TOWARDS A REAL-TIME IMPLEMENTATION OF ANALOGIQUE B

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ABSTRACT

In this paper I discuss an attempt at implementing Analogique B in a real-time digital audio process. My effort is based not only on Xenakis's own description, but also on analytical evidence gatherered in previous research work, both concerning the composer's own "mechanism" (set of rules yielding into the markovian process) and the practicalities of his working method in the GRM studio, in 1958. My tentative implementation consists in a single, all-encompassing patch (in Max-Msp), yet of course it reflects two distinct computer programming tasks: (1) rendering of the Markov chain process, (2) real-time granular sound synthesis engine (whose parameter space is driven by the former process). Such a two-fold task reflects an element peculiar to all programming and compositional exploration of grain- or particle-based approaches on sound: a representation of the grain event sequences (synthesis), and a representation of the control structure (or "front-end processor", with Curtis Road's terms) necessary to access and handle the largest amount of data required at the grain level.

In describing my implementation of Analogique B, I discuss some non-marginal technical problems, and sketch future developments aimed at surpassing the relative predictability of the (closed and memoryless) stochastic process Xenakis explored for himself.

1. INTRODUCTION

In 1958 Iannis Xenakis composed Analogique A et B, for 9 strings and tape. As is known Analogique B was initially composed as a short, autonomous piece of electronically generated music, independent of the instrumental Analogique A. After completing it, the composer changed his mind and pasted the two pieces together, to make Analogique A et B. The two "parts" were for Xenakis as different projections of one and the same constructive principle, namely a stochastic process known as Markov chain. He projected the process on a larger time scale (instrumental score) and on a smaller, micro-level time scale (electronic sound generation).

For several reasons, the project behind Analogique B really represented a major (theoretical and practical) challange. A kind of algorithmic method (a formalized mathematical method, virtually indentical with the process behind Analogique A) was to guide the composer in shaping the fine structure of sound and its changes in time. Crucial, in this regard, was a view of sound not in the terms of classical Fourier analysis (summation of sine and cosine continuous functions) but in terms of acoustical quanta (time-finite functions, having a real and an imaginary part).

While working on Analogique B, Xenakis came to know of Dennis Gabor's seminal quantum theory of hearing. His sound particles (a "continuing texture of buzzing insects", in Angelo Orcalli's words) are known today as the very first instance of granular sound synthesis.
In short, Xenakis' goal was to create large configurations of small sonic quanta - that he used to call sound clouds - and let a Markov chain process articulate them in time. An important hypothesis here was, that the low-level interaction among sound particles would bring forth higher-level qualities ("sonorities of 2nd order"). Regardless of the aesthetic quality actually achieved, and despite the insurmountable technical difficulties he had to deal with at the time, this astonishing list of theoretical and technological implications makes of Analogique B certainly a ground-breaking step in the history of electroacoustic music.

2. THE MACHINE OF ANALOGIQUE B

2.1. What Xenakis wanted to do and why

In 1947 Dennis Gabor formulated his theory of Acoustic Quanta. He considered a signal s(t) and his Fourier Transform S(f). Now one can find the maximum of energy focused in a gap of frequency Δf and in a time Δt where: $\Delta f * \Delta t \geq 1$

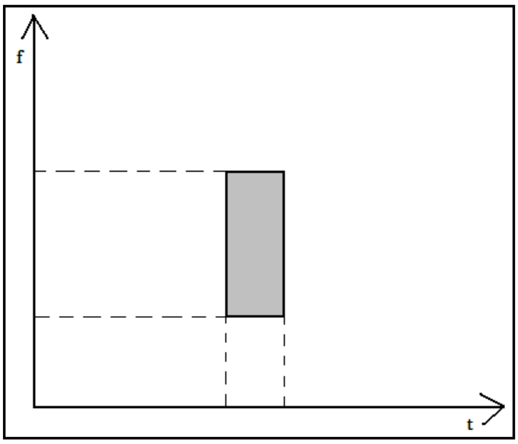

Fig. 1

Gabor found that signals which can minimize to 1 this relation are sinusoidal waves multiplied by gaussian envelopes (grains). Thus superimposing and/or overlapping these grains along time one can re-synthesize or create sounds since every grain is a localized amount of energy.
Starting from this point in 1959 Iannis Xenakis wanted to apply this theory in his music in order to create “Second order sonorities”. He understood that operating in a small time scale the composer can produce coherently the sounds and the macro-form of a piece.
He composed Analogique B using grains 40ms long and with a rectangular envelope. This composition follows the same rules he formulated for his previous work “Analogique A”.

2.2. The process

The process that Xenakis impose to his composition trace his roots from Markov Chains.

He built a 8x8 “General Transition Probability Matrix” starting from six elementary 2x2 matrix.

The General Transition Probability Matrix is used to chose one of the eight possible states of the grains.

Every state is a possible configuration of three basic musical parameters: frequency, intensity of a single grain and density of the grains-texture. The values of these parameters are grouped by Xenakis in various regions. In every region the current value is chosen in a completely random way.

GENERAL TRANSITION PROBABILITY MATRIX

	A	B	C	D	E	F	G	H
A	0.021	0.357	0.084	0.189	0.165	0.204	0.408	0.096
B	0.084	0.089	0.076	0.126	0.150	0.136	0.072	0.144
C	0.084	0.323	0.021	0.126	0.150	0.036	0.272	0.144
D	0.336	0.081	0.019	0.084	0.135	0.024	0.048	0.216
E	0.019	0.063	0.336	0.171	0.110	0.306	0.102	0.064
F	0.076	0.016	0.304	0.144	0.100	0.204	0.018	0.096
G	0.076	0.057	0.084	0.114	0.100	0.054	0.068	0.096
H	0.304	0.014	0.076	0.076	0.090	0.036	0.012	0.144

Tab.1

The GTPM shows the probability that each of the eight states has to follow the former.

Xenakis call them “screens” and every screen describes the composition of the “grains-texture” of the music for a half of a second. Frequencies are grouped in 16 regions, intensities in 4 regions and densities in 7 regions but Xenakis didn’t use the last region surely due to practical issues. The whole “recipe” of the process and the composer’s decision are described in the his book “Musique formelles (1963)”.

Screen A

	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10	f11	f12	f13	f14	f15	f16
I4			2													0
I3					0										1	
I2		5											3			
I1	0						4			5				2		

Fig. 2

As we can see, the first screen (fig. 2), called screen A, impose that the grain-texture is made of 10 streams of grains. The first belong to the density region number 0 (1.3 gps), the intensity region number 1 (from 50 to 60 phones) and the frequency region number 1 (from 42 to 63 Hz). The second stream is composed by grains belonging to the density region number 5 (315.9 gps), the intensity region number 2 (from 60 to 70 phones) and the frequency region number 2 (from 63 to 84 Hz) and so on.

2.3. Xenakis's results

Xenakis realized that his "machine" couldn't generate neither "a second order sonority" nor the musical form.

For the first problem we now could say that he just failed the choice of the operating time scale.

For the second, the issue is more complicated and I'll try to provide a possible solution later.

In order to interrupt the monotony of the normal working of his machine, Xenakis stop it in a perturbed state. This means that he repeat more times the same screen creating an attraction point of the resulting sound. If we call E the equilibrium state (normal working) and P the perturbation state we can decompose Analogique B into 10 pieces:

SEGMENT	DURATION [seconds]	STATE
1	$30*\Delta t = 15$	E
2	$10*\Delta t = 5$	P (screen C)
3	$24*\Delta t = 12$	E
4	$8*\Delta t = 4$	E
5	$14*\Delta t = 7$	E
6	$72*\Delta t = 36$	P (screen A or C)
7	$44*\Delta t = 22$	P (screen B)
8	$30*\Delta t = 15$	E
9	$37*\Delta t = 18.5$	E
10	$30*\Delta t = 15$	P (screen D)

Tab. 2

where $\Delta t = 0.5$ s

As we can see, Xenakis didn't obtain exactly what he wanted but his work was a success because of its originality and the influence it had on the other composers who decide to investigate his particular way of composing.

3. TOWARDS A REAL-TIME IMPLEMENTATION

3.1. My machine

There are two purposes, the first is to remake the “machine” of Analogique B in order to compare the two implementations, the second is to develop the original goal to create musical form starting from sound and his physical analogy with clouds.

I choose Max-Msp for implementing both the calculation stage of the machine and the synthesis stage carried out by a granular synthesizer.

There is a unique “patch” that wrap all the process for producing Analogique B.

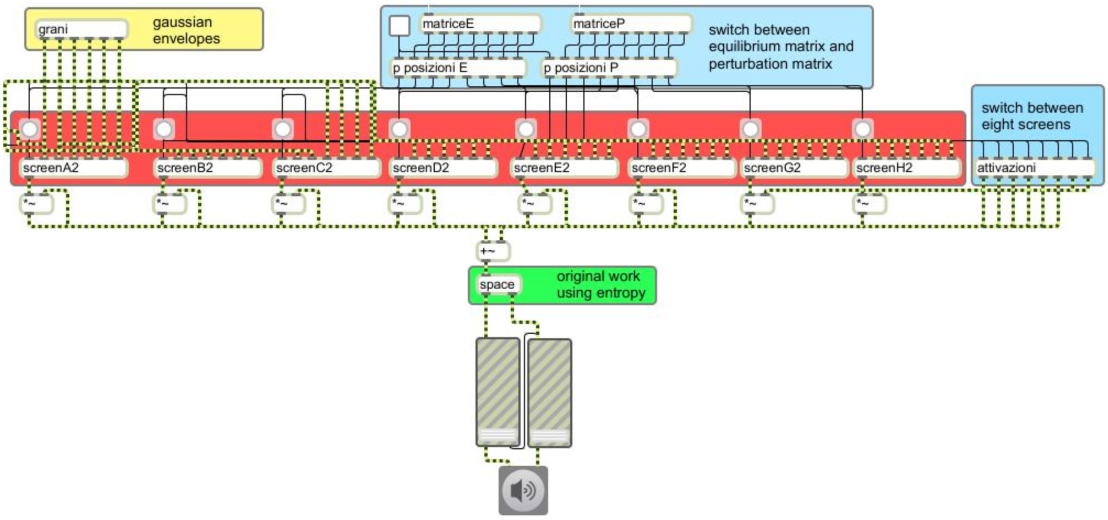

Fig. 3

We can see 4 sections (fig. 3), in the blue section there is the Markov process, the output of this section are 8 “bang” one for each screen, this section produce one bang every half second. There's also the possibility to switch between the E and the P state. In the P state is loaded a second matrix:

0	142	143	143	143	143	143	143
1000	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0

Fig. 4

as we can see the screen A can go in every other screens with the same probability but the other screens can go only in the screen A.

In the yellow section there is the production of the grains envelope. These envelopes are then multiplied by sinusoidal waves.
Thus in the red section there's the core of the synthesizer. This section receive in input both the gaussian envelopes and the bangs for the activation of the eight screens. In every screen take place the multiplication between envelopes and waves. Every wave has a frequency token in a prescribed region. After multiplication the resulting grain is multiplied by his prescribed amplitude.
The basic advantage of the digital implementation of Analogique B is the shortness of the experimentation time in respect to Xenakis's implementation. A change in digital world can be immediately audible, instead, on a tape, this could take several minutes, hours or days.
Another big difference is the sound. The original version of Analogique B sounds very different from this digital version, that's surely due to the technologies but also the shape of the grains and the strong band-pass filtering used in the original version.
In the main patch of the algorithm of Analogique B there's a green section called “space”. This box controls both the stereo panning of the signal (using a Markov chain with a 2x2 matrix) and the duration of the grains.
The probabilities of the matrix are calculated from the input signal by means of a physical process.
Now, if the signal is produced by a main Markov process, one could think to control this process using the signal that it generate! Thus the sound rule itself as time unfolds.

3.2. Theory of the physical process in the box called “space”

The starting point is the beautiful analogy between grain-texture and clouds.
So we can compare a mass of gas with a signal considered as a mass of grains or samples or vectors of samples. We can compare the energy of a particle of the gas with the energy of a snatch of the signal, so we have neglecting some constants:

$$m * v^2 = E(x) \qquad [1]$$

where *m* is the mass of a particle, *v* his speed and *E(x)* the energy of a snatch of the signal *x*.
In this case the snatch is made of two consecutive samples.
The signal *x* is low-pass filtered with a cut-off frequency of 25 Hz corresponding to a duration of 40ms in other words the duration of the grains in Analogique B.
We now consider the amount of motion of a particle and we take into account the entropy as a perturbation of the signal:

$$m * v = e^{(x+H)} \qquad [2]$$

where H is the entropy.

In this case the signal is high-pass filtered with cut-off frequency of 25 Hz.
Ideally filtering should allow us to separate the gaussian envelope from the sinusoidal wave.
From the equations [1] and [2] we obtain:

$$v = \frac{E(x)}{e^{(x+H)}} \qquad [3]$$

For the calculation of m, I wanted to follow another way.
Let us consider the following probability law (*Formalized music – appendix 1 – second law*):

$$f_m * dm = \frac{2}{v}\left(1 - \frac{m}{v}\right) * dm \qquad [4]$$

solving the integer from 0 to *m* where *m* belong to (0 ; *v*) we have:

$$p = \frac{m}{v}\left(2 - \frac{m}{v}\right) \qquad [5]$$

Since m∈(0;v) and p∈(0;1) we define m as:

$$m = \frac{v}{2}\left(\sin\left(E(x)\right) + 1\right) \qquad [6]$$

Knowing “v” and “m” it’s possible to calculate the value of “p” from the equation [5], the next values of v and m should be calculated basing on the energy and the entropy of the signal. The energy is calculated on just two samples while the entropy as:

$$\mathrm{H} = -\mathrm{p} * \ln p \qquad [7]$$

The new values of m and v are used to calculate a new value of p, this value of p coupled with (1-p) generate the 2x2 matrix used in the Markov process implemented in the box “space”. Thus in this box there is a feed-back of the values of entropy.
This process must be repeated for every value of “p” one want to obtain.
In this case we consider a 2x2 matrix (left and right channels) so we apply the process just one time basing on two consecutive samples of the input signal.
If we want generate a dynamic GTPM we need to repeat this process eight time on at least nine samples considering them in pairs such as: 1-2; 2-3; 3-4; 4-5; 5-6; 6-7; 7-8; 8-9.
We can also consider 16 samples in pairs such as: 1-2; 3-4; 5-6; ecc.
After that we should normalize the “p” values!

On my website [http://www.luciama.altervista.org/] there is an audible example of the functioning of my algorithm where the box “space” rules both the stereo panning of the grains-texture and the duration of a single grain.

4. CONCLUSIONS

To sum up... in this work the signal is seen like a grains flow organized by a Markov process, thus we can think to extract from it the related matrix changing in time in order to generate musical form, in this way the sound rule itself by means of a physical calculus process. The starting point is the evocative image of clouds and the goal is music, nothing more.

Every sound has written inside his history, the physical causes that generated it, for this reason it suggests us his destiny. We can say that sounds behave like humans so the musical form is like their life.

Transforming a sound into another or silence into noise is a beautiful way of composing, one can transform a sound by means of granulation or physical modelling but I think transformation should be like different aspects of a human being; in other words the resulting sounds must be dual, they must imply the same musical form. These are the principle of the nature and I think Nature sounds very good!

5. FUTURE DEVELOPEMENTS

The problem of musical form and the coherent transformation of sounds is the core of my next activities, I’m developing an augmented instrument, a *feed-guitar* which is able not only to do infinite sustain and feedback but also to transform the incoming sound with a process that uses his history in order to define his destiny. Sound evolve but also the process and this create a musical form in both the short time level and the long time level. The calculation stage is based on the study of the physical model of a string but it is extended at the feedback functioning and it is used artistically in order to create artificial texture shaped by the excitation of the executor. Other kinds of excitation functions are injected on the instrument by the algorithm and other kinds of resonances are created around the direct sound.

On my website [http://www.luciama.altervista.org/] there are links to some early experiments with this instrument.

6. REFERENCES

Di Scipio, A. "The problem of 2nd-order sonorities in Xenakis electroacoustic music", Organized Sound, 2(3), 1997

Di Scipio, A. "Scienza e musica dei quanti acustici: l’eredità di Gabor", Il Monocordo, 6, 1998

Di Scipio, A. "Le nuvole di suono e i loro meccanismi. Uno studio di Analogique A et B", in Proceedings of the Iannis Xenakis International Conference (Milano 2005), Quaderni della Civica Scuola di Musica di Milano, 2006

Gabor, D. "Acoustical quanta and the theory of hearing", Nature, 159, 1947

Hagen, K.I. "Genetic Analysis of Analogique B", EMS Electroacoustic Music Studies Network, Montréal, 2005

Orcalli, A. Fenomenologia della musica sperimentale, Sonus Edizioni, Potenza, 1993

Roads, C. "Automated granular synthesis of sound", Computer Music Journal, 2(2), 1978. Revised and updated version printed as "Granular synthesis of sound" in (C. Roads and J. Strawn, eds.) Foundations of Computer Music. Cambridge, Mass., MIT Press, 1985

Roads, C. Microsound, Cambridge Mass., MIT Press, 2001

Truax, B. "Real-time granular synthesis with a digital signal processing computer", Computer Music Journal, 12(2), 1988

Xenakis, I. Musique formelles, special issue of La Revue Musicale, 23-24, 1963

Xenakis, I. Formalized music, Pendragon, Stuyvesant-NY, 1992