outcomes for future investigations and collaborations. It aims to cover both the conceptual/philosophical/artistic as well as the technological and practical challenges for digitally mapping materialities in Xenakis' work.

Bios

Katerina El Raheb is a human-computer interaction researcher, Assistant Professor at the Department of Performing and Digital Arts of the University of the Peloponnese, and dance artist. Since 2009 she works as researcher on digital applications in cultural/pedagogical contexts focusing on human, embodied and cultural aspects and had a key role in relevant EU funded projects e.g., WhoLoDance, Aria, Transitionto8, BRIDGES as an adjunct researcher at the University of Athens and Athena Research Center. She has a PhD/MSc in computer science (University of Athens), BSc in engineering (National Technical University of Athens, Professional Diploma in Classic and Contemporary Dance (Kontaxaki Dance School).

Marina Stergiou is a researcher in human-computer interaction and a designer and developer of eXtended Reality applications. She is an adjunct researcher at Athena Research Center and National and Kapodistrian University of Athens since 2017, participating in projects such as WhoLoDance, Aria, Transitioto8. She is a PhD student at the University of the Aegean, department of Product and System Design Engineering. She holds a Chemical Engineering Diploma from National Technical University of Athens, a MEng in Design of Industrial and Interactive Products and Systems, University of the Aegean and a Piano Degree from National Conservatoire of Athens.

Pavlos Antoniadis (PhD in musicology, University of Strasbourg-IRCAM; MA in piano performance, University of California, San Diego; MA in musicology, University of Athens) is a pianist, musicologist and technologist from Korydallos, Athens, Greece, currently based in France and Germany. He performs complex contemporary and experimental music, studies embodied cognition and develops tools for technology-enhanced learning and performance. He is a Humboldt Stiftung scholar at the Berlin Institute of Technology (TU-Audiokommunikation) and a research associate at IRCAM, team interaction - son - musique - mouvement and at EUR-ArTeC, Université Paris 8
https://pavlosantoniadis.wordpress.com/about/
http://ismm.ircam.fr/pavlos-antoniadis/
https://eur-artec.fr/projets/habiter-avec-xenakis/

Iannis Zannos studied Composition, Musicology and Information Engineering with applications on Music. He is currently Professor for Computer Music at the Ionian University. His main interests are cyber physical performance arts, live coding and acoustic ecology. He works mainly with various Open Source programming environments such as SuperCollider, openFrameworks, EMACS a.o. Since 2018 leads research on telematic dance, and creates and coordinates performances taking place at various distant locations worldwide, employing motion tracking with wearable devices and digital audio and graphics synthesis methods.

Pablo Palacio is the founder and director of Instituto Stocos, a performing arts company focused on the transfer of abstractions taken from other disciplines such as artificial intelligence, biology, mathematics or experimental psychology into performative contexts. With Instituto Stocos has produced several performances that operate as an artistic form of dissemination of this research. The trilogy Acusmatrix, Catexis, Stocos, Piano& Dancer and Neural Narratives Series or the Marriage of Heaven and Hell constitute some of the outcomes of this investigation. He is a visiting lecturer of sound space on the Master in Performing Arts and Visual Culture (UAH-Madrid).
https://www.stocos.com/en/
https://www.pablopalacio.com/

Maria Roussou is an Assistant Professor in Interactive Systems at the Department of Informatics & Telecommunications as well as the graduate program in Museum Studies, University of Athens. In 2003 she founded and co-directed makebelieve. Previously (1998-2003), she established and directed the Virtual Reality Department at the Foundation of the Hellenic World, where she was responsible for setting up and managing the research, design and development of the VR programs and related visitor experiences. She has also collaborated with museums, such as the Walker Art Center and the Acropolis Museum. She holds a PhD in Computer Science from the University of London (UCL), a Master in Fine Arts (MFA) in Electronic Visualization and a M.Sc in Electrical Engineering & Computer Science from the University of Illinois at Chicago.

Dimitris Batsis is a sound artist and academic researcher. His interest covers the field of biological functions in relation to new media and sciences, sound design and interactive systems. His output involves sound installations, performance and video art through audiovisual applications and coding. He holds a PhD in Biomusic (the transformation of biological signals into sound art through research in new mediums) from the Department of Fine Arts and Art Sciences at the University of Ioannina and an MA in Contemporary Arts and Music at Oxford Brookes University.

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Algorithmic Composition with Max/MSP and OpenMusic

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Abstract

The workshop is designed to give a perspective on Iannis Xenakis' general approach to composition using algorithms within popular visual programming languages for music. In particular, we will focus on such concepts as sieve theory and cellular automata, as well as extra-temporal architecture based on the theory of groups of transformations. We will be using the seminal Xenakis works *Rebonds* (1987-89) for solo percussion and *Nomos Alpha* (1965) for solo cello to showcase analysis, with pedagogy and pre-compositional applications in mind. Simplified versions of Xenakis' algorithms will be recreated through Max/MSP and/or OpenMusic patches as part of a live-coding demonstration. Furthermore, throughout the workshop we will be utilizing Max/MSP's BACH library for computer aided composition, the CAGE modules for standard 20th- and 21th-century compositional techniques, and DADA to utilize non-standard graphical user interface for music generation and processing. Finally, we will be employing some of Vincze's pre-built OpenMusic code as a starting point, for the sake of time, in OpenMusic. All patches throughout our workshop will be made freely downloadable afterwards as well.

Since 2017, Andrew Watts and Davor Vincze have taught an intensive summer workshop at Stanford University's Center for Computer Research in Music and Acoustics (CCRMA). The workshop has served as a formalized journey into the basics of algorithmic composition, using Max/MSP and OpenMusic as pre-compositional tools to the aid the artist and engineer alike. Here, students ranging from undergraduates to industry professionals explores how simple algorithmic models can result in intriguing sonic results. Our daily tutorials have focused on isolated musical parameters, though not to the extent as to prevent touching on related topics when relevant. The ultimate goal has been for students develop their best work over the week into a short composition that uses one or several of the models that we will be explaining during the workshop. Furthermore, we show that working with algorithms is not only useful for schematic problem solving, but can also be a good tool for expanding musical and creative thinking.

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