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Rediscovering Xenakis: Decoding the *Free Stochastic Music Program's* Output File

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ABSTRACT

Composer Iannis Xenakis (1922-2001), in his book *Formalized Music* (1963), includes a piece of Fortran IV computer code which produces a composition of stochastically generated music. This early example of indeterminate music made by a computer was in fulfillment of his goal of creating a musical composition of minimum constraints by letting the computer stochastically generate parameters. Stochasticity is used on all levels of the composition, macro (note density and length of movements) and micro (length of notes and pitches). This paper carefully analyzes the output composition and the variations the program might produce. My recent and successful attempts to convert these compositions into Standard MIDI format are then presented in order to promote their preservation and increase their accessibility. My actions to preserve the *Free Stochastic Music Program* is beneficial to understand one of the first examples of indeterminate computer music, with similar techniques being found in modern day composition and music creation software.

1 Introduction

The early history of indeterminate and stochastic music cannot be discussed without mentioning one of its earliest pioneers: Iannis Xenakis. Born in 1922, and active from 1953-1997, his compositions are regarded as innovative, bridging the gap between musical composition and mathematical processes. Though stochastic methods are common in music production software like digital audio workstations and audio plugins, Xenakis' early compositions show the strength mathematical

models lend to artistic processes. In an attempt to make a piece of music with minimum constraint, Xenakis employed a relatively new technology—the computer. In 1962, he composed six pieces with aid from an IBM-7090 mainframe computer.

The code used to produce these pieces was included in his 1963 book *Formalized Music*. Written in the Fortran IV computer language, the code and the output file it produces seems to be an unexplored musical artifact. When run, parameters such as the length of a movement, the density of notes within a movement, the

start point of an individual note, the pitch of a note, or the instrument playing a note are stochastically (drawn from statistical distributions) generated to produce a piece of music. The *Free Stochastic Music Program*'s output is a massive text file which is often thousands of lines long, and it is not in a format which can be easily listened to. For his *ST* compositions, Xenakis would transcribe this output by hand to traditional musical notation to be played by musicians in an orchestra or ensemble. Though recordings of Xenakis' original *ST* series are available to listen to, new compositions created by the *Free Stochastic Music Program* are a challenge to hear, if not impossible because of the arduous process of transcription, performance (these pieces were notoriously hard to perform), and recording. Converting the *Free Stochastic Music Program*'s output to a MIDI file would be beneficial to the preservation of the early history of computer music, indeterminate music, and the legacy of Iannis Xenakis, as it allows us to use MIDI compatible notation and playback software to enjoy and document these pieces without the hand orchestration Xenakis might have had to do. Not to mention, it would also let a new generation of listeners appreciate Xenakis' groundbreaking computer code over 60 years since its inception.

This paper documents my initial research into this program, its output file, and a successful conversion of it into MIDI, to promote the preservation of Xenakis' innovative approaches to music composition.

2 Background

Greek-French avant-garde composer Iannis Xenakis' (1922-2001) music could be described as angular, dense, and chaotic, and to the average listener: inaccessible. Most active from 1953-1997 [1], his compositions were notoriously hard for musicians to perform [2] and his artistry regarding them were equally as mysterious. Xenakis published a book in 1963 called *Musiques Formelles* [3] (*Formalized Music* in English) which gives insight into his creative processes behind his earlier works and his philosophy behind composition. In the most broad sense, Xenakis was interested in how European/Western styles of music evolved along with the guiding philosophies of the times (i.e. the deterministic music of antiquity being influenced by the schools of Plato and Pythagoras; principle of causality). Philosophies of indeterminism (chance, disorder, disorganization)—the direct opposite of determinism

(logic, order, and reason)—were starting to develop in Xenakis' era. In more recent history, we have been engaging with pure indeterminism and how to tame it with the fields and theories of statistics and probability, or in Xenakis' words, "penetrate chance and [...] separate its degrees—in other words, rationalize it progressively, without, however, succeeding in a definitive and total explanation of the problem of 'pure chance.'" Along with principles from mathematical algebra and the operational laws of logic, Xenakis creates an approach to music composition known as "Stochastic Music." As well as classifying fundamental sound sensations, understanding their cause, and mastering their usage in his compositions, Xenakis' theories unite to create a formalized music, one whose parts can be abstracted and experimented on.

These explorations culminate into Chapter V of *Formalized Music*—"Free Stochastic Music by Computer". Using the Fortran IV computer language and an IBM-7090 mainframe computer (one of the most powerful computers in the world at the time), Xenakis set out to create a stochastic piece of music with minimum constraints. Known as the *Free Stochastic Music Program* or the *ST Algorithm*, the program generates numerical output drawn from various statistical distributions, which are then assigned to various components of the musical composition. For example, a single note in a composition has its pitch, dynamics, instrumentation, and duration completely stochastically drawn. Sections or movements have their note density, length, and amount of notes stochastically produced. Xenakis made six compositions using this method: *ST/48-1*, *ST/10-1*, *Amorsima-Morsima (ST/10-2)*, *ST/4-1*, *Morisma-Amorsima*, and *Atrées (ST/10-3)*. These pieces were not fully composed by computer, as Xenakis would pick and choose parts and applied his own artistic judgment in the final composition. Although a brief stint in his compositional career, Xenakis' stochastic music by computer was a groundbreaking approach to composition that appears to be forgotten to time. Already auditorily inaccessible, the *ST* series of pieces were met with academic criticism for their both "indiscriminate use of mathematical functions in music" and "for sully[ing], by intuition, the purity of algorithms." [4]

At the very end of the "Free Stochastic Music by Computer" chapter in *Formalized Music*, Xenakis writes of a need to circumvent the "pure composition" process by electronically synthesizing the piece, a process attainable with today's music technology. Until now, it

is unknown if any attempts have been made to fulfill Xenakis' wishes. My recent successful attempts in converting the *Free Stochastic Music Program*'s output to MIDI are a satisfying solution to this problem Xenakis proposed over 60 years ago.

3 Method

In order to run the *Free Stochastic Music Program*, two methods were used. A professor of mine, Dr. Michael Robinson, compiled and ran the Fortran code on his PDP-11 computer, a method closer to what Xenakis would have done in the early 1960s with mainframes such as the IBM-7090. Dr. Michael Robinson's PDP-11 output and program (modified to work on such a machine) are included in a GitHub repo. [5] Robinson's repo is a fork of GitHub user ronsquibbs' transcription of Xenakis' original code in *Formalized Music* pages 145-152, slightly modified for use in the Simply Fortran development environment. [6] User ronsquibbs' transcription was used to compile and run the *Free Stochastic Music Program* on my own computer using Simply Fortran. [7]

When run, the program generates an output text of musical information which ranges from 200 kilobytes to 1 megabyte. It is important to note that the music information does not simply start right away; tables used in generating the composition take up the first 242 lines of the output file (consistent in all program outputs which I have observed). After these initial tables, the music data begins. Each composition generates 50 sections. Each section is denoted by a header containing its sequential number, length of each section in seconds, and the number of individual note events. If a section contains more than 50 note events, its section header will repeat every 50 note events. Each section contains a certain amount of note events. Within a sequence, each note is cardinally assigned and includes stochastically generated parameters: its start time within the sequence, information relating to its instrument, its pitch, values relating to glissando (if applicable with its instrument), how long the note plays, and its dynamics. An excerpt from the output file is provided in Table 1.

Converting the *Free Stochastic Music Program*'s output file to a MIDI file is not as simple as using these values in a MIDI format. Xenakis' intentions concerning this data should be taken into account in order to produce an accurate MIDI representation of the score. In addition, the MIDI specification for General MIDI 1 [8] needs to

be considered for fully authentic recreation. To create the MIDI file, an open source Python library called MIDIUTIL [9] was used as it had an easy yet practical implementation of the MIDI specification. Each part of the output file was analyzed to see if it was useful both in its portrayal of musical information and effective in its implementation within the MIDI spec.

Information included in the header of each section:

JW - Sequentially counts the section number.

A - Shows the length in seconds of the section.

NA - Shows the number of unique note events in a section.

Q(i) - Related to the density of each class of instruments within a given section, though they aren't important in representing music.

Information included within each note event:

N - Sequentially counts each note event in each section.

TIME - Time of the note event relative to the beginning of the section.

CLASS and INSTRUM - Combined, **CLASS** and **INSTRUM** tell us the instrumentation of the note played. On page 137 of *Formalized Music*, Xenakis includes a chart of the intended interpretation of these columns. Classes (which value ranges from 1-12) tell us the timbre of sound, i.e., percussion, flutes, plucked strings. Instruments tell us more specifically which instrument in that class will play that note, i.e., if we use the Xenakis' composition chart, a value of 6 for **CLASS** and 3 for **INSTRUM** would tell us that a B $\flat$ bass clarinet would play this note. General MIDI instruments are selected for each instrument in the composition.

PITCH - The pitch of a note. Xenakis' says that this should be interpreted as semi-tones away from the lowest B $\flat$ of the 88 key piano, also known as B $\flat_0$ or MIDI note 22. These values include a decimal value in the tenths position. Within the MIDI spec, pitch bend can be used to approximate these micro-intervals.

Table 1: Excerpt from the *Free Stochastic Music Program*'s Output File

JW= 1 A= 26.62 NA= 3 Q(I)=0.18/0.08/0.03/0.03/0.16/0.05/0.02/0.02/0.05/0.07/0.03/0.27/									
N	START	CLASS	INSTRUM	PITCH	GLISS1	GLISS2	GLISS3	DURATION	DYNAM
1	0.00	1	2	0.0	0.0	0.0	0.0	7.81	13
2	1.34	1	9	0.0	0.0	0.0	0.0	3.11	9
3	20.05	12	1	43.5	0.0	0.0	0.0	10.59	18

JW= 2 A= 5.77 NA= 5 Q(I)=0.06/0.09/0.12/0.14/0.09/0.02/0.03/0.02/0.10/0.11/0.14/0.07/									
N	START	CLASS	INSTRUM	PITCH	GLISS1	GLISS2	GLISS3	DURATION	DYNAM
1	0.00	11	2	11.2	0.0	0.0	0.0	1.87	19
2	4.26	3	1	45.1	0.0	0.0	0.0	5.14	29
3	7.89	2	1	21.9	0.0	0.0	0.0	3.48	56
4	9.53	5	2	19.0	12.0	8.0	14.0	2.88	1
5	10.97	4	1	32.0	0.0	0.0	0.0	1.29	55

JW= 3 A= 15.93 NA= 14 Q(I)=0.07/0.04/0.17/0.21/0.13/0.02/0.03/0.02/0.15/0.06/0.06/0.04/									
N	START	CLASS	INSTRUM	PITCH	GLISS1	GLISS2	GLISS3	DURATION	DYNAM
1	0.00	5	1	43.6	-36.0	-53.0	-38.0	4.92	30
2	0.32	5	3	22.4	-47.0	-27.0	50.0	1.86	1
3	1.21	10	1	46.0	0.0	0.0	0.0	3.51	46
4	1.89	8	1	61.5	0.0	0.0	0.0	0.00	34
...	...	...	...	...	...	...	...	...	...

Continued for 7,847 lines

GLISS(1-3) - Three values related to Glissando. These are non-zero values only if **CLASS** is equal to 5 (signifying the group of glissando instruments). While their interpretation is unclear, especially due to the inclusion of three values, we can assume they relate to the speed of the pitch glide. Xenakis speaks on the general methods of stochastic parameter generation in the first chapter of *Formalized Music*, and the process of producing glissandi values is described as generating speeds. In addition, glissando implementation in MIDI past ± 1 whole tone is limited, and within the MIDIUTIL Python library it is impossible.

DURATION - The duration of a note in seconds. Percussion sounds in **CLASS** 1 have a duration of zero seconds.

DYNAM - relates to the dynamics/intensity of the note played. Xenakis intends for each value to be assigned to one of the 44 unique permutations of four degrees of dynamics—ppp, p, f, ff—taken three at a time, i.e. $ppp < f < p$. Like glissando, changes in dynamics have a limited implementation in the General MIDI 1 specification, and within the MIDIUTIL Python library it is impossible. Instead, it could be implemented in a way where a high value for **DYNAM** plays a loud note, and a low value plays a quiet note.

With this information sorted out, it should be a straightforward process to convert the output file to MIDI. Using the Python programming language and the open-source MIDIUTIL library, I wrote a simple script to parse through output from the Xenakis program and map its output to the MIDI format with respect to Xenakis' original intentions regarding the data. Functionally, the script starts by parsing through all the data in an input.txt file and placing it within a large matrix with 10 columns (one for each column in Table 1) and the same number of rows as there are note events. After this, a MIDI note is created for each matrix row, and note information is assigned accordingly. MIDIUTIL's addNote function allows for the creation of a note with specified pitch, starting point, duration and velocity. Given the stipulations above, parameters were adjusted accordingly to the MIDI standard. For the instruments, I recreated Xenakis' instrument chart on page 137 of *Formalized Music*, in a file called instruments.txt. When my program is run, MIDI tracks

are created for each instrument in instruments.txt, and when a note needs to be written, it refers back to this chart to know which track it is placed into. Each track has an appropriate General MIDI instrument assigned to it. A safeguard is put into place for tracks that might have zero values for important variables (i.e. a note with **CLASS** 1).

My program is available open-source on GitHub (<https://github.com/jaso-gerbs/xenakis-to-midi>) along with a sample of input files and outputted MIDI files.

4 Discussion

4.1 On Xenakis' Legacy

Without efforts to modernize Xenakis' computer program and the compositions created by it, this important piece of music history might be forgotten. The program is an extremely early example of indeterminate music by computer, and perhaps its the first example using the mathematical guidelines of stochasticity. Though pure composition by computer was only a brief period in Xenakis' body of work, Xenakis laid the stepping stones for a future of stochasticity and random mechanisms to be present in the music technology we use today. Random and semi-random processes are common in digital audio workstations and audio plugins and are implemented in a similar manner to the *Free Stochastic Music Program*, adjusting parameters like pitch, dynamics, or timbre. Not only did it lay the groundwork for software, modern day composers, especially in the electronic genre, claim Xenakis' work and process to have been influential in their own creations. Influential artists like Richard D. James (known as Aphex Twin) [10], John Frusciante (Red Hot Chili Peppers) [11], and Glenn Branca (post-minimal rock composer) [12] have cited Xenakis as an interest or influence. I hope my efforts to conserve the history of Xenakis' program promotes similar radical musical innovation to a new generation of listeners.

4.2 On MIDI

Xenakis created his algorithm in a period of history where a standard for digital music information had not been created yet. The format of his output file served its purpose for its era, but now it is a completely irrelevant and inefficient way to convey music. MIDI has become

a de-facto standard within instrument communication and musical information storage, and it was self-evident that it ought to be used to store the *Free Stochastic Music Program*'s output. MIDI's widespread usage and continual development gives outdated music formats like Xenakis' another chance at life and musical circulation with playback standards like General MIDI. Future efforts could be made to expand my program with extended MIDI functionality that MIDIUTIL doesn't support, or steps could be taken to cut out the middleman entirely: thoroughly analyze and reprogram the Xenakis algorithm directly to produce a MIDI file. Even further, a computer running the Xenakis code could be used to send information directly to synthesizers running digital instruments for a (to some extent) live performance of an *ST* composition. The choice of MIDI reveals more practical next steps for the evolution of the *Free Stochastic Music Program*.

4.3 On Limitations

Though my program produces a satisfactory recreation of an *ST* composition given its output file, there are some aspects that are limited by the libraries I was using, Xenakis' unclear original intent, and my personal skill as a developer. In my program there is no implementation of the glissando parameter. Xenakis wasn't entirely clear how the three separate columns should be implemented into a composition, and my research of *Formalized Music* gave little clues: only that Xenakis intended large intervals of pitch glided (evident by the recordings of the *ST* compositions). Even still, General MIDI implementation of glissando is limited past ± 1 whole tone on some devices and impossible using the MIDI library I was using. Similarly, the dynamics changes intended on a single note event are impossible with the MIDIUTIL library. With deeper knowledge of the MIDI standard, one could plausibly implement these important features. In addition, I am early in the stages of developing my skills as a software engineer, so the limitations of the project are a reflection of this fact.

5 Conclusion

At its core, this project was carried out for the purpose of accessibility. The *Free Stochastic Music Program* and its output were an inaccessible, esoteric, forgotten piece of music history. Only six pieces using the algorithm were ever composed by Xenakis, and outside

of certain circles, they never reached popular music culture. The MIDI format allows future compositions produced by the code to be modernized, visualized in composition software, or digitally heard once again. No longer does someone have to manually transcribe thousands of lines of note data. The exploration into the original intentions of each parameter of the output file helps us understand the creative processes of early stochastic and computer music, a radical approach to composition at the time. These same processes helped inspire popular musicians and laid the groundwork for today's common musical composition features. My open-source code can allow the next generation of listeners to appreciate a historical revolutionary musical idea, one which can inspire a brand new set of innovators, or at the very least, entertain a curious mind.

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