

Literature Review: On the usage of mathematical processes in the music of Iannis Xenakis

Note to the reader: *A summary of Xenakis' background and the mathematics used in his composition will be given (from Formalized Music with some additions), before research work is contextualized. A distinction should be made between the usage of mathematical processes, for which the writer takes the definition to be the direct usage of no less than undergraduate level mathematics (e.g. group theory, Markov chains) in the compositional process, and not simply the use of mathematical symbols to describe trivial calculations or to develop music theory which is superfluous to the compositional process. With this in mind, compositions based on architecture such as Metastasis (1953-54) and concepts such as Xenakis' "sieve theory" will not be discussed.*

The music of Iannis Xenakis is paradoxical: his legacy was to induce a radical change in music history (Varga p. 50), boldly composing music which contradicted even his own sentiments (p. 10):

I don't want to be moved...Feelings were planted in me because of my experiences as a child...It's not the music itself that affects me so much, but simply its subjective colouring.

yet he his material inspiration draws from ancient music and architecture and his musical landscape is emotionally shaded by his early, turbulent experiences (p. 52)¹:

Metastasis...was inspired not by music but rather by the impressions gained during the Nazi occupation of Greece...I would never have thought that one day all that would surface again and become music.

He has confessed that his music has a brutal quality and lacks lyricism (p. 62-3), yet his aim is to be musically all-embracing (p. 50):

My greatest achievement would be to compose something which could include any form of expression.

Born in Braïla, Romania in 1922 to Greek parents, Xenakis first trained as an architect at the Athens Polytechnic, until his involvement in the Greek resistance to an Italian occupation curtailed his studies. He studied basic music theory, but it was not until his emigration to Paris that he received formal training in composition, from Honegger, Milhaud and then Messiaen (Grove Music Online, Oxford Music Online), the last of which encouraged him to follow his own, mathematically-informed compositional path (Varga, p. 31).

As a teenager, Xenakis was deeply interested in ancient Greek philosophers, including Plato, Thucydides and Xenophon, and architecture, and felt at the time that "after classical Greek architecture, there was a decline." (p. 15) His influences as a composer often came from times past, explained by his sentiments on living in the 20th century (p. 15):

¹ A contradiction also flagged up by Murray, p. 55.

I felt I was born too late – I had missed two millennia. I didn't know what there was for me to do in the twentieth century. But of course there was music and there were the natural sciences. They were the link between ancient times and the present, because both had been an organic part of ancient thinking.

However, he does not admit to any direct musical influences, claiming that he writes “completely original music” (p. 10) and “in every case I start out of nothing. I consider this to be right because I try to break away from the past.” (p. 61). Concerning 20th century composers, he was interested in the music of Feldman (p. 158) and Varèse, stating in conversation that (p. 38):

I greatly appreciated his music and like it but it didn't have any influence on me...I regarded him as one of the most original composers of the century.

Indeed, Shere has compared the two composers explicitly, referring to them both as “phenomenological” composers, “whose music, not content with the organization of sound, achieves an almost physical substance” (Shere, p. 96).

In Paris, Xenakis worked under Le Corbusier, although the composer admits that he (Varga p. 22):

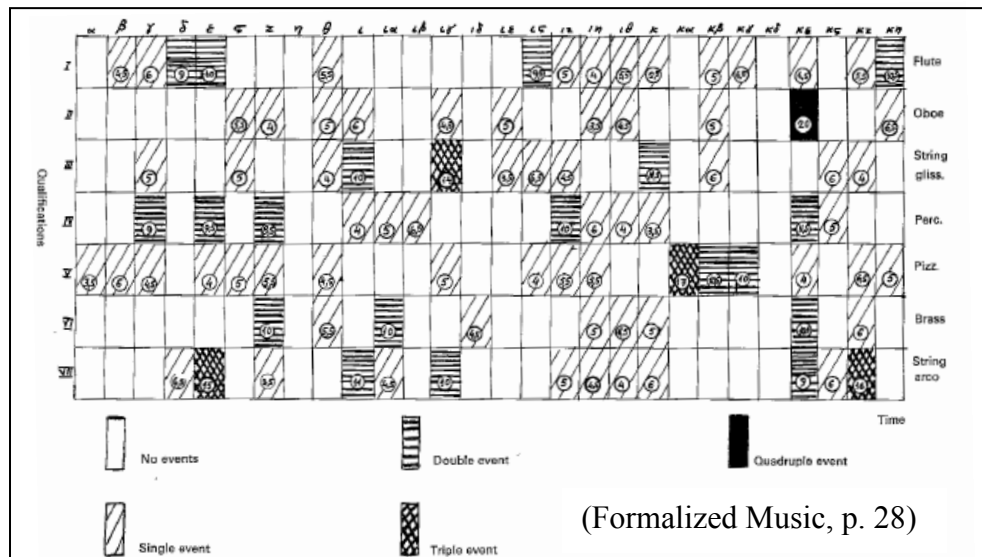
...read practically none of his writings, nor did we have time for conversation: we had to work. It was not from his books but from practice that I became acquainted with his ideas about architecture...

Xenakis' first usage of mathematical processes occurs in *Pithoprakta* (1955-56) for string orchestra, where certain passages consist of distinct linear glissandi with a different part for every player, with equal numbers of glissandi heading downwards in pitch as upwards at a given time instant, and the speeds of glissandi following a normal (or Gaussian) distribution.² In this way, pitches are treated as gas particles, with the direction of glissandi representing their movement and the speed their temperature. (Formalized Music, p. 15). However, mathematics is still only employed in isolation (Varga, p. 75):

Pithoprakta is a jump into the unknown. I was guided only by my ideas about its macroform. And by the time I had written it I became conscious of the musical aspects of my experiences with nature and mass demonstrations which appeared rather unconsciously in *Metastasis*.

Sterken notes that Xenakis has replaced “the concept of rhythm by that of density” (Sterken, p. 26). This idea is then developed in *Achorripsis* (1956-57) where musical sounds are grouped into various timbres (in this case, Flute, Oboe, String glissando, Percussion, Pizzicato, Brass and String arco) and their frequency of occurrence and the density of sounds at a given instant are both subjected to a Poisson distribution. In order to make the calculations possible, the composition is discretised into time bands of equal length, the result of which is to divide the music into cells:

² The calculation on p. 14 of Formalized Music to arrive at the normal distribution from a set of hypotheses is incorrect (in particular the argument that $h(x)$ being an arbitrary even function should imply that $h(x) = -jx^2 + c$.)



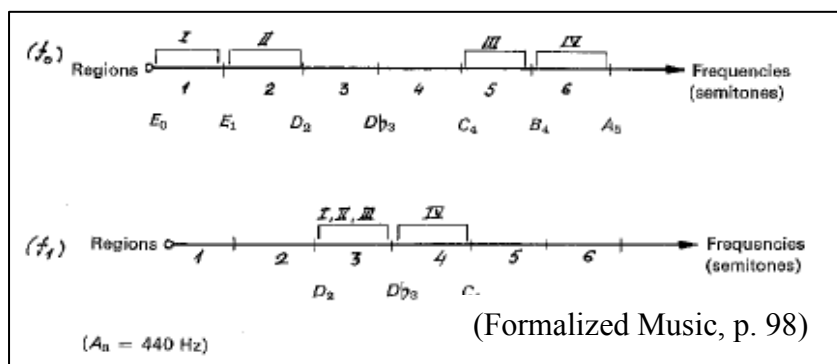
Within each string glissando cell, Xenakis then applies the working of *Pithoprakta*, with the square of the mean speed of glissandi being proportional to the sonic density. However, the composer does not mention his treatment of the other timbres within each cell³. Xenakis coins the term “Free Stochastic Music” to describe the musical results, claiming that (Zaplitny, p. 94):

...if you use...a stochastic approach...then you have unexpected results each time, but only in the detail. On the larger scale, you have an identity of form, that is, you have created a kind of family of possible, mutual works, pieces.

This view is shared by Paul Griffiths (Griffiths, p. 329). The composer was interested in the idea of minimal constraints in music (Varga, p. 80):

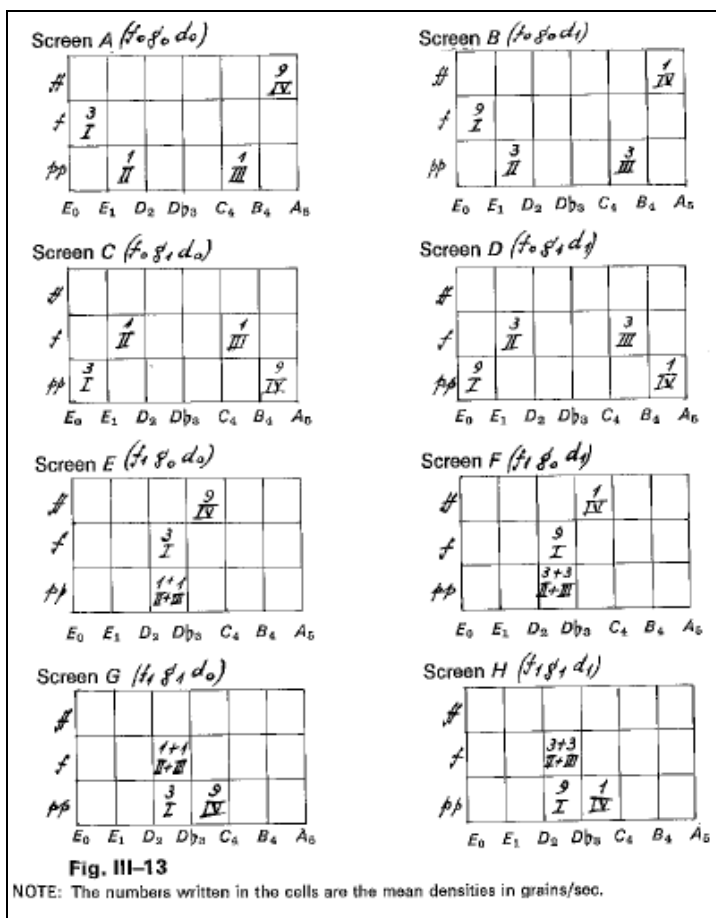
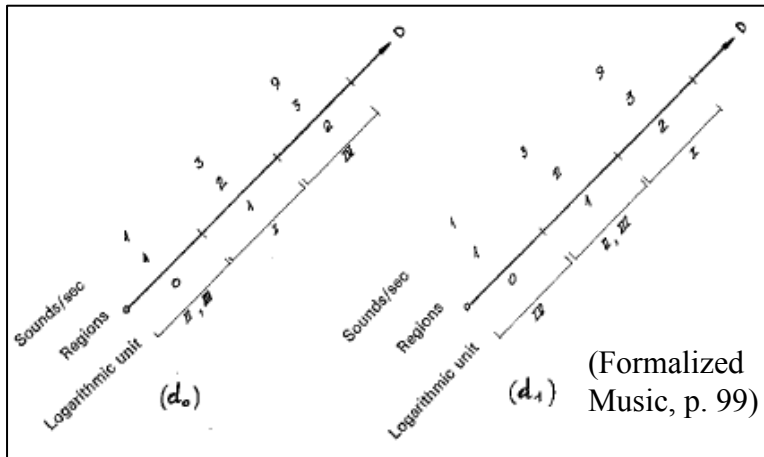
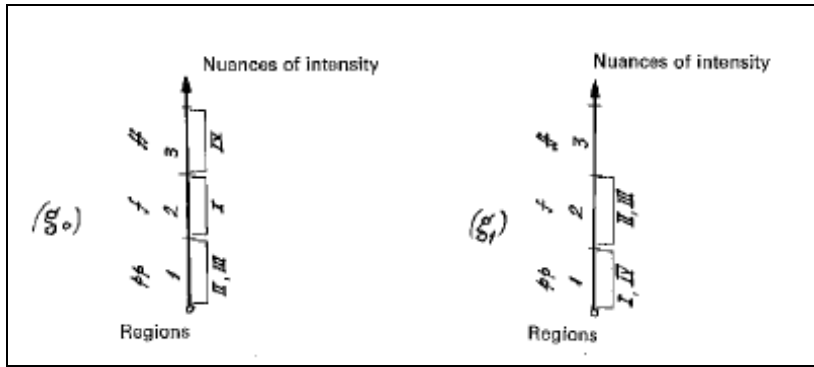
...the question was as follows: how to create, figuratively speaking, a ‘black box’ which has music at the other end, and not just music, but interesting music?

Xenakis uses Markov chains in *Analogique A* (1958) and *Analogique B* (1958-9)⁴ with eight states (labelled A-H) represented by permutations of bands of timbre, pitch and dynamic (below for *Analogique A*):



³ Squibbs suggests a greater freedom in his writing for winds and percussion (Squibbs, p. 260).

⁴ A similar analytical exposition is given by Di Scipio.



(Formalized Music, p. 101)

Given choices of transition probabilities, he then calculates the stationary state (i.e. the long-term probabilities of being in each state) mathematically and juxtaposes music composed by following the Markov chain with music composed by realising perturbations away from the stationary state⁵. In the composer's own words (p. 94):

The natural process is that provoked by a perturbation...imposed on the system...and the advancement of this system towards its goal, its stationary state, once the perturbation has ceased its action.

Xenakis employs game theory in *Duel* (1959), *Stratégie* (1959-62) and *Linaia-Agon* (1972) (Sluchin, p. 299⁶). For example, in *Stratégie* (1959-62) two orchestras, each with their own conductor, are instructed in turn (with overlap) to play one texture out of a predetermined set of textures (in this instance, there are 19) and the conductors are each awarded points according to a scoring system which assigns a mark to the superposition of any given texture onto an existing texture. The conductor with the most points at the end is declared the winner by a referee keeping the score.

In *Herma* (1961) for solo piano, elementary set theory is used to generate musical material. Three distinct sets of pitches are determined and further sets are generated by the operations of intersection and union⁷. Xenakis then states each set of pitches sonically by instructing the pianist to play each element of the set separately in a random order. His justification for the sufficiency of such a method to give a clear aural perception of each set is as follows (Varga, p. 82):

Luckily, my wife Françoise, who was working in psychology, called my attention to the experiments of Jean Piaget: he examined the development of the perception of time and space in children...He showed that time has an ordering structure and that time intervals can be added and permuted, and consequently that they have a group structure.

In *Akrata* (1964-65) (see Schaub for an analysis), *Nomos alpha* (1965-66) for solo 'cello and *Nomos gamma* (1967-68) for string orchestra, Xenakis uses group theory in passages to structure his musical material⁸. Similar manipulations are used in *Tetora* (1990) in conjunction with the composer's sieve theory (see Exachos or Jones). As Paul Griffiths mentions, the composer's exposition given in *Formalized Music* is "not ideally clear" (Griffiths, p. 330-1), but a more transparent account of the methods used in *Nomos alpha* is given by Thomas DeLio.

The composer himself admits that the mathematics is not central to the musical result and that his usage of mathematics is not a purely logical one (Zaplitny, p. 89):

The fact that we know a formula doesn't on its own ensure that it will achieve our aim. We have to work keeping an eye on the end result. In other words: I had to imagine how all that would sound. And that took a long time.

⁵ The theory of Dynamics of Markovian Particles (see e.g. Bergner) provides a continuous-time and continuous-state extension to the idea of a Markov chain.

⁶ There a detailed analysis of *Linaia-Agon* is given along the lines of that of *Duel* and *Stratégie* in *Formalized Music*. An extension of Xenakis' employment of game theory into three dimensions is made by Hadjileontiadis.

⁷ A more thorough analysis is given in Spyridis, pointing out some errors in calculation made by the composer. Similar processes are used in *Eonta* (1963-64) (see Chrissochoidis) and the techniques overlap with sieve theory.

Analysis has also showed that his musical results are often adjusted manually, according to the composer's taste (Solomos, p. 15). Indeed Jones has noted in analysing *Tetora* (1990) that after calculations "certain musical decisions are made about the end result by the composer" (Jones, p. 234). This process is supported by Zervos, who claims that (Zervos, p. 9):

The abstract relations and the logical operations...rise above the mechanisms of deconstruction and final reconstruction of sounds' components through reflective processes.

Xenakis' thus uses mathematics to pin down his aural conceptions, his use of mathematics being the reverse of that of a mathematician, in that (Gowers, p. 3):

Scientists devise a theory, based partly on the results of observations and experiments, and partly on more general considerations such as simplicity and explanatory power. Mathematicians, or scientists doing mathematics, then investigate the purely logical consequences of the theory.

However, the comparison with the work of an experimental scientist is alluded to by Zervos (p. 10):

The use of a certain model may frequently cause problems, which must somehow be solved, and consequently new models are discovered.

Xenakis has likened his usage of mathematics to that of a fugue, where compositional freedom is only limited by its macroform (Zaplitny, p. 95). There is therefore a danger in taking his "translation into sound of theorems" (Griffiths, p. 330) too literally, a trap which Iliescu falls into all too easily, attempting to pin down specific "correspondences suggested by Xenakis' musical, architectural and theoretical work", which include the following table (p. 49):

Mathematics	Physics	Music, Architecture
Non-being, zero, nothing	Empty space	Silence, obscurity
Series of points, discrete space	Series of punctual events, discontinuous matter	Scales, sieves, musical rhythm, visual rhythm, <i>Couvent de La Tourette</i>

With later compositions the composer frees himself from algorithmic constructions (e.g. Harley, p. 9, Di Scipio, p. 14, Zervos, p. 10), and in the composers' own words (Varga, p. 200):

All those years served as a kind of training. I can now work with the theories intuitively – they've become an innate part of my thinking. Most of the time I don't need rules or functions for composing. They're in my blood.

Indeed, in later works Xenakis recycles material which "did not always relate to theoretical problems. Most of the time, they were selected for their particular sonic qualities or transformed in order to create new ones" (Gibson, p. 265).

The composer admits that his compositions are often "experiments" (Preface to *Formalized Music*, see also Matossian, p. 156), and in particular after *Analogique A*

(1958) and *Analogique B* (1958-9), the composer's use of Markov chains is abandoned (Di Scipio, p. 2). However, a search for originality (Varga, p. 50) through experimentation is not "synonymous to the concept of innovation" (Zervos, p. 7).

Opinions on Xenakis' music, and his usage of mathematics, are varied. Some critics are in awe of the musical results, regardless of the internal processes employed (e.g. Powell, p. 320, Schiffer, p. 32 or Whittall, p. 8), whereas others are in awe of the musical results in part due to their construction (Butchers, p. 5, despite appearances)⁹:

...with Xenakis the music can be happily listened to in complete ignorance of the theory: for the logic of its operations is axiomatically the logic of the listener's every mental process.

although Butchers' use of mathematical terminology is incorrect and cringe worthy, and in parts makes claims which are wholly incorrect (p. 3):

Xenakis is, to my knowledge, the first in any artistic field both to invoke the notion of chance and to use it in a way which is acceptable rigorously to modern logic.

This division of appraisal is alluded to directly by Matossian, in particular questioning the cause of success of *Herma* (Matossian, p. 154).

Others are more critical, either of the purpose or clarity of his mathematical methods (e.g. Griffiths, p. 330 or Kay, p. 23) or of the music itself, for example Sadie describing *Stratégie* as "Great fun no doubt for the conductors, rather boring for everyone else." (Sadie, p. 897). *Analogique A* and *Analogique B* are generally considered amongst the least successful of Xenakis' works (Di Scipio, p. 2). However, as Kay states (Kay, p. 24):

However disturbing we find his sound world, and however arrogantly the composer tells us that the listener of the future will not only hear, but will think aurally, no one can predict the meaning that will be given to this sound.

The question of whether Xenakis' mathematics registers aurally or genuinely gives his music structural strength relates to matters of deconstruction in musical analysis. The composer wished to remove all subjectivity from his compositional methods (Brown, Rahn & Xenakis, p. 27), but the deduction of analytical structures from musical works does not come without implicit association (Krimms, p. 316):

The music analyst... cannot 'deconstruct' musical structure and the unitary, self-present subject in one fell swoop. Simply finding a presumably deconstructive set of musical events may well leave an implicit unitary subject; in fact, the unitary subject is a real danger, since traditional discussions of musical effects tend to assume none other than the self-present hearer, whose emotional responses form something of a compensation for music's lack of a universally agreed-on semantic realm.

hence composition based entirely around analytical structures may permit unwanted connotations. Indeed, it is dangerous to assume "the existence of 'deep structures' beneath the signifying surfaces of texts" and "that an analytical method could abstract that 'deep structure' in an epistemologically reliable way." (p. 303). The connotations of structures in music are socially determined, a function of society being to hone in

⁹ See also DeLio, p. 232, Matossian p. 105

on and interpret a subset of the indefinite number of physical attributes that an object possesses (Cook, p. 178-9). These problems regarding the subjectivity of structure are avoided in mathematics, where no attempt is made to relate the mathematical model directly to real life (Körner, p. 3):

Mathematics is, at least in part, the science of abstraction. Mathematicians look at the rich complexity of the real world and replace it with a simple system which, at best, palely reflects one or two aspects of it. Roads become lines, towns become points, weather becomes a series of numbers...and human beings become units.

However, Sterken believes the discreteness of Xenakis' music is deliberate, alluding to his tastes in architecture (p. 26):

As an alternative to the organic model, Xenakis adopted the principle of collage and juxtaposition, which explains why many of his compositions consist of sections with no apparent connection. His collaboration on the Monastery of la Tourette might have been crucial in this respect.

One such, perhaps unintended, connotation arising from Xenakis' work with "arborescences" is alluded to by Zervos, who characterises his work from the 1970s by "continuous repetitions of specific rhythmic patterns to such a degree that sometimes some of their sections remind of minimalist music processes" (Zervos, p. 10). Dennis also has compared *Eonta* (1963-64) to Boulez's *Structures* (Dennis, p. 28), despite Xenakis being a critic of serialism (e.g. Varga, p. 54).

DeLio quotes the literary critic Charles Bernstein in saying that "form is 'how any one of us interprets what's swirling so often incomprehensively about us'" (DeLio, p. 232-3) but embraces the ambiguous use of structure in Xenakis' music, stating, albeit speculatively, that (p. 241-2):

...its forms are riddled with deliberately discomfiting contradictions and disruptions...his music teaches us that those contradictions and disruptions form the basis of our understanding. It teaches us that any attempt to comprehend and explain our experience of the world must be rooted in that fabric of discontinuities which constitutes the very essence of that experience.

Emphasis should be placed on the musical result: Bužarovski quotes Hanslick¹⁰ in stating that "...the measurable tone and the complete system are merely the means with which the composer produces, not what he produces." (Bužarovski, p. 182).

To summarise the body of research carried out on Xenakis' mathematical workings, it is perhaps important to view Xenakis' mathematics as a means to an end, rather than as algorithms for the production of musically coherent pieces. Indeed, as work on deconstruction in musical analysis has shown, such algorithms do not exist. He has experimented, and drawn aurally on the results of those experiments in his later works, which required no formulae to be created, and in doing so he has not been afraid to deem a given experiment a failure (e.g. his use of Markov chains). He has also not been afraid to move a step ahead of his experiments and adjust the musical results manually (e.g. in *Tetora*), and in any case, his methods cannot be free from subjectivity: the structures used in his compositions require parameters, to be chosen at will by the composer.

¹⁰ Hanslick, E., *The Beautiful in Music*, p. 110, Indianapolis & New York, Bobbs-Merrill 1957

It is important, as with any composer, to judge his work by the musical result and not by its method of creation (e.g. as do Butchers and, to a certain extent, DeLio), although defining closed criteria for a composer's greatness is impossible, as it relates again to problems in deconstruction. Xenakis is no doubt an original in his compositional methods, but to declare his musical output completely original is debatable (to which Zervos and Dennis, and also Powell have alluded). Nevertheless, regardless of the staying power of his music, his academic work has raised new questions about the relations between mathematics and music, mathematical structures and music, mathematical structures and musical analysis or even mathematics and musical analysis (distinctions should be made) and a study on any such topic could do worse than to place Xenakis at the focus.

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