THE DIGITAL INSTRUMENT AS AN ARTIFACT

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INTRODUCTION

At first, the computer program is neutral and exists only in terms devoid of any reference other than to itself. The program is its function. It is a tool. It does something; it instructs a computer to perform a task. Its working is often imperceptible beyond the surface of its interface—screen based or physical—and its material extension to the inner depths of its digital structure, the code. Reduced to its substance, being digital consists of one of two binary values, either 0 or 1—the bit—and its multiples, the byte. These elementary values cannot by themselves constitute an object of reflection; as Guerino Mazzola points out "The digital age is not centered around 'bits and bytes' but around their accessibility and handling."[1] Opening up the contents of the software and exposing its inner working enables theorizing about the relationships within the code itself, the coding architecture, the functioning of the code, and specific programming choices or expressions, upon which the code acts, outputs, processes, and represents.

However, focusing solely on a functional aspect of software limits our engagement with its wider assemblage of connotations. Beyond the functional and ostensible neutrality of its interface the software is an artifact, as Matthew Fuller points out: "software creates sensoriums" and participates in constructing "ways of seeing, knowing and doing in the world."[2] The software both contains a model of a world it ostensibly pertains to and it also shapes the world each time it is used. Subrata Dasgupta defines artifacts as "useful things that are produced or consciously conceived in response to some practical need, want or desire."[3]

With the UPIC (Unité Polyagogique Informatique de CEMAMu) Iannis Xenakis operationalized a multiscale approach to sound composition within a standard user interface. An incessant interpolation between temporal resolutions of the micro, meso, and macro scales[4] constituted a vital feature of the vision behind the UPIC. The system incorporated a particular view of sound composition which moved beyond the theory of Fourier[5] and took as a starting point the pressure versus time curve together with a sound conceived as quantum; a "phonon" imagined already by Einstein in 1910.[6,7] Xenakis's ambition was "to take possession of the sound in a more conscious and thorough manner," to conceive "the material of sound" as composable.[8]

The design of the UPIC mobilized a correlative gestural and conceptual exploration of the temporal, physical, and perceptual parameters of sound.

In my practice as a composer and researcher, I have been developing a computer program called the New Pulsar Generator (nuPG).[9] The program produces a form of synthesis called pulsar synthesis; its design draws upon and extends the original Pulsar Generator (PG) application by Curtis Roads and Alberto de Campo as described in the publications *Microsound*[10] and "Sound Composition with Pulsars."[11] The technique generates a complex hybrid of sounds across the perceptual time span between infrasonic pulsations and audio frequencies, giving rise to a broad family of musical structures: singular impulses, sequences, continuous tones, time-varying phrases, and beating textures. Through its inherently multiscale character, pulsar synthesis proposes a unique view on rhythm moving beyond a linear series of points and intervals tied to a time grid, and introduces a notion of rhythm as a continuously flowing temporal substrate. Both PG and nuPG relate to the UPIC through their graphical parametrization of synthesis data and systematic approach to composition across multiple temporal levels; an attempt at fusion between micro and macro scales. The study of pragmata of these systems and a reflection on their sonic output provokes many fundamental questions about computing, listening and understanding, creation, interaction, and computer music aesthetics.

This article aims to display how engaging with a digital instrument—particular qualities and propensities of its design, functional and conceptual encapsulation of sound and composition theories—contributes to a mediated model of creative music practice. Such an approach fits within a broader perspective viewing technology and its objects beyond their merely functional and instrumental roles, but as mediators of human experiences and practices.[12] Taking a comparative approach in which the UPIC and the nuPG systems are engaged with as tools of a particular epistemic modality, I propose a concept of an "epistemic tool" to further contextualize a practice of composing with computers in a current multiply-mediated musical reality.[13]

I shall focus on a particular epistemic perspective prescribed within the design of the UPIC, an integration between conceptual, sound and visual realms under a notion of multitemporal sound composition. I propose a parallel narrative of the UPIC and nuPG that display an osmosis of concepts and technologies of design. Throughout, key themes of this text are composition across multiple timescales and computer program as an artifact.

THE UPIC AND A MULTITEMPORAL PARADIGM

A key idea behind the UPIC was that everything in the composition could be solved in the time domain by working out various shapes, such as waveforms, pitch curves, and dynamic envelopes. This concept, also called "graphical synthesis"[14] can be linked back to early experiments in optical synthesis from the early twentieth century.[15]

When working with the UPIC, the user is confronted with a clean slate, a tabula rasa; the system is mute and to generate sound it requires input. The whole aspect of compositional labor—requiring the user to specify objects from the microstructure of sound, its dynamic development in time, and to the overall form of the composition—should be seen as an intentional aesthetic and conceptual stance.[16] At the level of sound microstructure, the user specifies the waveform and a shape of the dynamic envelope, which together can be thought of as an elemental timbre of the instrument. At a higher level of organization, the user operates the music page function, drawing shapes—lines, curves, and points, called arcs—on a frequency (vertical) versus time (horizontal) axis.[17] FIG. 1

These drawn shapes need to be assigned to previously specified timbres. However, up to this point each input to the system—the waveform, envelope, and frequency time shapes on a page—exist only as a simple drawing. To use a Xenakian notion, these shapes exist outside-of-time—they lack temporal boundaries. By defining a duration (or multiple divisions of it) for the page, the user decides how to temporalize these drawings: how to bring the outside-of-time abstract shapes into-time. Only when the duration is defined are these shapes then converted to music waves.

An essential aspect of UPIC's setup are the editing capabilities that each of the arcs could be subjected to: the user can cut, copy, and paste individual shapes, and compress or stretch them in time and frequency. An example of all these procedures can be found in Xenakis's UPIC composition (1978), which consists of arborescent shapes, cut and pasted, compressed and stretched in time and frequency.[18] The reading position and direction on a page and between pages can be variable, too. As observed by Curtis Roads,[19] arcs written to a page with a duration of a second become a characteristic of the sound's microstructure. An opposite manipulation is possible as well; the microstructural pressure versus time curve can be stretched in time and used as a structuring element at meso or macro time levels.

The uniform treatment of composition data and objects at every level mobilizes a creative grafting across and between the micro, meso, and macro time resolutions, a dialectical couplet of local and global perspectives. The design of the UPIC favored a flexible work between two strands of conceptualization: the inductive—a bottom-up glueing of the elemental into the global—and a deductive—a top-down carving of the whole into smaller parts. As such, the UPIC might be described

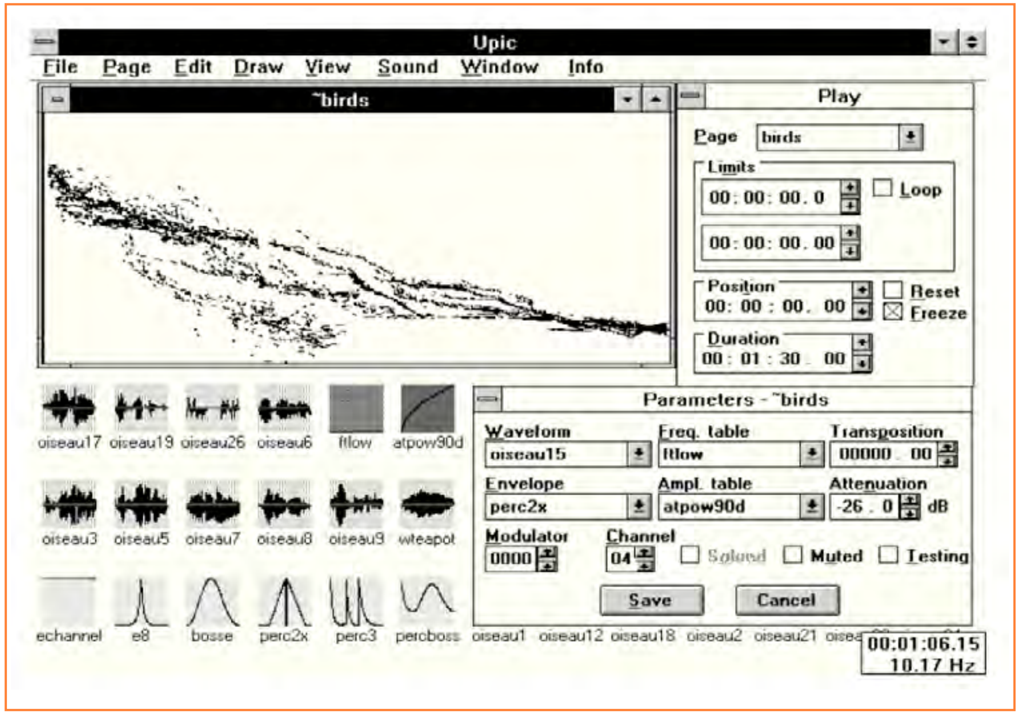


FIG. 1 A workspace of UPIC 3 running on a PC displaying partial data of a composition by French-American composer Brigitte Robindoré, 2003, screenshot. Notice a variety of shapes used as envelope and waveform as well as complexity and richness of the page. © Brigitte Robindoré

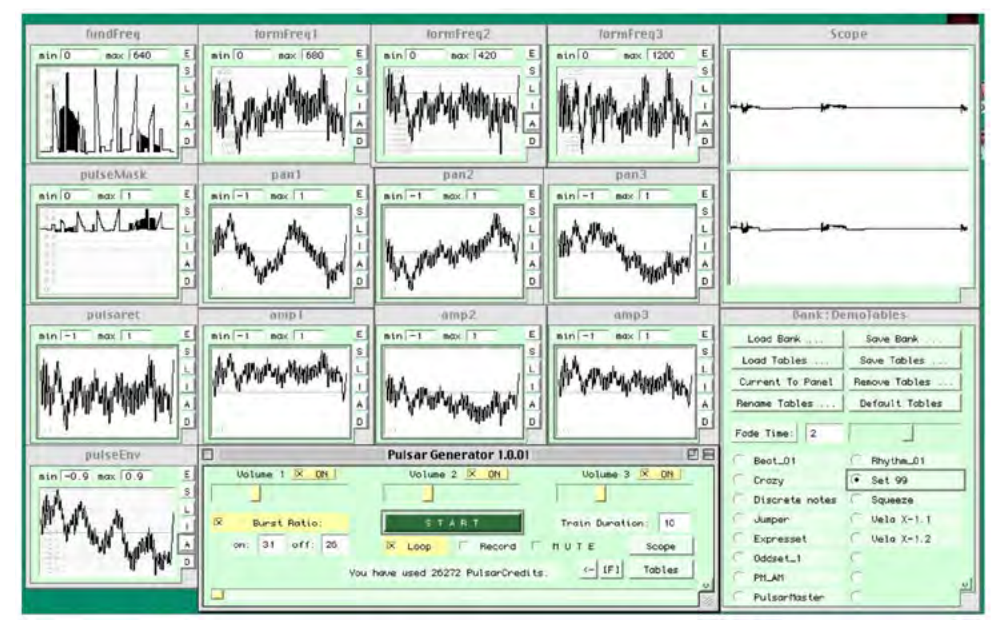
as a system of "transparent stratification" rendering entirely open for a pendular process of differentiation and reintegration of sound materials and forms at all the levels of temporal organization.[20] Such a bimodal process problematizes the duality between form and material: the same object can be conceived as material or form (substance or container) depending on the level of investigation.[21]

The design of the UPIC extended the temporal field of compositional activity and attempted to functionalize a multiscale approach to musical form. To operate within a full register of timescales is to shift the aesthetic focus away from discrete sound entities occupying well-defined time frames towards continuous and evolving objects with fuzzy boundaries. These new objects rarely conform to traditional angular forms of musical structure, and tend toward cloud-like evaporative and continuously evolving morphologies. The multiscale approach favors flexibility, as Curtis Roads points out: it mediates between a high-level abstract plan (the top-down global structure) and opportunities emerging from a low-level of sound material operations (the bottom-up local structures). All temporal levels are to be composed; at any time in the compositional process, we can intervene by synthesis and transformation at any timescale, from a macro scale of the whole work, down to sections, phrases, sound objects, grains, and even individual samples.[22] A dialectic of inductive and deductive processes, observed within the workings of UPIC, forms a key characteristic of the multiscale composition approach: to approach musical composition from a multiscale perspective is to allow an interplay between inductive (specific and local) and deductive (general and global) thinking. These issues are pertinent to the theory and practice of pulsar synthesis.

PULSAR SYNTHESIS: FROM PG TO NUPG

As an integral part of my artistic research practice, I have been involved in a systematic exploration of the technique of pulsar synthesis. Over the past two decades, the technique of pulsar synthesis and its various software instrument implementation—such as, Pulsar Generator (2000) by Curtis Roads and Alberto de Campo, Pulsar Generator (2004) by Tommi Kerannen and Particularity (2010) by Chris Jeffs—acted as a material point of connection, linking practitioners in and outside research institutions. Whether as input sound material for further processing,[23] a raw synthetic output,[24] or as a model for auditory display of data,[25] the practice of pulsar synthesis activated discourse in a variety of functional, aesthetic, and conceptual contexts.

The technique of pulsar synthesis is a powerful approach to digital sound synthesis; it is named after a highly magnetized rotating neutron star that emits a beam of electromagnetic radiation at a frequency between



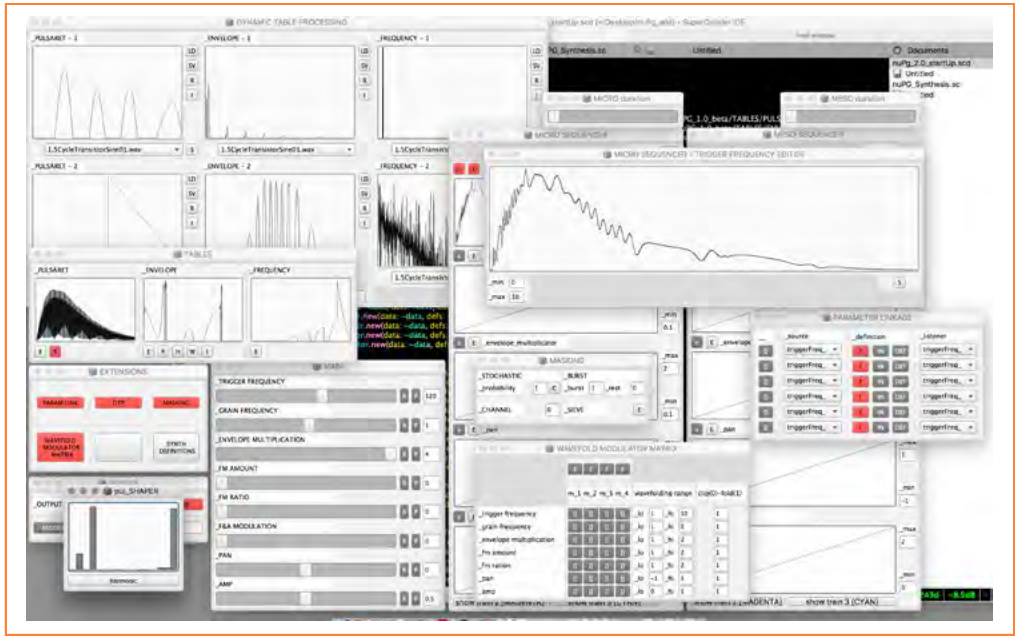


FIG. 2 A workspace of the Pulsar Generator program designed by Curtis Roads and Alberto de Campo in 2000, 2019, screenshot. Notice the complexity of the pulsaret and the envelope tables, as well as the variation in fundamental frequency and three sets of formant frequencies, panning, and amplitude trajectories. These could be designed in advance of synthesis, or manipulated in real time as the instrument plays. The program implemented a scheme for saving and loading these envelopes in groups called settings. The program lets one crossfade at a variable rate between multiple settings, which takes performance with Pulsar Generator to another level of synthesis complexity. © Curtis Roads

FIG. 3 A workspace of the New Pulsar Generator with its various extensions (e.g., wavefold modulators of synthesis parameters via matrix, parameter linking, multiple tables for micro and meso scale trajectories, and preset system), 2019, screenshot. The user can control all parameters of synthesis via the graphic interface, as well as through text of the programming language via a set of predefined functions. © Marcin Pietruszewski

0.25 and 642 Hz.[26] Pulsar synthesis operationalizes the notion of rhythm with its multitemporal affordances as a system of interconnected patterns evolving on multiple time scales.

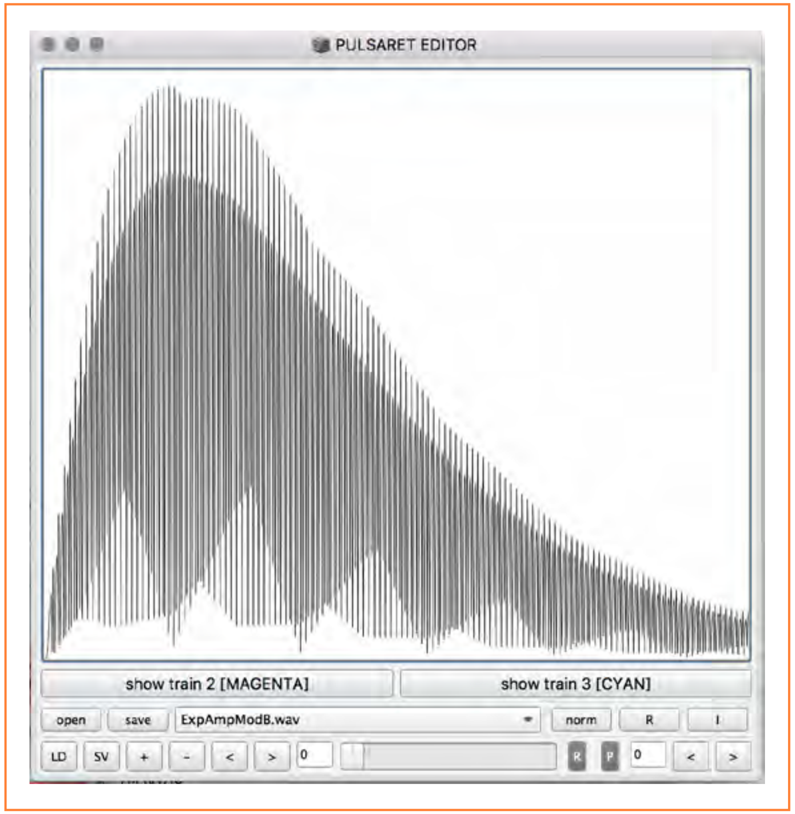
The fundamental functional unit at the microstructure level in pulsar synthesis is called a pulsar. A spectrum of a single pulsar is a result of a convolution between pulsaret and envelope. The pulsaret table can be considered "a template of spectrum shape,"[27] while the envelope is a function limiting it in time. An important generalization is that both tables, pulsaret waveform and envelope tables, can be any shape. A repetition of the pulsaret forms a pulsar train; a stream of pulses emitted at a user-stipulated rate which can vary from infrasonic pulsations to audio frequencies.

Developed in 2000 by Curtis Roads and Alberto de Campo, the PG program generalized the technique of pulsar synthesis and provided a powerful interface to control its various parameters.[28]

As part of my ongoing PhD research at the University of Edinburgh, I have been developing a new version of the historic PG. The nuPG program is developed in SuperCollider 3 programming language and incorporates an extensive set of graphic interface tools to control various parameters of synthesis.[29] Additionally, the underlying Just-In-Time programming paradigm[30] used in the development of the program means that all objects of the nuPG can be redefined in real time. A coupling between graphic and textual interfaces allows for powerful control of visual and formalized compositional models.

At the microstructure of the sound the New Pulsar Generator provides a set of tools to manipulate the shape of the pulsaret waveform. FIG. 4 The shape can be also generated using a harmonic or the Chebyshev shaper function FIG. 5. The waveform has a fundamental effect on the spectral shape of the generated pulsar stream.

Foundational for the discussion on the digital musical instrument design is the concept of representation.[31] Roads and Wieneke[32] distinguish between iconic (also called analog) and symbolic representations. "A sign is said to be iconic when there is a topological similarity between the signifier (the sign) and its denotata (i.e., what it represents)." A sequence of numbers stored in the memory of a computer corresponding in value to the shape of an acoustic signal is one example of such representation. "A sign without either similarity or contiguity but only a conventional link between its signifier and denotata is called a symbol."[33] A syntactic arrangement of symbols plays a functional role within formal languages. Such symbols do not usually mirror the surface structure of a composition; rather, they represent the "background" interrelations or "deep structure."



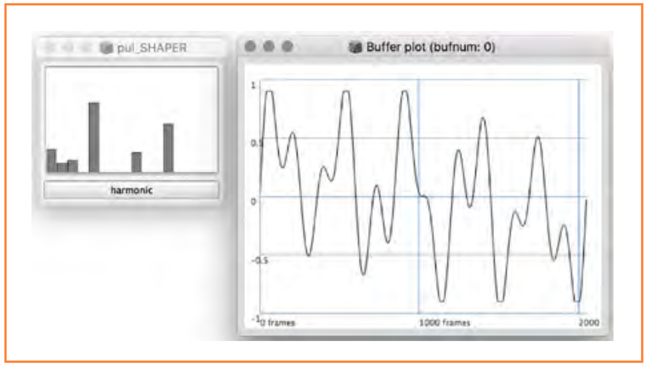


FIG. 4 An editor of the pulsaret waveform, 2019, screenshot. The shape can be drawn directly or loaded from predefined functions. A sound sample can be used as a waveform, too. Located at the bottom of the window, preset functionality allows for saving and interpolating between waveforms. © Marcin Pietruszewski

FIG. 5 A simple tool allowing generation of various shapes for a pulsaret waveform, 2019, screenshot. It can be thought of an incorporation of additive synthesis paradigm—where multiple harmonics are added together—within pulsar synthesis. © Marcin Pietruszewski

The question of iconic versus symbolic, discrete versus continuous, as well as graphical versus textual representation of musical information is a perennial issue in the context of digital instrument design.

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As a way of synthesizing the discussion about UPIC, PG, and nuPG I propose to expand the notion of digital instrument as an artifact. the UPIC, as well as PG and nuPG programs, as any other piece of human-made technology, do not function in a vacuum. As Anne Sauvagnargues points out:

> *A tool or a machine should not be studied in isolation without taking into consideration the milieu of individuation that surrounds it and allows it to function. No machine or technical tool exists by itself [...] they only function in an assembled milieu of individuation, which constitutes their conditions of possibility: there is no hammer without a nail, and thus the interaction between a multitude of technical objects makes the fabrication of hammers and nails possible, while also forming the conditions of their utilisation and the practices and habits associated with them.*[34]

Systematic engagement with an artifact must acknowledge its constituent multiplicity and contexts activated via its use. Artifacts are complex conglomerates of things and composition of "components, which are continuously rearranged and reassembled in their specific modes of appearance throughout history".[35] Artifacts are "like organisms, they manifest evolution."[36] Any artifact is surrounded by the knowledge that is prior to its emergence and also by the knowledge that appears only after the artifact was made.

Every artifact generates an interpretative cut. With a particular perspective prescribed within its design and function, UPIC, PG, and nuPG can all be thought of encapsulations of knowledge and carriers of a sound theory. Moreover, engaging with such instruments is not limited only to interaction with their physical dimension—the interface. These instruments engage their user with a prescription of a compositional model; a projection which embodies a particular epistemological perspective of what is to be composed: what is the material, its possible transformation and formal organization. By mediating their compositional model, UPIC, PG, and nuPG framed the boundaries of perception and thought.

Don Ihde conceptualized a variety of phenomenological modalities of instruments and their role in our relationship with the world. Among these are embodied relations, where the instrument acts as an extension of the body and amplification of the senses; and hermeneutic relations, where the instrument provides us with data (e.g., a sonogram) which we have to interpret (from Greek hermēneuein, interpret.)[37]

The underlying design technology of UPIC, PG, and nuPG correlates the embodied and hermeneutical within one design based on a bimodal evolution between gestural and conceptual. All the systems incorporated embodied relation; the UPIC especially, through its corporeal interface relying on the drawing capacity of the human hand and the proportion of a CAD/CAM drawing board, ergonomically designed to follow the proportions of the human body.[38] The ability to use the various objects (a waveform, an envelope, the page, pulsaret editor, etc.) of these systems, however, required interpretative work, and it is here that UPIC, PG, and nuPG incorporated a hermeneutical relation. In this perspective, all three can be seen as compound devices extending the body, eye, ear, and mind, as instruments impregnated with knowledge, which can serve as a model of how our conceptions of what is musical material and form are being constructed.

FOOTNOTES

1. Guerino Mazzola, *The Topos of Music: Geometric Logic of Concepts, Theory, and Performance* (Basel: Birkhäuser, 2012), 105.
2. M. Fuller, *Behind the Blip: Essays on the Culture of Software* (New York: Autonomedia, 2003), 19.
3. Subrata Dasgupta, *Technology and creativity* (New York: Oxford University Press, 1996), 9.
4. For an extended discussion on temporal scales see Curtis Roads, *Microsound* (Cambridge, MA: MIT Press, 2004).
5. Iannis Xenakis, *Formalized Music* (Hillsdale, NY: Pendragon Press, 1992), 258.
6. Ibid. xii.
7. In the 1940s, British physicist Dennis Gabor proposed that all sounds can be viewed as a succession of elementary particles of acoustic energy. The question of "realness" of these particles is an attractive one and relates to the age-old dilemma of pre-existence of all possible divisions within a whole.
8. Bálint András Varga, *Conversations with Iannis Xenakis* (London: Faber and Faber, 1996), 44.
9. For the documentation see https://www.marcinpietruszewski.com/the-new-pulsar-generator.
10. Curtis Roads, *Microsound* (Cambridge, MA: MIT Press, 2004), 137.
11. Curtis Roads, "Sound Composition with Pulsars," in *Journal of the Audio Engineering Society*, 49, 3 (2001), 134–147.

12. Such a view is grounded in theories of Feenberg, Fuller, and Manovich; see Roger F. Malina and Sean Cubitt, *Software Studies: A Lexicon* (Cambridge, MA: MIT Press, 2008).

13. Georgina Born, "On Musical Mediation: Ontology, Technology, and Creativity," in *Twentieth-century Music* 2, (2005), 7–36.

14. Curtis Roads, *The Computer Music Tutorial* (Cambridge, MA: MIT Press, 1996), 329–330.

15. For an in-depth discussion on optical synthesis see Thomas Y. Levin, "Tones from Out of Nowhere: Rudolph Pfenninger and the Archaeology of Synthetic Sound," in *Grey Room,* 12 (2003): 32–79; László Moholy-Nagy, "Production—Reproduction: Potentialities of the Phonograph" [1922] in *Audio Culture: Readings in Modern Music*, ed Christopher Cox and Daniel Warner (London: Continuum, 2004); Luc Döbereiner, "Models of Constructed Sound: Nonstandard Synthesis as an Aesthetic Perspective," in *Computer Music Journal* 35, (2011), 28–39; Kristine Helen Burns, *The History and Development of Algorithms in Music Composition*, 1957–1993, PhD thesis, Ball State University, Muncie, Indiana, Ann Arbor, 1994.

16. Herbert Eimert related to this approach as the "absolute composition" through which "real musical control of nature" can be asserted; see Herbert Eimert, "Von der Entscheidungsfreiheit des Komponisten," in *die Reihe* 3 (1957), 5–12.

17. A detailed technical specification of various iterations of the UPIC system have been already described in detail: Henning Lohner, "The UPIC System: A User's Report," in *Computer Music Journal* 10, (1986), 42–49. Gérard Marino, Jean-Michel Raczinski, and Marie-Hélène Serra, "The New UPIC System," in *International Computer Music Conference Proceedings*, vol. 1990, https://quod.lib.umich.edu/i/icmc/bbp2372.1990?rgn=full+text; Gérard Marino, Marie-Hélène Serra, and Jean-Michel Raczinski, "The UPIC System: Origins and Innovations," in *Perspectives of New Music* 31, (1993), 258–270.

18. For an analysis see Benjamin R. Levy, "Clouds and arborescences in *Mycenae alpha and the Polytope de Mycènes,"* in *Xenakis Matters: Contexts, Processes, Applications*, ed. Sharon Kanach (Hillsdale, NY: Pendragon Press, 2012).

19. Curtis Roads, *Microsound* (Cambridge, MA: MIT Press, 2004), 159.

20. Robin Mackay, Russell Haswell, and Florian Hecker, "Blackest ever Black", *Collapse 3* (2007), 109–139.

21. Gottfried Michael Koenig, "Genesis of Form in Technically Conditioned Environments," in *Journal of New Music Research* 16, (1987), 165–175.

22. See Chapter 9, "Multiscale Organization," in Curtis Roads, *Composing Electronic Music: A New Aesthetic* (New York: Oxford University Press, 2015). 283–317.

23. For example, see the compositions by Curtis Roads: *Half-Life* (1998), *Tenth Vortex* (2000), *Eleventh Vortex* (2001), and Kim Cascone's *Pulsar Studies* (2004) EP.

24. Florian Hecker, *Recordings for Rephlex* (2006), CD, Rephlex.

25. Marcus Schmickler utilized a pulsar synthesis model in a sonification of pulsars in the Bonner Durchmusterung project, for details see http://piethopraxis.org/projects/bonner-durchmusterung/

26. Pulsars are rotating neutron stars that appear to "pulse" because the beam of light they emit can only be seen when it faces the Earth. Pulsars were discovered by Jocelyn Bell Burnell, which is considered one of the greatest astronomical discoveries of the twentieth century.

27. Curtis Roads, *Microsound* (Cambridge, MA: MIT Press, 2004), 146.

28. Ibid. 154.

29. For the User Manual describing all objects of the New Pulsar Generator see: https://www.marcinpietruszewski.com/the-new-pulsar-generator

30. Julian Rohrhuber, Alberto de Campo, and Renate Wieser, "Algorithms Today: Notes on Language Design for Just In Time Programming," in *International Computer Music Conference Proceedings*, vol. 2005, 291, https://quod.lib.umich.edu/i/icmc/bbp2372.2005?rgn=full+text

31. Meinhard Müller, *Fundamentals of Music Processing: Audio, Analysis, Algorithms, Applications* (Heidelberg: Springer, 2015).

32. Curtis Roads and Paul Wieneke, "Grammars as Representations for Music," in *Computer Music Journal,* 3, (1979), 48–55.

33. Thomas A. Sebeok, "Six Species of Signs: Some Propositions and Strictures," in *Semiotica,* 13, (1975), 233–260.

34. Anne Sauvagnargues, *Artmachines: Deleuze, Guattari, Simondon* (Edinburgh: Edinburgh University Press, 2016), 186.

35. Paulo de Assis, *Logic of Experimentation. Rethinking Music Performance through Artistic Research* (Leuven: Leuven University Press, 2018), 107.

36. Subrata Dasgupta, *Technology and creativity* (New York: Oxford University Press, 1996), 114.

37. Don Ihde, *Technology and the Lifeworld: From Garden to Earth* (Bloomington, IN: Indiana University Press, 1990).

38. The drawing board featured in the early version of the UPIC system and later had been replaced with an interaction on a computer's screen with a mouse. In the early version of the system, the drawing field of the board had a calibrated area of 60 cm high by 75 cm wide.

COLOPHON

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