

Events per Unit of Time: Density as a Compositional Parameter in the Music and Synthesis Techniques of Iannis Xenakis

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1. Overview

- Density
- Composing with densities at the event level
- Composing with densities at the granular level

2. Density

- Events per unit of time
- Normally follows from changes in tempo and texture: faster tempos are more dense
- Not until recently has it been considered a compositional parameter

3. Density in Natural Sounds

- Many natural sounds can be thought of as collections of short sonic events
- Cicadas: individual insect sounds make a whole
- Maracas: individual particles hitting a gourd

4. Density and Probabilities

- Dense events can be modeled in terms of probabilities
- Stochastics in music: use of probability to model random processes

5. Iannis Xenakis

- Theorist, mathematician, architect, composer
- 1958: Worked on Brussels Worlds Fair Philips Pavilion
- Building designed by Le Corbusier (1887-1965) with Xenakis as assistant



- Xenakis based his design on structures used in the composition of a musical work

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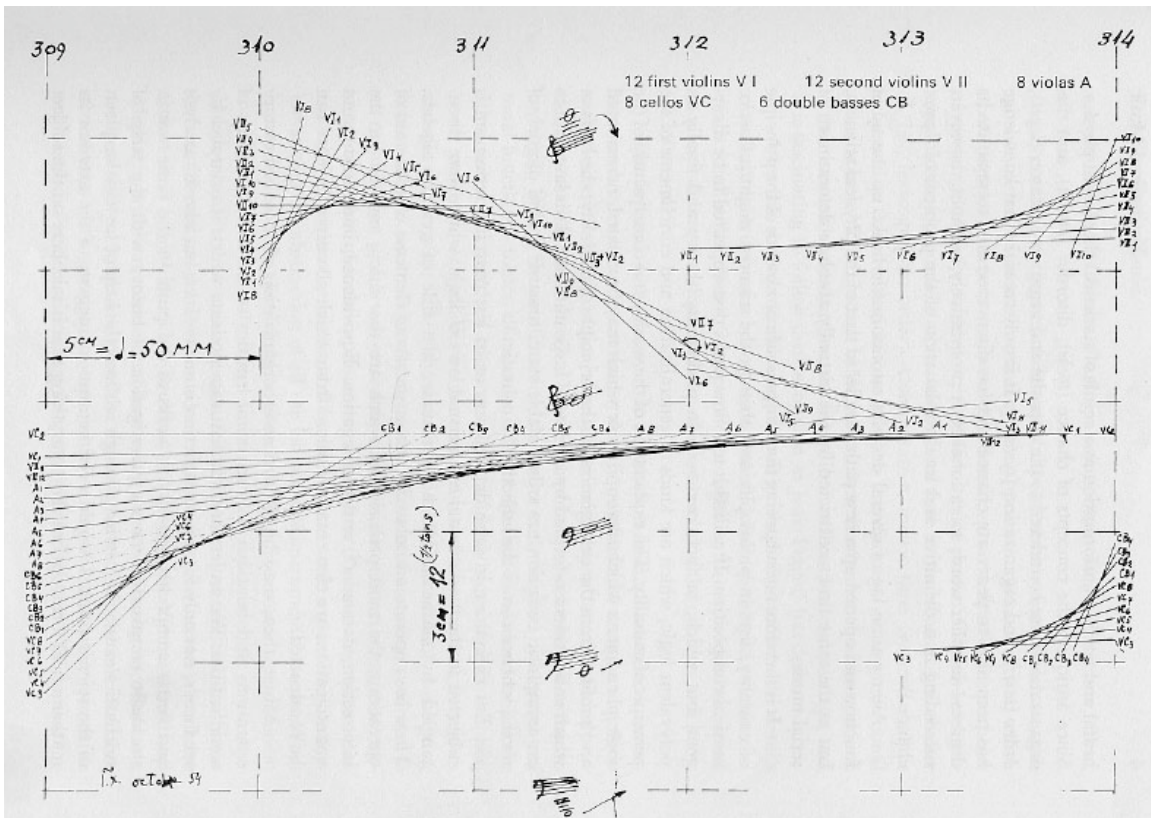
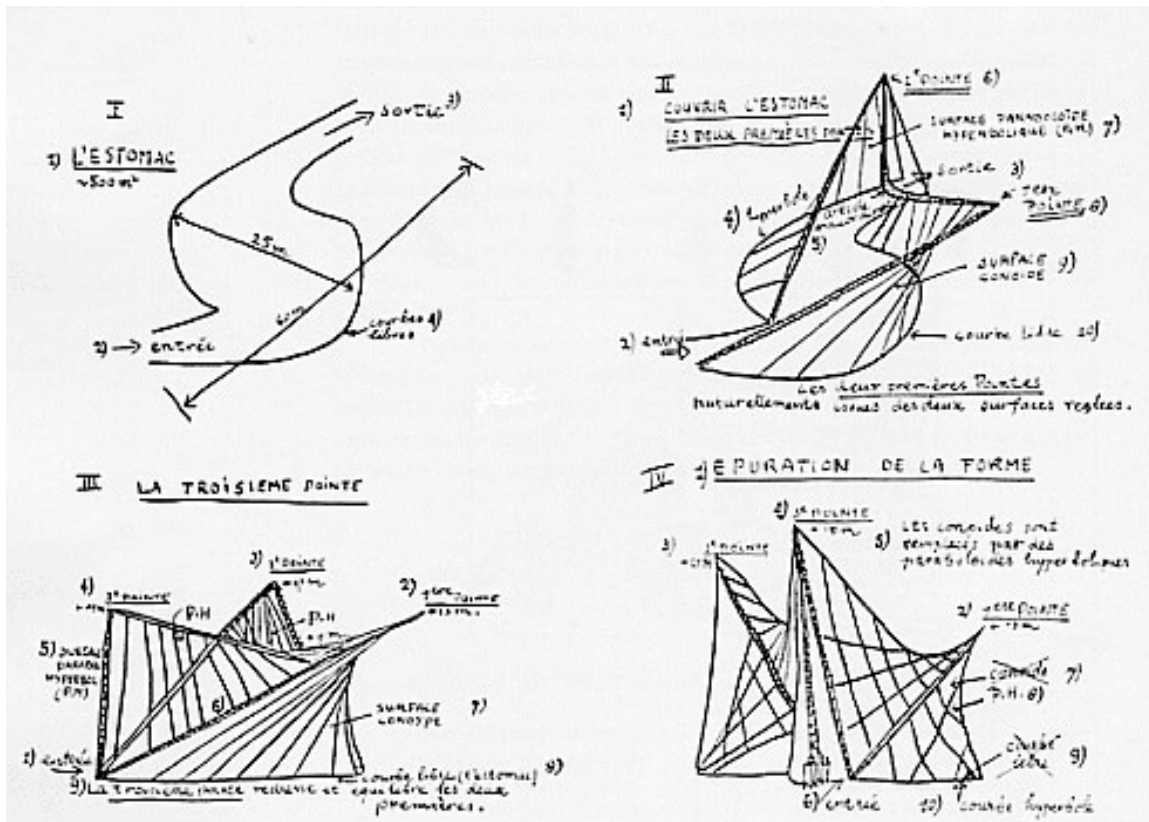


Fig. I-2. String Glissandi, Bars 309-14 of *Metastasis*

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6. Xenakis: Pithoprakta and Achorripsis

- *Pithoprakta* (1955-56) and *Achorripsis* (1956-57): composed with systems based on probability and statistics
- Employed techniques of “stochastic music”: specify statistical trends, densities, and ranges rather than all note parameters
- A procedural approach to composition
- A response to the “Crisis of Serialism” (Xenakis 1955)
- “But other paths also led to the same stochastic crossroads -- first of all, natural events such as the collision of hail or rain with hard surfaces, or the song of cicadas in a summer field. These sonic events are made out of thousands of isolated sounds; this multitude of sounds, seen as a totality, is a new sonic event. This mass event is articulated and forms a plastic mold of time, which itself follows aleatory and stochastic laws.” (Xenakis 1992, p. 9)

7. Listening: Pithoprakta and Achorripsis

- *Pithoprakta* (1955-56) [0 to 4:42]

- *Achorripsis* (1956-57) [4:50 to 6:41]

8. Xenakis: The Stochastic Music Program

- 1961: Xenakis gains access to an IBM 7090 at IBM France



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- Programs the Stochastic Music Program (SMP) based on techniques used for *Achorripsis*
- System produces “score tables” that are transcribed into Western notation



JW= 1 A= 7.71 NA= 67 Q[1]=0.09/0.15/0.16/0.16/0.15/0.02/0.08/0.13/0.06/

N	TA	CLAS	INST	H	VIGL1	VIGL2	VIGL3	DUREE	DYNAM
1	0.	8	10	33.0	0.	0.	0.	0.	22
2	0.07	6	41	25.9	0.	0.	0.	13.94	54
3	0.09	9	1	60.7	0.	0.	0.	3.98	15
4	0.14	3	4	20.6	0.	0.	0.	0.89	1
5	0.24	3	2	50.1	0.	0.	0.	1.20	36
6	0.28	7	28	48.7	0.	0.	0.	0.	54
7	0.33	7	25	47.2	0.	0.	0.	0.	9
8	0.40	8	40	33.0	0.	0.	0.	0.	11
9	0.54	5	34	26.4	-8.0	-10.0	-6.0	4.72	53
10	0.68	8	38	24.1	0.	0.	0.	0.	54
11	0.72	2	5	42.0	0.	0.	0.	1.39	22
12	0.83	4	3	43.4	0.	0.	0.	1.60	15
13	0.85	2	4	58.3	0.	0.	0.	1.59	56
14	0.98	4	3	34.0	0.	0.	0.	1.76	55
15	1.23	4	2	42.0	0.	0.	0.	0.74	44
16	1.26	2	6	43.4	0.	0.	0.	2.12	15
17	1.28	3	2	61.9	0.	0.	0.	1.70	2
18	1.30	2	3	55.7	0.	0.	0.	0.29	38
19	1.34	2	3	58.1	0.	0.	0.	2.97	13
20	1.35	8	5	64.4	0.	0.	0.	0.	31
21	1.37	3	2	41.4	0.	0.	0.	0.	22
22	1.52	4	2	49.8	0.	0.	0.	0.02	53
23	1.59	5	32	46.7	-13.0	14.0	-11.0	4.10	25
24	1.63	7	28	44.7	0.	0.	0.	0.	7
25	1.68	6	38	41.5	0.	0.	0.	13.68	41
26	1.73	4	4	40.9	0.	0.	0.	0.66	13
27	1.73	2	6	18.4	0.	0.	0.	0.64	32
28	1.83	8	33	28.6	0.	0.	0.	0.	46
29	1.86	3	1	61.1	0.	0.	0.	0.79	14
30	1.95	2	3	40.1	0.	0.	0.	2.34	48
31	2.07	3	2	41.2	0.	0.	0.	1.21	9
32	2.19	1	4	0.	0.	0.	0.	8.63	56
33	2.33	5	16	47.8	-36.0	-24.0	-31.0	4.20	19
34	2.56	9	1	63.9	0.	0.	0.	1.84	54
35	2.61	5	22	67.6	-37.0	-50.0	31.0	12.97	41
36	2.67	8	46	23.4	0.	0.	0.	0.	33
37	2.75	4	1	67.9	0.	0.	0.	1.52	51
38	2.78	9	2	70.3	0.	0.	0.	6.06	6
39	2.92	4	4	25.1	0.	0.	0.	0.48	52
40	2.93	4	2	73.1	0.	0.	0.	1.02	25
41	2.98	7	42	25.9	0.	0.	0.	0.	43
42	3.08	4	2	54.7	0.	0.	0.	0.95	38
43	3.15	5	45	24.3	32.0	-20.0	26.0	5.78	60
44	3.17	5	43	38.4	21.0	-20.0	17.0	9.33	33
45	3.22	4	2	67.2	0.	0.	0.	0.34	60
46	3.22	8	41	33.6	0.	0.	0.	0.	5
47	3.25	7	2	59.9	0.	0.	0.	0.	43
48	3.34	9	1	57.0	0.	0.	0.	2.50	47
49	3.32	1	7	0.	0.	0.	0.	17.06	10
50	3.67	8	13	54.3	0.	0.	0.	0.	41

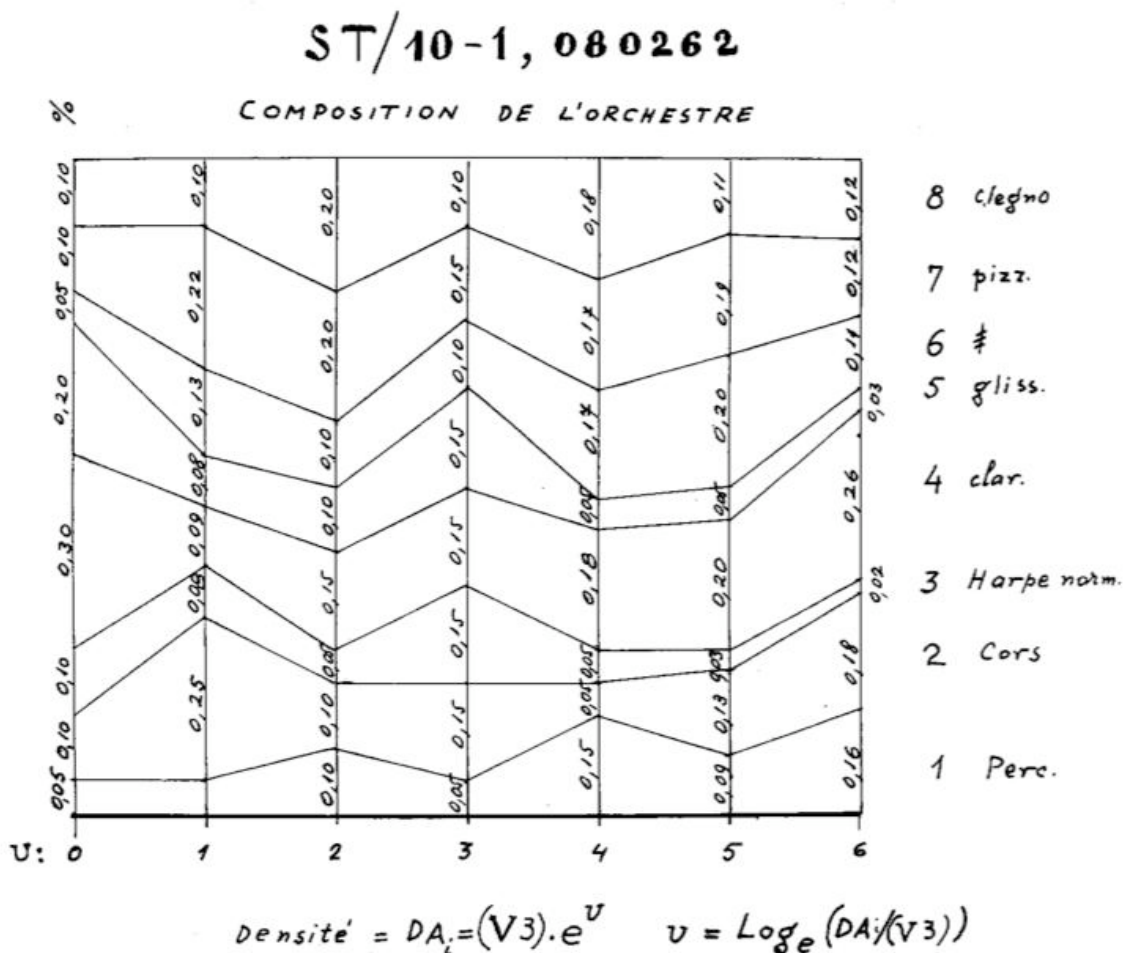
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- 1962: *ST/10-1, 080262* (1956-1962) was premiered at IBM France
- Numerous related ST compositions were created
- 1965: Complete program, in Fortran, published and distributed

9. Xenakis: The Stochastic Music Program and Density

- Employed density as a compositional parameter at many levels
- Method
 1. Duration of each movement is determined
 2. The mean density of notes during a movement is calculated (in events per unit of time)

3. Percentage of events given to each timbre class is determined



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4. For each event, the starting time point within the movement is calculated
5. From previously selected timbre classes, an instrument is chosen
6. A random chromatic pitch is chosen (as a shift of the instrument's previous note)
7. The duration of the note is determined based on an instrument-specific mean
8. The events dynamic contour is selected from a list of 44 options

10. Listening: ST48

- ST48 1962 [0 to 2:51]

11. Xenakis: The Pilot

- “With the help of an electronic brain the composer turns into an astronaut pressing the buttons of his musical space-ship to introduce co-ordinates and keep the course of his vessel on its journey through constellations and galaxies of sound, controlling from his easy chair what the imagination of yesteryear could have envisaged only in its remotest dreams” (Xenakis 1971, p. 131)

12. Density as a Compositional Parameter at the Event Level

- A compositional procedure that is nonlinear, out of time
- Numerous general purpose software systems permit creating musical structures in terms of density
 - AC Toolbox (Berg 2003)
 - athenaCL (Ariza 2005)
- Two approaches to density regions in athenaCL
 - TimeFill: given a number of events, use a Generator to select start time of events within the duration of the Texture
 - TimeSegment: divide the duration into segments (based on a Generator), select the number of events per segment (based on a Generator), select start time of events within each segment (based on a Generator)

13. athenaCL: TextureModule TimeFill

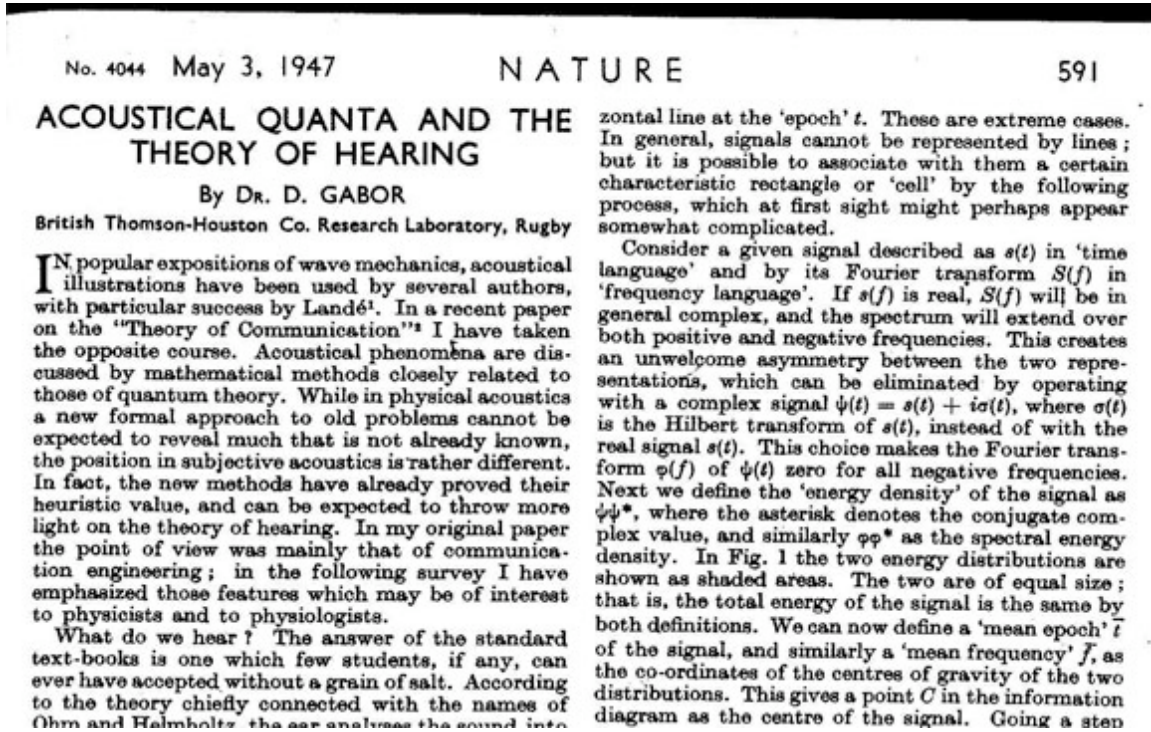
- Probabilistic generators can use shaped distribution to create dynamic densities
- Gaussian or normal distribution with two parameters (mean, variance or precision) [Logic track 1, 2]
- Beta distribution with two parameters (when less than 1, left and right attraction or tightness) [Logic track 3, 4]
- Exponential and reverse exponential with one parameter (exponent) [Logic track 5, 6]

14. Density as a Compositional Parameter at the Granular Level

- Xenakis first explored density as compositional parameter at the score level
- Xenakis theorized, but did not apply, density at the synthesis level

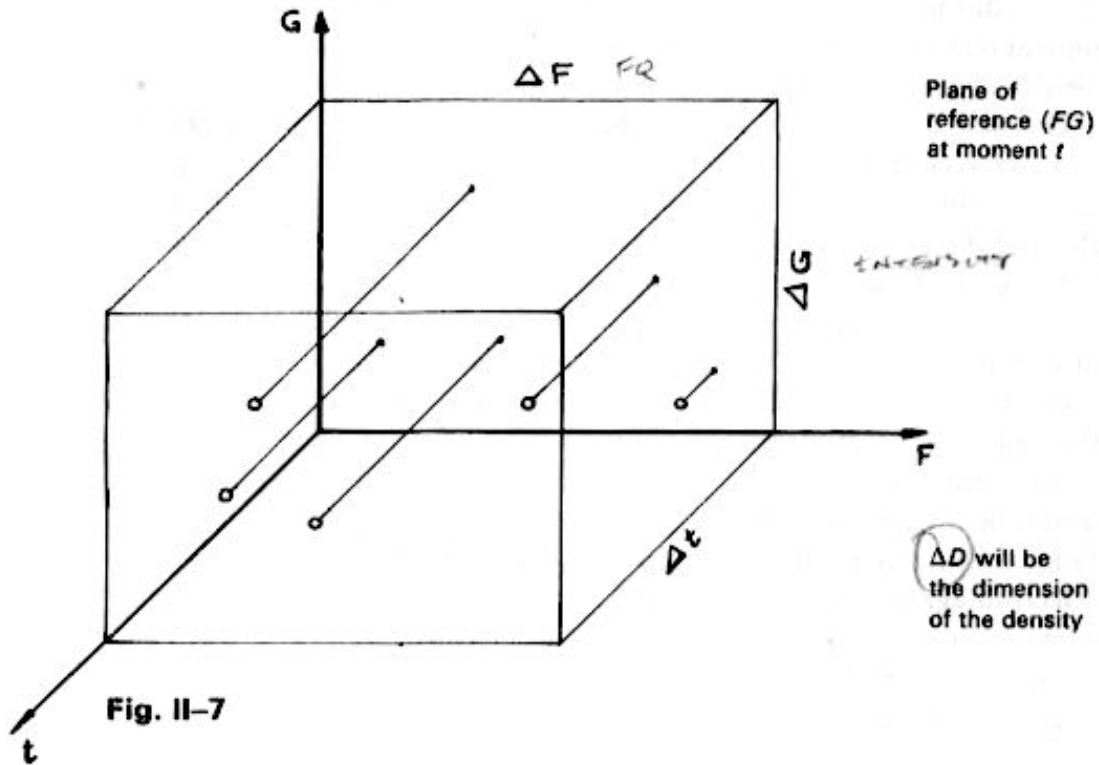
15. Granular Synthesis

- 1947: Gabor proposes acoustical quanta: like photons for sound

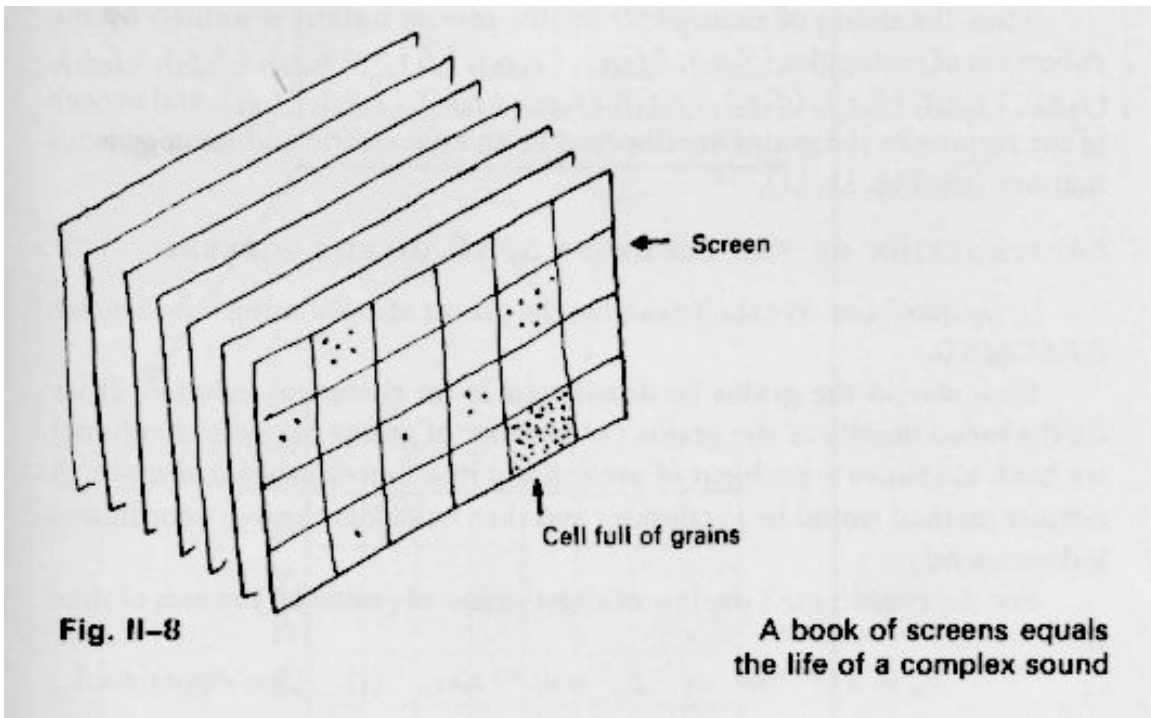


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- 1960: Xenakis, in the chapter "Markovian Stochastic Music," develops a theory of screens, clouds of grains that change over time



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- 1978: Curtis Roads introduces general purpose software for granular synthesis (Roads 1978, 1996, p. 168, 2002)

16. Granular Synthesis: Concepts

- Produce a stream of sounds with very short envelopes (10 to 200 ms)
- Sounds may be derived from synthesized or sampled sources
- Parameters (grain size, frequency, amplitude, etc) are randomly adjusted
- Multiple grain streams are layered
- A technique idiomatic to computer-based synthesis and available in numerous implementations

17. Grains of Sines

- Produce a very short sine tones [01.grain01]
- Control rate of grains and random grain muting (here called density) [02.grain02]
- Control rate of grains, random grain muting, and frequency [03.grain03]

18. Piloting

- USB game controllers offer practical and affordable interfaces
- Example: Logitech Dual Action Gamepad

Image removed due to copyright restrictions.
Photo of Logitech Dual Action gamepad controller.
<http://www.logitech.com/en-us/gaming/controllers/devices/288>

19. Grains of Sines: Expanded

- Randomly select different sine frequencies for each grain within dynamic boundaries [04.oxGrainSine]
- Alter sine tone with frequency modulation

20. Grains of Samples

- Read through portions of an audio file cyclically [05.oxGrainBufferUnit]
- Each grain randomly varies start and end points around selected region
- Each grain has a different playback rate based on upper and lower boundaries
- Control rate of grains and random grain muting (here called density)

21. Listening: Curtis Roads

- Curtis Roads: “Now”: *Line Point Cloud*

22. The Pilot

- The opportunity of piloting a space ship is not just to journey to new places, but to explore new types of control: density

References

- Ariza, C. 2005. *An Open Design for Computer-Aided Algorithmic Music Composition: athenaCL*. Ph.D. Dissertation, New York University.
- Berg, P. 2003. *Using the AC Toolbox*. Den Haag: Institute of Sonology, Royal Conservatory.
- Roads, C. 1978. "Automated Granular Synthesis of Sound." *Computer Music Journal* 2(2): 61-62.
- Roads, C. 1996. *The Computer Music Tutorial*. Cambridge: MIT Press.
- Roads, C. 2002. *Microsound*. Cambridge: MIT Press.
- Xenakis, I. 1955. "La crise de la musique sèrielle." *Gravesaner Blätter* 1.
- Xenakis, I. 1965. "Free Stochastic Music from the Computer. Programme of Stochastic music in Fortran." *Gravesaner Blätter* 26.
- Xenakis, I. 1971. "Free stochastic Music." In *Cybernetics, art and ideas*. J. Reichardt, ed. Greenwich: New York Graphic Society. 124-142.
- Xenakis, I. 1992. *Formalized Music: Thought and Mathematics in Music*. Indiana: Indiana University Press.

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