Meta-Xenakis

New Perspectives on Iannis Xenakis's Life, Work, and Legacies

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Cover image: Iannis Xenakis at the C.R. MacIntosh Museum, Glasgow, Scotland, 1987. Photo by Henning Lohner, courtesy of CIX Archives, Lohner collection.

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35. *Phoenix-Albatross*: An Approach to Iannis Xenakis's Work on Game Theory through Live Coding and Networked Dance

Iannis Zannos and Takumi Ikeda[1]

Introduction

In this chapter we present an attempt to reinterpret aspects of Xenakis's work in the context of twenty-first century performance practice using live coding and embodied performance or dance with sensors. Xenakis worked at a time when live interaction with computers was just starting. He worked mostly with non-interactive computer systems, but at the same time he launched the visionary project UPIC (Unité Polyagogique et Informatique de CEMAMu (Centre d'Études de Mathématique et Automatique Musicales)) to develop technology that enabled interactive sound design. His experiments with game theory had pioneer character also in terms of performance practice, and led to works that placed exceptionally high demands on the performers, as noted by Benny Sluchin and Mikhail Malt.[2] Thus, we view creating interactive works based on Xenakis's vision as a natural and necessary continuation of his legacy. In fact, the present project takes a radical stance toward this idea. It engages at the same time with three current challenging aspects in the field of contemporary computer music and performance. These are:

1. Live coding: executing code during the performance in order to generate the event sequences and the sound generating processes that produce the music.

1 The implementation of the work for this paper was supported by the research project Hub of Art Laboratories (HAL) of the Department of Audiovisual Arts of the Ionian University.

2 Sluchin and Malt, 2011, and Chapter 15 in this volume.

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2. Linking human body movement to sound generation ("embodied performance"): in our case, dancers use sensors to influence the parameters of the sound generating processes and thus to fundamentally modify the qualities of the sound during the performance. Dancers become almost like instrumentalists interpreting the piece, with one important difference: they in fact enter into dialogue with the live coders, by modifying what they specify with their code in real time
3. Enabling a distributed mode of performance worldwide through the internet: performers play the piece in different venues in different locations at the same time, sharing control data and code over the internet to communicate and create one distributed performance.

The work which is presented here is based on the part of Xenakis's work which is by far less performed than any other. These are works based on game theory, namely *Achorripsis* (1956–7), *Duel* (1959), *Stratégie* (1962), and *Linaia-Agon* (1972) which incorporate a live simulation of a game within the performance itself.[3] As a result, these works are extremely difficult to perform instrumentally on stage, because they involve the making of live choices by the performers, based on complex game rules. On the other hand, such a setting is naturally more suitable for performance in a setting involving computers in real time. Computers could in fact perform a simulation of the game in real time without the intervention of humans, as is often done in game simulations for both peaceful and non-peaceful conflict scenarios. In our piece, we re-introduce the human performance factor by relying on the performers to make the choices based on live calculations and spontaneous action, using the computer to track the score and to provide visual cues about the state of the game.

Theoretical Background: Heteronomous Music and Musical Battles

In his introduction to the chapter on "Musical Strategy," Xenakis describes the idea of "Heteronomous Music," as a way to introduce a concept of external conflict between opposing orchestras or instrumentalists.[4] The sonic discourse which arises in this setting is seen by Xenakis as "a very strict, although often stochastic, succession of sets of acts of sonic opposition." We regard this setting as a fundamental aspect of the aesthetic and musical goals of the works discussed here. Xenakis explains that this kind of heteronomy is present in traditional musical forms as for example in Indian classical music, where two instrumentalists engage in playful competitive musical dialogue. In fact, there are also references to this genre in classical western music, in the

3 Arsenault, 2002, p. 58–72; DeLio, 1987, p. 143–64.
4 Xenakis, 1992, p. 111–13.

genre of "Battaglia" mainly in the seventeenth and eighteenth century. A prominent example inspired by this genre is the work by Claudio Monteverdi (1567–1643) *Il Combattimento di Tancredi e Clorinda* (1624), based on Canto 12 from Torquato Tasso's (1544–95) *Gerusalemme Liberata* (1581).[5] In a way, Xenakis's work in this field coincides with major events in geopolitics on the one hand, and with budding developments in computer and telecommunications technology on the other. In geopolitics, the Cold War conflict between the USA and the Soviet Union was a decisive factor in the development of game theory. The biography of mathematician John Nash (1928–2015)[6] illustrates in a dramatic way the mutual interdependence between the theoretical work of a mathematician and the geopolitics of the Cold War Period. John Nash's work on game theory, that won him the Nobel Prize, addressed problems of Game Theory at a time when the USA were engaged in a conflict for world domination with the USSR. The USA government and particularly their realized the importance of understanding the mathematics of game play for developing a strategy within the context of global politics. This context was rendered particularly complex, because it involved many players, i.e. the member states of the two opposite blocks of the western and the communist sides, and the points of view or specific intentions of each partner were hidden from the other partners. John Nash attempted a mathematical definition of the relative merits of trust and cooperation in a game of absolute conflict between players. [7] Another characteristic event in this context is the Cuban Missile Crisis of 1962, which happened in the same year as the composition of *Stratégie* by Iannis Xenakis. In computer technology, the development of computer games coincides with the birth of interactivity in computing and has become a driving factor in the field. Computer games are now interlinked with development of virtual reality (VR) and so-called virtual worlds such as the Metaverse. Our work approaches the potential of this field from the grassroots or rhizomatic perspective of open source and DIY (do it yourself). In this way, we want to point out an alternative, playful, and creative approach to technology, that emphasizes empowerment of the artist and independence from large multinational gaming, social media, and VR corporations. In parallel, we are aware of other performance forms that employ the battle-paradigm in popular culture, such as dance battles, as well as the hacking marathons of the "Demoscene" subculture, which open alternative creative approaches to mainstream gaming technology.[8]

5 Monteverdi, 1638.
6 Nicholson, 1991, p. 643.
7 Nasar, 1998.
8 Seifert, 2012.

Project Background: A Framework for Telematic Dance Performance and Computer Music

The background for this project is provided by a telematic dance project started by Iannis Zannos in 2018 as part of a sabbatical residency at the University of Arts of Tokyo, which resulted in a series of collaborations with Japanese dancers and composers. The online live coding framework that enabled the collaboration was developed by Zannos with the help of senior undergraduate students and post-doctoral students at the Department of Audiovisual Arts of the Ionian University, where he works. This framework does not rely on streaming audio over the network. Instead, only program code and sensor data are streamed over the network, using the UDP-based protocol Open Sound Control (OSC).[9] The sound is then synthesized on SuperCollider locally at each venue. In other words, one may say that the score as well as the movements of the interpreters are broadcast over the network, and the instruments that render this score are the computers at each venue. This method requires the minimum amount of data to be sent over the network and is therefore very fast. The delay between coders and dancers at each location and the reaction of the computers at remote locations is very small, as small as a fast internet connection permits (usually less than 1/5 or 1/10 of a second between Greece and Japan).

In 2021, Zannos approached the composer Takumi Ikeda, who is an experienced SuperCollider programmer and performer, and proposed a collaboration along these lines. The collaboration gradually developed into the present project in the course of several online as well as face-to-face meetings. Ikeda quickly became familiar with this framework and contributed sound processing algorithms that formed the main skeleton for the present piece and performances. Starting early in 2022, we rehearsed these algorithms in live coding sessions with dancers in Greece, with Ikeda joining us remotely live coding over the network. In parallel, we worked on models of the game described by Xenakis in Chapter 4 of *Formalized Music*, which were implemented mainly by Ikeda.[10] In early September 2022 we performed the first full version of the piece in Tokyo, while the Greek dancer Tasos Pappas-Petrides joined us from Athens over the network. This session has been recorded and is available for viewing on YouTube.[11]

9 Wright, 2005, p. 193–200.

10 Xenakis, 1992, p. 110–30.

11 Videos of *Phoenix-Albatross* by Ikeda and Zannos are available on YouTube, as follows: Iannis Zannos, "Phoenix-Albatross Part 1: Prelude" (19 September 2022), *YouTube*, https://www.youtube.com/watch?v=3bpukYHt8YM&list=PL1yHvCYr9BvbQc9A_1ZZUNNAjDKLum4-I&ab_channel=IannisZannos; Iannis Zannos, "Phoenix-Albatross Part 2: Duo" (19 September 2022), *YouTube*, https://www.youtube.com/watch?v=EWkqTDcEk9A&list=PL1yHvCYr9BvbQc9A_1ZZUNNAjDKLum4-I&index=4&ab_channel=IannisZannos; and Iannis Zannos, "Phoenix-Albatross Part 3: Trio" (19 September 2022), *YouTube*, https://www.youtube.com/watch?v=AurcuVQoBfM&list=PL1yHvCYr9BvbQc9A_1ZZUNNAjDKLum4-I&index=3&ab_channel=IannisZannos

The Score

Xenakis's orchestral work *Duel* (1959) is a "game for 56 musicians divided into two orchestras with two conductors" based on game theory, or in other words, the mathematical theory of game play.[12] The players of the game are two conductors, and the orchestras play "tactics," chosen by the conductors. Tactics correspond to individual cards in a card game. In the score of the piece, tactics correspond to score sections which have clearly distinguishable sonic characteristics. Xenakis describes the characteristics as follows:

- Event I: A cluster of sonic grains such as *pizzicati*, blows with the wooden part of the bow, and very brief arco sounds distributed stochastically.
- Event II: Parallel sustained strings with fluctuations.
- Event III: Networks of intertwined string *glissandi*.
- Event IV: Stochastic percussion sounds.
- Event V: Stochastic wind instrument sounds.
- Event VI: Silence.[13]

The two conductors take turns choosing tactics in a similar way as players in a card game choose playing cards to achieve a high score. The performance is formed by playing the sections from the score which are assigned to each chosen tactic. As a result, the music is generated as a byproduct of playing a game, and the aesthetic intentions of the piece are encoded as rules of the game in the assignment of matrix cells ("cards") to sections of the score. In this sense, it may be said that the music is the result of at least partly extra-musical rules, which is what Xenakis calls "Heteronomous Music," as opposed to "Autonomous Music" or "musique pour la musique."[14]

As a means of directing the performance towards the general direction of a desired aesthetic goal, Xenakis examined the desirability of sound combinations as a basis for the game rules, which he then encoded as a payoff (game) matrix. Therefore, the execution of the game automatically generates music that he generally finds favorable. Also, different music is generated each time the game is played. In Ikeda's view, this is an effort to create a humanized version of algorithmic composition through computers.

Xenakis's game theory works, *Duel, Stratégie*, and *Linaia-Agon*, are rarely performed due to their extreme technical complexity to prepare and to perform. *Linaia-Agon*, in particular, requires the performers to choose their own tactics while playing an extremely difficult score, forcing them to decide what to play in advance, which is a realistic approach. Ikeda believes that the lack of these performance opportunities

12 Xenakis, 1992, p. 110.
13 Xenakis, 1992, p. 113–14.
14 Xenakis, 1992, p. 110–13.

has led to a lack of validation of the game itself. The *Duel* rules themselves can easily be written in a programming language. Running it as a simulation or game program, rather than with an orchestra or musical score, would facilitate the refining of Xenakis's idea of the musical game he envisioned. After receiving a proposal from Zannos for a remote performance based on *Duel*, Ikeda created a version of the game matrix described by Xenakis in *Formalized Music*. After running several simulations of games on a computer he discovered that the rules of these matrices do not result in a fair game, but are biased to let the first player win more often than the second player. Xenakis also mentions this property and the need to create a fair game.[15]

In the quest to create such a fair game, Ikeda created a seven-by-seven game matrix, which was first performed live by two improvisers with Ikeda himself as referee. In Figure 35.1 we show the game matrix, represented as the score for Ikeda's piece *Laysan Albatross* (2022). The symbols at the top and left margins of the matrix frame approximate the character of the textures that the improvisers are asked to produce, namely as indicated in the legend, repetition, random movement, and static sound. Furthermore, the tactics include two types of instruments: a Japanese instrument (shakuhachi) and a Western instrument (either trumpet or violin depending on the player). This is thus at the same time an experiment in western-eastern sonic sensibility.

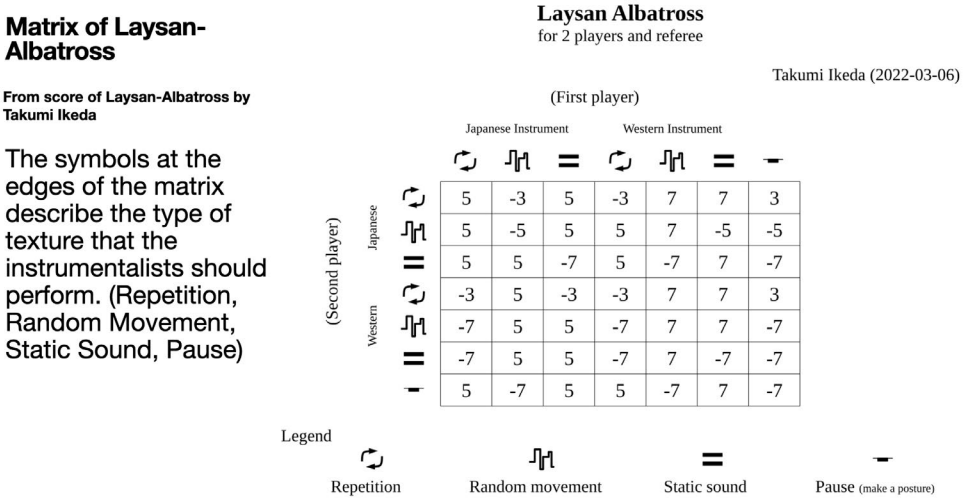

Fig. 35.1 Score of *Layan Albatross* by Takumi Ikeda (2022).

Ikeda-Zannos formed a collaborative duo to realize a new piece called *Phoenix-Albatross*. The idea of East–West dialogue from *Laysan Albatross* led to the formulation of the new piece's title, *Phoenix-Albatross*, namely "Phoenix" in reference to the mythical bird of

15 Xenakis, 1992, 116.

Chinese mythology (Houou, 鳳凰)[16] and "Albatross" in reference to the Albatross in "The Rime of the Ancient Mariner" by Samuel Taylor Coleridge (1772–1834).[17] This seemed fitting as the piece was conceived to be performed telematically from Greece and Japan at the same time. In the version which is presented here, the piece was performed in the dance studio Omikron3 Art Space in Athens, Greece by a third interpreter, the dancer Tasos Pappas-Petrides. The dancer used wireless wearable inertial measurement unit (IMU) sensors to control and modulate the textures defined in SuperCollider by the two performers in Tokyo. This performance is thus true to the name of the piece, *Phoenix-Albatross*, even if the musical performers were both situated in Suidobashi, Tokyo at the time of the performance at the location of the independent venue Ftarri.

Ikeda created a model of the game logic in SuperCollider as well as a graphic display of the matrix which both players consult at each move (see Figure 35.2). We call the two players x (Phoenix) and y (Albatross). Player x chooses moves from the columns of the matrix and player y chooses moves from the rows of the matrix. At each move, the matrix display updates to show which row or column has been chosen by the move of the last player. The other player has the responsibility to choose from that row or column one cell which maximizes the possibilities of winning the game. Player x must choose the greatest value from the column indicated by the most recent choice of player y, and player y must choose the smallest value from the row indicated by the most recent choice of player x. This approach corresponds to an interpretation of the *Duel* score as a zero-sum game, in which a positive number in the matrix is a profit for X, and a loss for Y, and conversely a negative number is a loss for X and a profit for Y. Consequently, the Y preferably chooses the cell with the smallest (negative) value, while X choose the cell with the largest (positive) value. This manner of playing the game corresponds to playing the game with a strategy of maximum gain using the minmax strategy, as shown in Figure 8 of Sluchin and Malt.[18]

Ikeda applied a simplified genetic algorithm (GA) to derive a fairer version of the original game matrix written by Xenakis; i.e., a version which would tend to result in an equal number of wins and losses for each of the two players when playing multiple games. The basic idea of the algorithm was to subject variants of the original matrix to one hundred game simulations and select amongst them the one that resulted in the fairest (most equal or balanced out) game result. This variation and selection process was iterated thirty times, to obtain an even fairer matrix within the limits of available computation time. The algorithm for obtaining variants from the original matrix at each iteration was to add and subtract the integer value 1 to one of the cells of the original matrix in turn, iterating over all cells in the original matrix. (Note: adding 1 and subtracting 1 to each of the 36 cells of the original matrix results in 72 matrices, each of whom differs from the original matrix by an integer value of 1 or –1 at a single cell.) The algorithm can be outlined as follows:

16 Nozedar, 2006, p. 37.
17 Coleridge, 1921, p. 186–209.
18 Sluchin and Malt, 2011.

1. Start with a selected or given game matrix m0 (input matrix).
2. Obtain the set v of all variant matrices of m0 which differ from m0 by a value of 1 or -1 at one single cell only. (Iterate variants +1, -1 over all 36 cells of m0 to obtain a set v comprising 72 matrices.)
3. Play the matrix game on each of the 72 matrices vn in v for 100 times, and collect the resulting score set sv containing 72 scores, one for each matrix, summing the results of the 100 games played with this matrix.
4. From the scores of step 3, select the matrix m1 which in which the number of wins and losses for each player differs the least. (50 wins and 50 losses is the best outcome, 100 wins and 0 losses is the worst.)
5. Repeat steps 1 to 4, using the matrix m1 output by step 4 as input matrix m0.
6. Repeat steps 1–5 thirty times. The matrix m1 selected by step 4 at the thirtieth iteration is the matrix to use for the *Phoenix-Albatross* game.

The matrix obtained from the above algorithm was used in our performance of *Phoenix-Albatross* and resulted in a draw of 2-2, which confirmed our sense that it is a fair matrix.

Phoenix-Albatross Matrix

From Display Programmed in SuperCollider by Takumi Ikeda

Phoenix corresponds to player X and Albatross to player Y.

The yellow colour indicates the player who is expected to make the next move.

display

PHOENIX \ ALBATROSS	0	1	2	3	4	5
0	-1	-1	3	1	1	-1
1	-1	-1	3	-1	1	-1
2	3	-1	-3	3	1	-3
3	1	3	2	-2	-3	1
4	-1	-1	1	-1	1	-1
5	-1	-1	-5	-4	-2	3

PHOENIX ALBATROSS

Fig. 35.2 The game matrix of *Phoenix-Albatross* (2022). Figure created by authors.

Contrary to *Laysan Albatross*, *Phoenix-Albatross* does not involve a referee. Instead, the two performers choose the best move by consulting the points written on the game matrix. It would be easy to create a function that chooses the best move for each player and suggests it or plays it automatically. We decided however to leave this task to the players themselves to increase the demand for concentration and create a sense of suspense, which is part of the human and musical aspect of the performance.

The sonic realization of the piece is based on prototypes of sound textures written

in SuperCollider by Ikeda, employing the infrastructure for accessing sensor data via OSC written by Zannos. The piece was performed in a three-movement form, as follows:

- "Prelude": free improvisation by Ikeda and Zannos with dance by Tasos Pappas-Petrides modulating the sounds from SuperCollider through wearable sensors.
- "Duo": game play in two rounds by Ikeda and Zannos (without dance).
- "Trio": game play in two rounds by Ikeda and Zannos, with dance by Tasos Pappas-Petrides modulating the sounds from SuperCollider through wearable sensors.

Discussion

Phoenix-Albatross is a radical re-interpretation of the game-theoretical and heteronomic music ideas of Xenakis in the new medium of dance-driven music, telematic dance, and live coding. This performance context is radically different from that of the orchestral music setting for which Xenakis wrote *Duel*. Control of sound structures through "dance" represents a departure from the classical instrumental paradigm in terms of the relationship of the performer to the sound structure, which is more fluid and direct but at the same time less predictable and more complex. In fact, while a professional dancer performed the piece, this type of performance is not dance in the traditional sense, but a new hybrid and experimental performance medium. This piece explores the nature and potential of the medium through a dialogue with the musical thought of Xenakis. The dynamics of sound control through movement connected to live coding of synthesis algorithms created a new way of interaction and interpretation during the performance; a kind of hybrid between dance, gestural music expression, and instrumental performance. The design of the sound synthesis algorithms must take into account the dynamics and constraints of this kind of performance, and especially consider the cognitive affordances of the dancer/performer, e.g. how causality between bodily movement and sound is perceived, and what types of movements are preferred or perceived as suitable. To this already complex situation is added the fact that the flow and balance of sound is affected by the code choices made by the two live coding musician interpreters (Ikeda and Zannos) prompted by the decisions of the game-matrix algorithm. The interventions of the live coding performers into the sound flow act as extraneous disturbances in the causal context established by the interdependence between the dancer's movements and the resulting sounds. It can be argued that the interplay between causality and non-causality could be a decisive formal factor, and that in fact interactive dance performances need to explore this interrelationship in depth in order to give rise to new aesthetics or performance art forms involving sound and movement. Furthermore, while the design of the sound algorithms took into

account the generic descriptions of sound textures in *Duel*, the requirements of body-sound interaction favored building algorithms from scratch, rather than building on transcriptions of the event textures found in the orchestral score of *Duel*. It should be mentioned that Stefano Kalonaris created a different live-coded version based on *Duel*, which emulates more closely textures found in the score, while eschewing gestural interaction and relying entirely on live coding.[19] A comparison of these two approaches could be fruitful for future research.

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19 The piece by Kalonaris, called *Duel Revisited*, was performed on 17 December 2022 at the Xenakis Networked Performance Marathon 2022, with Zannos as one of the live coders. A link to a video recording is included in Chapter 40 of the present volume, which presents this Marathon event.