THE *GRAIN* OF XENAKIS' TECHNOLOGICAL THOUGHT IN THE COMPUTER MUSIC RESEARCH OF OUR DAYS

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ABSTRACT

The scope of this article is to present the diachronic value of Xenakis' technological thought in computer music research and creation of our days within a comparative and critical approach. On the one hand, we will refer to the main domains of Xenakis' contributions to Music Technology: the conquest of the computer as a tool for logical transformations of symbols into music and a laboratory of automation for certain compositional tasks on meta-musical and compositional design issues; his pedagogical and compositional approach by the sound-design system UPIC as an interface between musician and machine; his granular approaches of sound synthesis as a link between algorithms and the creation of new sounds; the multi-sensoring approach of the conception of *Polytopes* where he combines various technological tools in order to achieve a kind of a *total art* work.

On the other hand, we will exalt the impact of his research in current music technology (use of the granular model in modern synthesizers, the marriage between sound and light in modern interactive performances, the design of new user-friendly tools for the music education, etc).

At the same time, we will discuss in which way many of the headmasters of computer music research have been profoundly affected by Xenakis' technological and epistemological approach.

1. INTRODUCTION

Iannis Xenakis could de characterized as a genius bridgemaker. He raised a bridge between the antiquity and the modern era by redefining the technical tools in his own rules, his own experiences and his particular personality. He not only rediscovered the hidden and neglected relationship between music and science, as it was described in the Pythagorean model, but also reinvented the relationship between theory and practice. He raised bridges and practiced the tradition of the "continuum" between the past and the present, the occidental music with extra occidental cultures, the electronic through the orchestral sound, the orchestral with the electronic sound, the *choros* and *chronos*, the sound and the light, the microkosmos with the macrokosmos.

His architectural tools, such as the table, the millimeter paper, the pencil, the rule and the mathematic models were gradually and partially replaced, in one way or another, by the computer, using various original interfaces such as UPIC, the design of sound synthesis techniques and the sound synthesis software, till the edge of the interactivity.

2.PIONEER OF COMPUTER MUSIC RESEARCH

Computer was the ideal tool for investigation and formalization for Xenakis. He started his research in music by putting the basis, among other pioneers, in almost all the current computer music domains: algorithmic composition, sound synthesis, design of interfaces and new ways of performance through technology.

In his writings, the term *Metamusic* is persistent, as is the necessity of using the computers for further research and creativity in music:

"I believe that music today could surpass itself by research into the outside-time category, which has been atrophied and dominated by the temporal category. Moreover this method can unify the expression of fundamental structures of all Asian, African, and European music. It has a considerable advantage: its mechanization-hence tests and models of all sorts can fed into computers, which will effect a great progress in the musical sciences. [31:*200*]

"Life and sound adventures jostle the traditional theses, which are nevertheless still being taught in the conservatories. It is therefore natural to think that the disruptions in music in cultural and historical *conditionings*, and hence modifiable. These conditions seem to be based roughly on the a) the absolute limits of our senses and their deforming

power (e.g.Fletcher contour); b) our canvas of mental structures, some of which we treated in the preceding chapters (ordering, groups, etc.); c) the means of sound production (orchestral instruments, electro-acoustic sound synthesis, storage and transformation analogue systems, digital sound synthesis with computers and digital to analogue converters). If we modify any one of these three points, our socio-cultural conditioning will also tend to change in spite of an obvious inertia inherent in a sort of 'entropy' of the social facts." [31:*243*].

And as M.Hamman says :"In embracing modern technology as a context for technical experimentation, a composer like Xenakis in many ways, returns modern technological practice to its roots in autonomous craft labour by particularizing the things, events, and conditions which define the musical task environment. And yet in directly linking that activity to a modern aesthetic and technical practice, he transforms the very principles which define autonomous craft labour, infusing it with the dialectical nature of modern". [8]

In the last decades the Computer Music community has generated a large amount of scientific research in many domains including composition, performance, education and design of new interfaces where the main reference is Xenakis' scientific and compositional approach. By then, many research areas -such as music modeling and generation (algorithmic), sound synthesis modeling, conception of new interfaces, music performance analysis–synthesis and the research domain on understanding music through modelling (music cognition and psychoacoustics)- have emerged as disciplines of a new era where the computer stands as the powerful tool for revealing and organizing the hidden knowledge behind the music structures .

3. THE IMPACT ON COMPUTER AIDED COMPOSITION

In contemporary computer music research history and creation, I.Xenakis stands as one of the most important pioneers in computer assisted composition, together with L.Hiller, P.Barbaud, M. G. Koenig. In the early '60s he used the new-born computer like a natural continuum of his mathematical needs. As he had to generate his first piece *Metastaseis* (1955-56) mainly by brain, dealing with vast numbers of data, he started using computers as a necessity to assist his calculations for mainly instrumental compositions, producing the works ST/4, ST/10, and ST/48 in 1962 (a considerable rate of increase in his output). All these early pieces have been constructed by an IBM 7090 computer for note sequencing, instrumentation, pitch, duration, and dynamics and the computer's *ability* to calculate his ideas faster was a propelling force for many of his works.

Since then, algorithmic music[1] and research has evolved and spread over the academic institutions; as a consequence, new tools have been developed the last fifty years. The tendencies in contemporary computer music include new algorithms, which are constantly being incorporated in to musical systems, many of which imported from the world of science, like cellular automata, stochastic processes, fractals, chaos generators, grammars, neural networks, etc[2]

To date, there is a multitude of algorithmic composition tools which allow a composer to work more quickly, by offering him a close match between his creative methodology and the implemented algorithm, as well as an accurate mechanism for quickly determining the viability of a specific phrase. One of the most used popular programs in the circles of the computer music composers is Max/Msp (by Cycling 74)[3], a 'modulable' programming environment which has been used by composers and researchers [3], who have been inspired by the stochastic and dynamic algorithmic stochastic methods of Xenakis in order to remodel his theories via new environments.

At the same time, other music composers and researchers in the field of mathematics and music who have been affected by the mathematical thought of Xenakis, have reconstructed through Openmusic (IRCAM) an hermeneutic and paradigmatic analysis of his works [1][13]. The workshops which have been organized in the frame of the *International Symposium Iannis Xenakis* have as central theme the paradigmatic computer-aided analysis of Xenakis works as creative tools for algorithmic composition.

Xenakis' technological thought also impressed many composers of computer music who have referred broadly to the composer's work and have made it known through the academic world. According to Curtis Roads "Xenakis, a major figure in the area of algorithmic composition, developed stochastic technique with his compositions His approach was based on random generation and probability theory, which is used to generate material in a number of ways. Statistical analysis has been used as a modelling technique in most of the algorithmic music compositions"[21]. It is worth saying that the book "*Formalized Music*"[31] stands as one of the most significant books in the computer music bibliography and many writers-researchers use it as a main reference.

Although the term 'algorithmic' refers to compositional choices made by a human linked to a machine, by a systematic experimentation in producing a score, Xenakis broadened this approach by connecting pure algorithmic composition and sound synthesis with his dynamic stochastic synthesis [31:289]. This approach has been prophetic in the domain of algorithmic composition through signal processing and sound synthesis, and has inspired researchers and composers of the next generation in the software design conception based on this model. The dynamic stochastic

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[1] Many names characterize this kind of music such as automatic music, stochastic music, computer generated music.

[2] We can find more information at www.flexatone.net/algoNet. This site provides a comprehensive resource in systems for computer aided algorithmic music composition, including cross referenced links to research, software downloads, documentation, and additional resources.

[3] www.cycling74.com

synthesis program GENDYN produces the micro- and macro-structure of the work from the composer's specific input [9][10].

According to Gerard Pape, director of CCMIX, who states to have been profoundly influenced by the technical and musical thought of I.Xenakis, and especially of his algorithmic approaches on GENDYN, writes: "The idea behind the GENDYN program is that free, autonomous evolution of the music itself takes the place of the micro-formal choices usually made by the composer.' [17:19].

When Xenakis wrote in the 70s that "With the aid of electronic computers the composer becomes a sort of pilot sailing in the space of sound, across sonic constellations and galaxies that could formerly be glimpsed only in a distant dream" [31] could he have ever imagined the *computer arborescence* of his musical algorithmic *grain* on the upcoming generations of composers?

4. THE IMPACT ON THE MULTIDISCIPLINARY APPROACH OF ELECTROACOUSTIC MUSIC COMPOSERS

Fascinated by his research on sound, Xenakis inevitably experimented on the concrete music of the late '50s, in inconvenient ways, applying his stochastic methods on the sound material by bridging the gap of technicity between electronic and concrete music, electroacoustic and instrumental, electronic and computer music. He also explored multi-channel mixing and new techniques in sound spatialisation. His attempts on the mathematical organization of the acoustic material quickly led him to the computer, starting from the algorithmic compositions and continuing with computer aided synthesis. Xenakis also stands as one of the pioneers in the diversification of techniques in the early electroacoustic music, as he had worked with sounds of both natural and electronic origin and as a result contributed in computer music new techniques for sound synthesis manipulation and music which was fully automated.[4] His criticism of electronic music on the lack of subtlety and complexity [25] resulted in computer-controlled synthesis which evolved to new forms of music, such as computer generated music and its use in the polytopes. By this approach we could say that Xenakis had "emancipated" the early concrete music through other paths of technicity and led to new territories of technical and aesthetic conceptions of the sound material.

According to James Harley "In the domain of electroacoustics, Xenakis' music evolved a great deal, from origins in the music concrete style through more abstract noise based sonorities that were fashioned into continuously evolving ways of intensity, to the incorporation of transformed instrumental sounds, to, finally digital synthesis".[8].

As a consequence, Xenakis' impact on the electronic music world has been profound, as he initialized new methods of controlling the sonic material - which were not compatible with the early concrete techniques - by applying stochastic methods in order to achieve discrete sonorities[5]. [31:*43*]

Many composers of the modern era who have visited, studied or worked in CEMAMU, today CCMIX[6], in electroacoustic music, state to have been profoundly influenced by the electroacoustic approach of Iannis Xenakis; Especially those who apply stochastic methods and use granular synthesis like Curtis Roads, Barry Truax, Gérard Pape, Richard Barrett, Cort Lippe, and others.

Other composers have also developed a particular musical dialect, having as a starting point Xenakis' stochastic methods in composition. Some of them, such as James Harley, Agostino di Scipio [6], Curtis Roads [19], [20] have continued the research on the stochastic procedures in electroacoustic music by writing excellent articles on Xenakis' technological thought.

Apart from the world of academic and intellectual electroacoustic and computer music community, Xenakis has left his traces in the community of the modern avant-garde D.J. culture by the intervention of D.J. Spooky[7] in *Kraanerg, Analogique A+B*, the remix *of Persepolis* etc. According to Discipio "a number of Web sites devoted to Internet audio art describe "*Concrete Ph* as a precursor of today's glitch. A protagonist of this scene Dj spooky, was invited to manage the tape part of Analogique A+B for a recent CD release of that work. Such a link between two historically distant music situations is only possible because early Xenakis' pieces, decades earlier than today's *electronica*, can be and have been described as a kind of carefully composed *bruit de fond*." [5:*24*]

This new linkage between the experimental compositional structures of the 20th century avant-garde classical music to the art form of dj'ing seems to be a consequence of the mechanical implementation of sequential and non-sequential form of text, as well as a cultural phenomenon where the DJ culture, meanwhile, has its own large impact on the

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[4] Makis Solomos categorizes his electroaoustic pieces by technical approach into four periods[25]. The first includes those works produced at the Groupe de Recherches Musicales (GRM)- *Diamorphoses, Concret PH, Orient-Occident* and *Bohor*- where the composer has created strange sonorities derived from both concret and electronic sources. Of the later pieces, *Hibiki-Hana-Ma* (1970) and *S.709* (1992) represent, respectively, the music Xenakis composed for his polytopes and compositions done most recently with the GENDYN system. Last, *Kraanaerg*, is an epic electro-acoustic work, one of Xenakis's best, and a quintessential example of "stochastic music" where he alternates between live orchestral sections and electronic tape sections .

[5] "The first thesis is that stochastics is valuable not only in instrumental music, but also in electromagnetic music.We have demonstrated this with several works: *Diamorphoses* 1957-58 (B.A.M. Paris), *Concret PH* (in the Phillips Pavillon at the Brussels Exhibition, 1958) and *Orient-Occident* , music for the film of the same name by E.Fulchiagnoni , produced by Unesco in 1960" [31:43]

[6] The CCMIX centre stands at the antipode of IRCAM , as on of the research and creation music centres which continue to trace the compositional line of Iannis Xenakis .

[7] More information at www.asphodel.com

fetichization of older music. After plundering every other source imaginable, DJs finally got around to the 20th Century avant-garde.

5. THE IMPACT ON THE INVENTION OF NEW INTERFACES

Being interested in linking research with architectural design in many respects, Xenakis invented the very idea of the interface for musical design. Though he did not invent *rule-based design per se,* his working method sublimated rule-based design, *transforming it from mere 'shop-talk' to near iconic status*[7]. The table of architectural design has been transformed to an interactive acoustic terrain where the image was translated to sound. The sound-design system UPIC(1977)[8],one of his pure technological achievements, stands as an autonomous tool outside his theories. This innovative invention not only exalts Xenakis' pedagogical[9] [15] and compositional approach, but also opens new directions in the conception of music instruments, and especially on interface design as a medium between performer and computer.[10] After all, we could say that Xenakis stands also as one of the mentors of new interfaces in computer and visual music.

In computer music research of our days, the conception of new interfaces (hardware and software), the interaction between forms of music and the translation of image in sound, create the crucial domain of research which links the composition, the performance and the improvisation with the help of the computer. Real-time systems now permit the composer to become performer of the composition, directly affecting the microstructure of sound in an immediate and direct way. Many software designers have been inspired by the real-time UPIC environment. Between them we can mention software systems like Metasynth [29] or Hyperupic [32], which offer the composers a wide palette of designing sounds, but which do not go into detail concerning the control parameters of the microstructure of sound. During the last years, new environments like Sonos[11] [23] or the environment *Iannix* [4] follow the traces of UPIC and offer more elaborated aspects of controlling the sound, allowing the composer to act immediately, due to a big choice of graphics and control parameters.

In the 80's Xenakis' interest in the direct synthesis of the time pressure curve led him from the initial implementation of the UPIC system to the GENDYN algorithm [2], where sound and music are generated *ex nihilo.*

6. FROM THE *GRAIN* OF SOUND TO *SOUNDS* OF GRAINS.

Xenakis had always been interested in Musical Acoustics, Psychoacoustics and the microstructure of sound. He also undertook a systematic exploration of aleatoric means to composition and sound synthesis using, for example, "clouds and points and their distributions over a pressure–time plane . . . (to) . . . create sounds that have never before existed" [31]. It was a consequence of his entire philosophy: by examining the world of music in his micro and macro structure. It was one of his abilities : to go through the various compositional worlds or by viewing similarities in his micro and macro compositions, from the universe to the particle and vice-versa. From his *new proposals in microsound structure* [31:242] till the dynamic stochastic synthesis [31:289] he tries to trace new particular ways in studying the microstructure of sound and synthesizing it in a different ways.[12]

As a consequence, Xenakis redefined the sound synthesis technical approach through granular synthesis[13], which today stands as one of the most popular techniques of sound synthesis. "All sound is an integration of grains, of elementary sonic particles, of sonic quanta...All sound, even continuous musical variation, is conceived as an assemblage of a large number of elementary sounds adequately disposed in time." ([31:*44*]. The resulting sounds (and eventual compositions) are simply these little slices of waveforms pieced together using probability models.[14]

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[8] The UPIC is a simple, easy-to-learn device for composing electronic music: a drawing board - an "extension" of the traditional five-line staff representing in two axes the pitch and time continua, where the composer is able to note every conceivable sound - connected to a computer which is connected to a synthesizer which directly converts to sound everything written on the drawing board. By 1979, his UPIC system was able to translate graphic ideas into musical results. Drawing always played a major part in the former architect's thought process, and in the seventies, his sketches frequently took the shape of what he called *arborescences*, sets of organic curves branching out into tree-like formations. Points on these curves would be interpolated to dictate musical elements, especially pitches within melodic lines.

[9] Xenakis didn't want to exclude anybody to "compose" on UPIC ; he introduced many groups of dancers, kids, computer-minded people, non-musicians and composers to the UPIC tool.

[10] From the other side the conception of such a tool which permits someone to create his own graphical and musical composition creates many aesthetic problems where the creator is also the performer. Which is the background of the performer –creator concerning the musical acoustics and the compositional rules? Which sounds correspond to the images and which are the threshold of the system?

[11] *Sonos* is a real-time interactive software. It is a visual interface based on the STFT analysis. The aim of *Sonos* is to transform the sound helped by a graphical interface of the sound itself after analyze.

[12] Xenakis wrote in 1971 about the 'obvious failure, since the birth of oscillating circuits in electronics, to reconstitute any sound, even the simple sounds of some orchestral instruments' [31:243–4]. At that time he identified the failure as due in part to (i) a lack of subtle variations, (ii) a lack of complexity such as noisy sonorities and complex transients, and (iii) an inadequate understanding of psychoacoustics. The introduction of the computer as a musical tool provided what seemed like the final justification for declaring that all sounds were possible.

[13] A method used mostly by mathematicians and composers, granular synthesis is the combination of very short waveforms (20 to 30 milliseconds long) just below the threshold of distinction. They are repeated at a given rate, and combined with other segments of a given frequency content.

[14] Xenakis' first works involving granular synthesis were created by splicing magnetic tape into tiny segments, rearranging the segments, and taping the new string of segments together.

Xenakis also invented a highly promising method of sound and music creation, the *Dynamic Stochastic Synthesis*, which consists of the direct computation (with the aid of a computer) of the sound wave, according to several intricate rules. Since then, the granular synthesis has been undertaken by several researchers and composers, and the "grain" of Xenakis' thought has evolved by many "arborsceneces"[15] in the domain of computer music research and creation.

In the '80s and the '90s many systems used complex mathematical formulae (e.g. probabilities) to control the production of the granules.[27][21][12]. Precise control of these grains is difficult since hundreds, perhaps thousands, of them are combined at any given time in order to achieve a desired result. The use of genetic algorithms, which have been evolving till our days, serves to facilitate the regulation of granular synthesis parameters[11].

Many approaches have been conceived on the control of granular synthesis: *Chaosynth* [14] uses cellular automaton, the *Stochos program*[3]an algorithmic, stochastic, and micro-sonic methodology, many other programs like the *Csound objects, Granulab, cloud generator, Pulsar generator, Super collider, Audio Mulch, and Max/MSP[16], etc.* Especially in the Max/Msp environment we can find many objects devoted to granular and stochastic synthesis, continuously evolving as "cellular automata" in the memory of I.Xenakis.

7. THE POLYAESTHETIC APPROACH OF *POLYTOPES* AND ITS IMPACT ON THE *MIXED MEDIA ARTS*

Xenakis was interested in a concept of music that was capable of going beyond the limits of the music. He achieved this surpassing of the music itself by crossing over into other expressive means[17], through techniques, often exalted by the use of the computer such as the UPIC System[18], through the multi-sensoring concept of the *Polytopes* and the *Diatope.*

In his *Diatope and Polytopes* (Paris, Montreal, Persepolis, Mycenes, and others) Xenakis achieved the creation of futuristic virtual spaces by the technological means which have inspired many contemporary mixed–media artists in research and creation. Through the use of modern technology, like evolutionary spatialisation systems, slide-projectors and exploration the sound, projection, light and architectural of space, Xenakis inaugurated a new world of polyaesthetic approach: "These compositions offer the perspective of open, interactive presentations which use the possibilities of today's technology of 'intelligent control' with flexible programs and scenarios to allow for reaction to the environment and the behaviour of the user and to permit manual intervention."[16:44]

In contemporary computer music literature, a new section of mixed-media composers is starting to be established as a new tribute of experimenting through the synthesis of arts by the new interactive powerful technological tools. The multiplicity of modes of interaction, as developed from sensory input technology, has challenged the relationship between compositional control and the design of malleable environments. At the center of the design of interactive worlds lies the issue of navigational activity, which allows for the user/performer to trigger/render pre-determined or generative material [19].

Xenakis had predicted these new tendencies, and the redefinition of the *Total work of art* through the new technologies:"The 46-minute spectacle consumes 140,500,000 binary commands. Naturally, to control and coordinate all these configurations, their transformations, and their movements, it is necessary to use the computer either interactively or by writing a digital tape according to a special light-machine program score. This digital type, decoded every twenty-fifth of a second, commands the states of thousands of light sources or optical devices of the visual music".[19]

Interactive dancing, interactive spaces, virtual operas by the new technologies of data capturing (video tracking, body extensions, touch sensitive pads, infra-sound beams and so forth) continue this *Gesankunstwerke* idea of Xenakis in an innovatory way.

8.EPILOGUE

In the computer music research of our days, Xenakis stands as the mentor of innovation. He has redefined the status of the composer through his original scientific and technological thought as the conquest of the computer and the related

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[15] *Arborescences*, sets of organic curves branching out into tree-like formations. Points on these curves would be interpolated to dictate musical elements, especially pitches within melodic lines.

[16] www.granularsynthesis.live.com.au. Especially in the Max/Msp environment we can find many objects devoted to granular and stochastic synthesis , continuously evolving as "cellular automata" in the memory of I.Xenakis.

[17] As it happened for the transformation of the graphical-musical sketches of *Metastaseis* into architectural schemes for the shape of the Phillips Pavillon .

[18] That associated the graphic construction (to compose as in writing a score) with the sonorous performance (to compose as in producing a sonorous result).

[19] "Musical Universes" by I.Xenakis, in the page of Ars Electronics : www.aec.at/en/archives/festival_archive/

technology gave him the ideal medium to the exploration of his *sound beings*. "What is a composer? A thinker and plastic artist who expresses himself through *sound beings*. These two claims probably cover his entire being" [31:*255*]. His paradigmatic technological thought has had a great impact on many researchers and composers of electroacoustic and computer music, and has inspired many of them in studying and continuing his research on the micro and macro structure of the compositional process. The computer music community is continuing to honour this great thinker and composer of the XXth century by various activities paying tribute to his memory.

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