On Technology and Art: Xenakis at Work

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ABSTRACT

In embracing modern technology as a context for technical experimentation, a composer like Xenakis, in many ways, returns modern technological practice to its roots in autonomous craft labor by particularizing the things, events, and conditions which define the musical task environment. And yet in directly linking that activity to a modern aesthetic and technical practice, he transforms the very principles which define autonomous craft labor, infusing it with the dialectical nature of modern technical practice. This paper considers the wider context of Xenakis' highly personal and idiosyncratic design approach to modern technology in music composition. It begins with a brief explication of Andrew Feenberg's *critical theory of technology*, which outlines necessary social and political parameters for a democratized technology. It then goes on to examine the potential role of the computer in the democratization of technology, both at the social level and at the epistemological level. This potential is realized when the computer is understood as a tool for designing task environments. As such, the signifying imperative of the computer interface is becomes a focus of computer-use, not something which is pre-packaged within the computer system itself. Laske used the term 'rule-based' design to describe this interpretive approach to the design of computer artifacts. In Xenakis' own rule-based approach to designing musical artifacts, he extended compositional technique into the domain of sound. His approach to sound material as a medium for constructive actuality reflects his more general design approach: sound, at its most elemental level, was already a site for dialectical mediation. In this way, Xenakis' work transcended the rationalist discourse which nevertheless enshrined many of his writings and ideas: his texts reflect, in intimate detail, the technique of his musical thinking while his musical works, at their most powerful, boldly reflect the technical ideas delineated within his texts. In this way, Xenakis' work exemplified the centrality of musical technique in any discussion of music, including its aesthetics. In so doing, Xenakis pointed the way toward an interpretive appropriation of technology more generally, pointing the way to an embrace of its deeply technical requirements while, in that very embrace, compelling a radical reframing of its discourse.

1. INTRODUCTION

I will never forget the moment when I first encountered Xenakis' *Formalized Music*. Though I had heard by that time several of his works, and was of course stunned by their sonic directness, this was my first encounter with the ideas behind those works. What was particularly striking to me about this book, and about the projects and ideas it articulated, was its bold formulation of an aesthetics of music within a technological frame. For the first time in my experience as a young musician, I had encountered musical thought that projected itself in technical experiment, while, through that very projection, significantly advancing the technique of music composition. And though I was well aware of *electronische Musik*, *musique concrète*, and other experimental composition activities of the 1950s, it was *Formalized Music* that helped me to understand the relevance of those activities to the expression of a radical interpretive stance in relation to technology. I began to see that the creation of tools and technologies for the purposes of compositional design was in and of itself compositionally and musically compelling.

This paper considers the wider theoretical context of Xenakis' highly personal and idiosyncratic design approach to technology. First I present a critical theoretical view of technology, based principally on the writings of Andrew Feenberg, Shoshanna Zuboff, and Pelle Ehn, which describe a more *democratized* technological frame. One way to do this is to democratize the discursive dimension of technology — i.e. to structure a technological base that projects a greater variety of social and, ultimately, epistemological imperatives. Empowering a technology that projects a variety of imperatives renders a technology that ontologically reflects a society and its members. The computer amplifies this reflective capability of technology, once it is understood as a tool for creating task environments. According to such an understanding, the signifying function of the computer interface is not given *a priori*, but is conditioned by the particularity of design activity; it provides a means for humans to design the very representational frames which condition how they think and act *vis á vis* a particular domain. Rule-based design (Laske, 1991) exemplifies this interpretive approach to computer system design, since it forces one into a more directly interpretive engagement with one's own ideas and designs. In so doing, it amplifies the subjective dimension of technology while empowering its projection into social spheres of discourse and interaction.

Xenakis' work exemplifies this centrality of rule-based thinking in musical activity. While advocating music as a technological art, he sought to ground musical thinking in the particularity of working process. His approach to sound material as a medium for constructive actuality reflects this design principle: sound, at its most elemental level, was already a site for dialectical mediation. In this way, Xenakis' work transcended the rationalist discourse which nevertheless enshrined many of his writings and ideas: his texts reflect, in intimate detail, the technique of his musical thinking while his musical works, at their most powerful, boldly reflect the technical ideas delineated within his texts. It is perhaps for this reason that his texts — and the ideas projected within them — have come to be regarded as inseparable from his musical works. Both reflect an engagement with a modern technology that seeks to advance its technical core while at the same time infusing it with deeply human experience.

2. TOWARD THE DEMOCRATIZATION OF TECHNOLOGY

Instrumental vs. Substantive Theories of Technology

Critics frequently blame technology for many of the ills confronting human societies: unemployment, globalization, consumerism, environmental degradation, economic and cultural hegemony — all are frequently ascribed to the advancement of technology. Theorist Andrew Feenberg asserts that problems such as these are "rooted not in technology per se but in the antidemocratic values that govern technological development" (Feenberg, 1991, 3). Moreover, he cautions that social reforms which ignore this fact will not succeed; rather than create social policies and educational institutions that attempt to cope with the effects of technology, we should engender for ourselves a notion of technology that empowers a broader range of human participation, in terms of design, philosophy, education, and application. The choices that people make "are increasingly mediated by technical decisions" (Feenberg, 1991, 3) — the tools that we use in our everyday life dramatically impact how we think about the world and the choices apparently available to us. It is thus critical that people have the ability to participate in the production of those technologies and tools which so condition the quality of our lives.

The theory of technology that Feenberg advocates differentiates itself from the more standard discourses on technology, which roughly break down into two distinct theoretical camps: the 'instrumental theory' camp and 'substantive theory' camp. Instrumental theory views technology as socially and culturally *neutral*, independent of social and political forces. Technology devolves into *tools* that are fundamentally divorced from the context of their use. It is the very nature of tools to stand apart from society, indifferent to the activities in which they are used. They epitomize "the 'rational' character of technology and the universality of the truth it embodies" (Feenberg, 1991, 6).

In contrast to instrumental theory, substantive theory regards technology as anything but neutral: in fact, according to substantive theories, the very nature of technology is to provide for the exercise of cultural and social domination of the many by the few. According to substantive theorists (among whom Feenberg counts Heidegger), technology controls and dominates all aspects of our lives: "We are engaged, [Heidegger] claims, in the transformation of the entire world, ourselves included, into 'standing reserves,' raw materials to be mobilized in technical processes" (Feenberg, 1991, 7). The only way to escape technology is to deftly identify where it intrudes, and to reject it wherever possible. From this rejection are born the various anti-technology movements (e.g. the new age movement, fundamentalist religion, etc.).

Critical Theory of Technology

It is somewhat surprising then, given how different these two camps are from one another, that they share a single premise; that technology itself is *immutable*. Like the weather, its forces may be tamed somewhat, but never brought under the control of human design. As such, common approaches to the control of technological forces tend to take a *reformative* posture; their efforts focus on setting moral and political boundaries in order to contain the most unacceptable consequences of technology. However, Feenberg argues that a post-industrial society cannot be fundamentally transformed through the imposition of mere boundaries over technological advances. What is required is a reinvention of the "politics of technological transformation," (Feenberg, 1991, 13) the formulation of a theoretical frame that facilitates not just analyses of the forms of oppression associated with the technological *themae* that govern work, play, and civic life, but a redesign of technology in order to adapt its forces to the needs of a genuinely free society. It is this reinvention of technology — this transformation of its ideological base — that characterizes what Feenberg calls the *critical theory* of technology.

Echoing many of the ideas of the critical theorists of the Frankfurt school, Feenberg's critical theory of technology understands the problems of technology as arising from its social and political application, rather than as an inherent quality of technology itself. At the same time, however, it also views technology as a force that structures fundamentally the way a society views and comports itself. Embedded within that structuring is a projection of the power relations that constitute a society. Within the modern post-industrial world, technical artifacts (machines, devices, etc.) encapsulate elite values and interests which form the overall dominant technological rationalism that characterizes our social organizations and productive imperatives. Technical artifacts propagate “technical codes” — ideological strata that “invisibly sediment values and interests in rules and procedures, devices and artifacts that routinize the pursuit of power and advantage by a dominant hegemony” (Feenberg, 1991, 14).

Critical theory of technology seeks to democratize the discourses and activities that determine how technology affects our lives, communities, and institutions. It does this by unpacking the political and economic forces that determine dominant technological rationalities, while trying to explain “how modern technology can be redesigned to adapt it to the needs of a freer society” (Feenberg, 1991, 13). Toward this end, critical theory of technology requires a rethinking of technology in order to bring about its transformation from an instrumental abstraction into a site for human thought and activity.

Toward the Democratization of Technical Work

One of the hallmarks of the industrial revolution, and its aftermath, was the systematic *deskilling* of the workforce. This transformation of work activity served to destroy “autonomous craft labor,” replacing craftsmanship with mechanization, pleasure with drudgery (Feenberg, 1991, 26). This mechanization of work attenuated the subjective capacity of labor, transforming workers’ knowledge “into an objective power owned by another” (Feenberg, 1991, 27).

Shoshanna Zuboff (whose work Feenberg treats extensively) observes in computer systems the possibility for a transformation of the post-industrial workplace. This transformation is constituted in two complementary developments. On the one hand, computers can automate human production, relieving humans of tedious and boring activities. On the other hand, computers facilitate work requiring greater skill and thus elevating the level of intellectual involvement required. Zuboff calls these complementary transformations *automating* and *informating*, respectively. In *automating*, the computer relieves the worker of drudgery through automation of repetitive tasks. In *informating*, the computer provides higher level control tasks, as well as means for observing, through feedback, one’s own activities.

In Zuboff’s words, “this communicative or ‘reflexive’ dimension of information technology gives rise to a ‘textualized’ work process that increasingly blurs the distinction between mental and manual labor” (quoted in Feenberg, 1991, 94). Moreover, in its combined transformation of automating and informating, computer technology brings about not only the production of goods, but it also *occasions the very representation of the world in which it is used* (Feenberg, 1991, 94). It is its joint unfolding in automating and informating that compels the advance of computer technology as a context for a democratized work place.

However, the communicative, *informating* capacity of computer technology is frequently blunted in favor of its *automating* capacity. This is due partly to the traditional systems theory approach to the use of computers — which seeks to create the “perfect” computer, thus making work simpler, less error-prone, and thus more rational — and partly due to the tradition of computer science, which is based in a theoretical and model-based view of computation that fashions itself as paradigmatically isolated from any social, cultural, or political context.

Computer system designer and theorist Pelle Ehn disputes this purely instrumental view of computer technology, arguing that where there are computers, there are people programming and otherwise using them for communication and design. He observes that “the idea of mathematics and natural science as normal science for a science of designing computer artifacts is due to history, tradition and coincidence, rather than fundamental reflections of the subject matter” (Ehn, 1988, 147). Ehn goes on to trace Habermas’ critical reflections on the nominal scientific interests in human knowledge, noting that in post-industrial society, “labor takes place in ‘the functional sphere of *instrumental action*’ where we, as human beings, encounter objects as things, events, and conditions that in principle can be manipulated. The knowledge interest of technical control concerns instrumental action” (Ehn, 1988, 149).

In an environment that emphasizes *automating* over *informating*, such an epistemological framework has pragmatic appeal within the context of a particular model of industrial production. However, it is essentially anti-democratic. In a more highly realized democratized work environment, those “things, events, and conditions” would arise as a consequence of the utter particularity of labor (Hamman, 1999) — they are, in a very real sense, *subjective* material. In order to amplify *subjective* involvement in the workplace — to bring about a more democratically endowed workplace — Ehn petitions a *design*-based understanding of computers: one that accounts for both their automating and informating transformational capacity. Such an approach to computer system design requires participation of both the system developers (programmers, designers, etc.) and the people who use those systems. As participants in the design of the systems they use, humans participate in the design of the very representations that condition their work and play environments.

3. FROM TAYLORISM TO ONTOLOGICAL DESIGN

“Interface Culture”

The computer constitutes a paradigmatic shift in the possibility for work as a learning experience, providing a supportive vehicle for an interpretive technological engagement. Nevertheless, the Tayloristic search for the “perfect” computer has translated most recently — and with almost devastating ubiquitousness — to the so-called user-friendly computer interface. By simplifying the interface, computer interface designers have reinvigorated the mechanistic legacy that computers threatened to undue when they forced the computer user to communicate by writing computer programs. The modern view of human/computer interaction regards the computer interface as a “meta-form” that guides us through an otherwise indeterminate “information-space,” thus sparing us “the risk of losing ourselves in the surplus information” (Johnson, 1997, 27). “Ease-of-use” has triumphed over representational flexibility, while the GUI (graphical user interface) has replaced programming as the primary means for communication. The principle model of contemporary interface design (often referred to as ‘user-centered’ design) is that of a gulf separating domain-specific activity and computer system behavior (Norman, 1986). Accordingly, interface design tends to privilege the former over the latter, adjusting the I/O behavior of the computer in order to better represent the objects and concepts reflective of a particular domain activity.

The notion of bridging different abstractions to facilitate system interaction is not a novel idea — it is the very foundation of computer system design, from hardware up through operating system. It is thus a bit inauthentic to legitimate the normalization of computer interfaces upon the principle of bridging a cognitive gulf. The question is not so much whether to bridge such a gulf: the question centers on precisely how the resulting representational frame is to signify the problem domain in question. Who is to say that the representations resulting from such a cognitive bridge is any richer or even more "useable" than the I/O representations to which it maps? What are to be the criteria that will define the signifying functions constituting an interface? Computers are not stovetops and doorways whose interfaces signify trivial domain activities — they are machines for constructing representations. However, in its search for the perfected and cognitively *smoothed out* interface, user-centered design reflects the rational idea that there exists a perfect representation for a particular kind of activity.

The resulting interface makes implicit particular design criteria in ways that can be very subtle. Oftentimes, users are not even aware that their own internal processes are being silently conditioned by the computer interfaces they use — a conditioning that can very often result in an impoverished view of the possible ways in which one might think and act with respect to the domain in question. It is because of this that interface design theorist Liam Bannon cautions that computer interface design should not simply focus on the performative aspects of human/computer interaction (i.e. making it 'easier' to use); it should strive "for a more comprehensive, more enlightened view of people that recognizes their need for variety and challenge in the tasks that they perform" (Bannon, 1986, 26).

Maturana and Varela understand the imperative of human design along similar lines; they propose a view of cognition, on biological grounds, that suggests the richer design imperative Bannon petitions. They view cognition not as a construction of representations in the brain, but as a patterning of behavior in response to stimuli, or "perturbations" (Maturana, 1980). The cognitive system is a 'closed system' that maintains its homeostatic equilibrium by continuously adjusting the structure of its components in response to stimuli. In so doing, cognitive systems become structurally *coupled* to other systems in their environment, thus participating with other interlocked systems in linguistic behaviors that constitute particular 'consensual domains' (Maturana, 1980). Interaction among systems becomes a kind of dance in which each system *learns* how to maintain its homeostatic equilibrium in the environment of the other. Language is thus constituted by the particular consensual interactions among systems. Understood in this way, language functions on a connotative, rather than denotative, level. As Maturana observes, "the basic function of language as a system of orienting behavior is not the transmission of information or the description of an independent universe about which we can talk, but the creation of a consensual domain of behavior between linguistically interacting systems through the development of a cooperative domain of interaction" (Maturana 1980, 50).

This notion of cognition and communication as an orienting behavior gets a boost from more recent research in cognitive psychology. Steven M. Smith, for instance (Smith, 1995), suggests that for tasks requiring creative thinking, memory needs to be periodically 'primed' with fresh inputs; otherwise, the thought process tends to recycle previous paths of memory activity, promoting what Stevens and others term *fixation*. More importantly, Smith's research shows how negative priming can inhibit problem-solving activity. This is most readily accomplished by introducing a cognitive trigger which makes the problem data appear more *familiar*.

Cues that transform unfamiliar data into familiar data are always more difficult to eradicate — they force the thinking process into a kind of deadlock. In (Luchins et al. 1950) an aggregation of such cues is said to impinge on humans' ability to solve problems and engage in creative thinking. This more general epistemological fixation was termed *einstellung*. They argued that creative thinking and problem solving activities call for fresh inputs in order to de-familiarize otherwise familiar principles and ideas.

Ontological Design

There are many tasks which require stable and fixed representations. Most people would argue however that these kinds of tasks ought to be of relatively short duration and should not dominate our work and play environments. In activity environments which value the *informating* capacity of computing, human/computer interaction ought to be less concerned with representing fixed and stable referents — that is, with being "user-friendly" — than with presenting dynamic and, to a degree, *unstable* referents in order to facilitate creative thought and activity. Constructed in such a way, computer interfaces can teach their users by bringing them into a kind of *dialog* — a mode of interaction in which otherwise familiar domain-related concepts can be, at least temporarily, called into question, their performative hegemony briefly arrested. Knowledge thus would no longer be purely passive and declarative, reflective of well-traveled modes of activity; rather it would become dynamic, activated within the particular unfolding of interaction. As Pelle Ehn writes, the result of such an interaction is *insight*: "By actively treating well-known situations as if they were something else, or by actively approaching them from a different point of view than the normal, we may produce new knowledge about them. To *obtain* insight you have to know the practice you are reflecting about. To *produce* insight requires the competence to reframe something well known in the light of something else" (Ehn, 1988, 90).

The goal of interaction is thus not so much to orient the user into a particular way of regarding the things and events that define a problem domain, but to help the user discover something new about the problem domain and, consequently, to enlarge her understanding and ability to creatively think in that domain.

Programming

Programming provides one way for engendering design thinking in a problem-oriented (problem-posing and problem-solving) domain. With this term — 'programming' — I refer not only to software development *per se* (though this is perhaps its most compelling form), but to an activity — an approach to design — that is *rule-based* (Laske, 1991). Rule-based design explicitly foregrounds the process and models by which design artifacts are molded. Artifacts derive their fundamental origin —their *essence* — from a specific design process. This is because rule-based design emphasizes the *particularity* of the labor and the thought exerted in the production of artifacts. These artifacts include the objects and distinctions whose manipulation constitutes the productive process.

This can be contrasted with *example-based* design methods, in which artifacts reflect, in some manner, already existing materials and derive from historical process and design models. In example-based design, the particular labors and thought which constitute production are attenuated in favor of the veridicality of the process, its results, or both.

One could say that programming is an activity which seeks to frame a domain of interactions in such a way that (1) its processes are repeatable; (2) the artifacts generated includes those which describe those processes; and (3) the generation of design descriptions is at least as important as the other artifacts produced. Understood in this more generalized context, we can describe programming as a mode of interaction requiring cognitive engagement that has both breadth and depth. It has breadth in that (1) it encompasses a large domain of possible interactions and representations; and (2) it makes it possible to build a broad range of interaction and representational implementations into a system. It has depth in that it invokes memory activities at all levels, from internal memory and thinking, to social memory and public articulation.

At the level of internal memory and thinking, programming provides an environment for the production of external cues, in the form of the explicitly externalized data structures and algorithms required in programming. At the level of social memory and articulation, programming requires the construction of representations that participate in a larger social language game. Programming artifacts include not only program source code, but design documents, research position papers, articles, and a variety of public forums in which the ideas expressed in those artifacts are discussed and exchanged.[1]

Programming is therefore an interactive framework which combines *automating* with *informating* in a manner that favors creative thought, idea formulation, and public communication. It is an activity by which people "form or achieve a certain kind of insight, a theory, of the matters at hand" (Naur, 2002, 227). The design artifacts, communications, and theories posed in programming *posit* a world — they "bend our way of thinking of the past and the future" (Ehn, 1988, 110) and provide a context to communicate that world within a larger community. In this regard, programming (again understood in the wider sense of the term presented here), emphasizes the *subjective* dimension of technology. This is because programming allows humans to externalize, in an explicit manner, the otherwise purely internal qualities of their thinking. Programming projects self-referential activity into an allo-referential realm (Laske, 1980), allowing humans to clearly realize (or perhaps knowingly reject) otherwise invisible qualities of their own thinking and activity. It is by such activity that subjectivity itself becomes fluid and dynamic; the 'subject' becomes mutable and emergent, rather than fixed and transcendent (Hamman, 1999).

4. XENAKIS AT WORK

Discourse

In many respects, Xenakis invented the very idea of the interface for musical design. Though he did not *invent* rule-based design *per se*, his working method sublimated rule-based design, transforming it from mere 'shop-talk' to near iconic status. In the opening pages of *Formalized Music*, he writes: "The effort to reduce certain sound sensations, to understand their logical causes, to dominate them, and then to use them in wanted constructions; the effort to materialize movements of thought through sounds, then to test them in compositions; the effort to understand

[1] One could say that *Journal of New Music Research*, to a great degree, constitutes a repository of programming artifacts.

better the pieces of the past, by searching for an underlying unit which should be identical with that of the scientific thought of our time; the effort to make 'art' while 'geometrizing', that is, by giving it a reasoned support less perishable than the impulse of the moment, and hence more serious, more worthy of the fierce fight which the human intelligence wages in all the other domains — all these efforts have led to a sort of abstraction and formalization of the musical compositional act" (Xenakis, 1971, ix).

In this opening salvo, Xenakis declares a technological imperative for music by rhetorically associating the needs of musical technique with the then-dominant technical rationality (e.g. "searching for an underlying unit which should be identical with that of the scientific thought of our time", etc.). This very declaration is itself fundamentally technological in that it takes music technique out of the tradition of 'craftsmanship' (and the centuries-long tradition that canonized it as such), and situates it within a modern technological discourse. Musical (and more specifically compositional) technique is no longer relegated to the role of 'parlor-conversation,' and the similes through which it was so often expressed. Nor was technical discussion to be grounded in the performative concern for communicating the artist's "intentions," or the specific "meanings" of a given work or set of works (e.g. music history). Rather, musical technique was to be understood as central to music expression itself.

One by-product of this shift in ideological foundation was a calling into question the criteria that defined aesthetics of the previous 150 years — the cult of 'beauty' and 'truth' which predominated musical discourse. Even where Kant's notion of the Sublime applied, it was understood allegorically, as would befit the literary tradition underlying musical discourse during this time. But as Xenakis writes, "the quantity of intelligence carried by the sounds must be the true criterion of the validity of a particular music" (Xenakis, 1971, ix). And though the cult of beauty in art had already long since been deposed, it was Xenakis (among others) who took it one step further: he posited a musical dialogic whose concerns were completely *orthogonal* to those underlying questions of beauty or ugliness. It wasn't that Xenakis sought to overturn the aesthetics of beauty in music (as, for instance, the Futurists and Dadaists had already accomplished some 30 years earlier); rather, his articulations had the effect of subverting the very relevance of such an aesthetics to actual music research. Beauty was to have a *holistic* integrity, as applicable to raw materials, data, algorithms, and constructed processes, as it is to the more traditionally apprehended musical works they engender.

Matter/Material

Xenakis' compositional process can be understood as a concern for the differentiation of matter and material. As it was for contemporaries Gottfried-Michael Koenig and Herbert Brün, for Xenakis, the genesis of sound was its constructive potential. Like Max Mathews, Xenakis invented languages for programming in music. But whereas Mathews sought to support the algorithmic isolation of sound — and hence create a design environment for the veridical projection of sounds — Xenakis sought to engineer a collision between the centripetal force of sonic matter and the centrifugal force of human mediation (Di Scipio, 1994). Within the domain of music analysis, the former attitude emulates Helmholtz' exchange of "intuition by rigorous scientific methods [making] a clear separation between art and science" (Leman, 1995, 10). For Helmholtz, the separability of the acoustical event from the context of its occurrence was a necessary form of data reduction. And yet, as Xenakis demonstrated, compositional technique provides the means for overcoming the otherwise unwanted resistance of material, returning material to its cultural facticity (on this, see also Koenig, 1978).

Example-based compositional thinking is reflected in a somewhat slavish attitude toward material — an unwillingness to permit in material the presencing of its own construction. Such an attitude reaches its apex in the notion of timbral mimesis (Emerson, 1986, 18) wherein, sounds are treated ontologically, as preexisting and largely self-contained artifacts constituted by particular features which make them, for some reason or another, musically 'interesting.' And yet, even in Xenakis' *musique concrète* works, the semiotic and ontological quality of sound was used as a foil in the performance of a resistance between those qualities and the manipulative genesis of its constitution as *specific* material. In *Bohor*, this transmigration formed the musical dramaturgy itself. In *Concret PH*, material derives not so much from its internal qualities as much as it derives from its composition as noise impulses (Di Scipio, 1998, 213). In both cases, *material* becomes *matter*; its inherent and certainly symbolic functionality is drowned out in its transformation into constructive actualization.

In a somewhat similar fashion, in his GENDY program, Xenakis transformed the waveform from an optimization technique (in synthesis algorithms and keyboard synthesizers) into an *idiomorph*. As was the case in Herbert Brün's SAWDUST (Blum, 1979; Grossman, 1987), the waveform became the sonic *glyph* which formed the basis for its own elaboration. Its constructive force projected a dialectical character: inherent in its very structure was the possibility for its elaboration as musical form (Jameson, 1971). Functions and transformations acted upon the most intimate aspects of the particular structure — they were coupled to that structure and would be, as such, unthinkable as disembodied and generic procedures for sound manipulation more generally. The very nature of the fundamental element of sound was its constructive capacity.

In GENDY, the computer provided for Xenakis a means for constructing matter and, through specified operations, transforming matter back into material (as his ST program already could do some 25 years before). The UPIC system provided similar means, though with dramatically different outcomes. As a GUI, UPIC preserved the constructive hermeneutics that by then (the early 1970s) characterized Xenakis' working style: the graphing out of linear transformations applicable to a specific ensemble of parameters. In all such cases, the composer was given the ability to infuse acoustical matter with the mark of his own hand and his own mind. The computer became an interpretive framework for the construction of a highly idiomatic and utterly personal task environment.

This is Xenakis' musical insistence: that material arise directly from an intrusion of *technique*; its very ontology (including its resistances) arises from the particularity of the labor that produces it. What compelled Georges Seurat's use of tiny colour dots was not so much the idea that the visual world was so-constructed (though one might note the cruel allegory associating Seurat's points with contemporary physics); rather, it was the set of painterly techniques that it made available: the use of dots provided for the painter a new way for engendering a material. Similarly, Xenakis' formulation of sonic 'microstructures' introduced the possibility for mediating the unfolding of sonic material which that particular formulation alone made possible. The very origin of sound was constituted solely in the labor (both physical and mental) under which it arose. It is for this reason that Xenakis' glissandi (his trademark sonic ideogram if you will) *sound* completely unlike those of other composers — their sonic identity is rooted in the very technical (some might say 'extra-musical') means by which they are formulated. It is a material that could never be divorced from technique, without disclaiming the very nature of that material.

Artificial Intelligence

Central to Xenakis' technique was the primacy of the *particularity of technical activity*. Precisely *how* one does things greatly determines the outcome: anything that productively results from a particular activity can be traced to the very particularity of that activity. Seurat's canvases could not have been made by any other technique than that which he adopted to make them. Similarly, Xenakis' musical works bear stark testimony to the experimental foundation of their composition — they could only have been produced through those techniques, by that composer.

It is in this way that Xenakis' approach to computing engendered a dialectical synthesis of *automating* and *informating*. For Xenakis, automation was not merely a means toward the production of music artifacts—a kind of computational book-keeper. Rather, automation provided a framework for epistemological investigation concerning the very nature of sound and music. In automating certain compositional tasks, Xenakis was able to bring about a focus on meta-musical and compositional design issues that simply would not have been possible otherwise. In doing so, he exposed the very "communicative" and, more importantly, the "reflexive" dimension of computing. The utility of computing arose not simply in rendering objects solely for their descriptive or qualitative characteristics, but in exposing the functional criteria by which those objects might be constructed.

The role of automation, therefore, was to increase the *informating* context of musical data—to make it possible to study and design both temporal and extra-temporal notions of music and sonic transformations without necessarily becoming bogged down in the particulate *quanta* itself. It is as such fitting that the restrictions imposed on musical data by functional rules were "more of a general canalizing kind, rather than peremptory. The theory and the calculation define the tendencies of the sonic entity, but they do not constitute a slavery" (Xenakis, 1971:34).

Such an approach to technological activity understands that activity—and its products—as *artificial* (Laske, 1992; Simon, 1969). Whether they are *intelligently* artificial depends on whether the choices made were genuine choices made by a human or were built into a system and thus invisible to the human (and thus not the result of choice). A system of interactions that empowers its user to make real choices bears witness to an explicit involvement of human thought, and, for this reason, constitutes a form of what Feenberg termed *subversive rationalization* (Feenberg 1995).[2] Subversive rationalization "represents an alternative to both the ongoing celebration of technocracy triumphant and the gloomy Heideggerian counterclaim that 'Only a God can save us' from techno-cultural disaster" (Feenberg, 1995: 20). Subversive rationalization counters the tendencies of modern technological discourse toward cultural totalization, admitting the centrality of the particularity of human labor and thought in the articulation of technological transformation.

In embracing modern technology as a context for highly particularized technical experiment, a composer like Xenakis, in many ways, returns modern technological practice to its roots in "autonomous craft labor" (Feenberg, 1991, 26),

[2] See also Di Scipio 1997.

particularizing, and thus radicalizing, the very “things, events, and conditions” (Ehn, 1988, 149) that populate human cognitive and intellectual environments. And yet in directly linking that activity to a modern aesthetic and technical practice, Xenakis transformed the very principles that define autonomous craft labor, infusing it with the dialectical problematic that informs modern technology.

5. CONCLUDING REMARKS

It might seem ironic that one would find in the activity of art-making — the very activity that, according to modern myths regarding art and science, most strenuously opposes itself to the rationalities of modern technology — the possibility for the transformation of the technological base. And yet art-making poses a unique set of epistemological and, as such, technical problems, since it is not just concerned with solving problems, but with generating and framing them. It values itself in the kind of *revealing* that Heidegger described as constituting the essence of technology. Though there is much to question in Heidegger’s position on technology, his comments regarding the ontological character of technology are pertinent. In particular, Heidegger finds a direct link between technological practice (*techne*) and art-making (*poiesis*) in that both are a form of *revealing*; for him, *techne* and *poiesis* constitute highly overlapping domains of activity. Regarding ancient Greek art, for instance, Heidegger writes: “What was art — perhaps only for that brief but magnificent age? Why did art bear the modest name techne? Because it was a revealing that brought forth and made present, and therefore belonged with poiesis” (Heidegger, 1977, 316)

Much the same could be said regarding advanced contemporary art. In embracing technology, advanced artists transgress the ideological foundation that otherwise marries technology to dominant power relations. They do this because it is in the very nature of radical art-making to push against the constraints which mastery brings with it — to radicalize the task environment that situates one’s working habits and practices in order to engender a new model of materials: a *re*-presentation of working process.

In this way, artists bring about the transformation of technology by redesigning the ideological base on which its founded. Moreover, in embracing modern technology and radicalizing the ideological imperatives by which it is dominated by power, artists return subjectivity from the merely individual and internal into “the network of exchange relationships and exchange values” that govern a society (Marcuse, 1977, 4). They do this not through the appropriation and internalization of dominant ideological and practical imperatives, but through a rethinking of the technical base upon which those imperatives are built. Such a rethinking of the technical base requires a commitment to a technical mastery — a commitment that is commonly thwarted by the productive incentive that guides many toward the very “user-friendly” interfaces which most strongly reflect the very dominant imperatives one might otherwise wish to subvert.

In this paper I have attempted to briefly present some ideas from critical theory as well as recent reflections regarding programming and software design in an attempt to understand the unique qualities of Xenakis’ way of working and composing. In doing so, I reviewed some of Andrew Feenberg’s ideas on the desirability for a democratized technological frame, one which reflects a variety of activity and philosophical and methodological imperatives. Such a democratized technological frame can, in my view, only be fully realized when it is the expression of *particularized* thinking and labor. User-centered interface design methodologies may make computers easier to use, but they also attenuate the capability for a user to develop cognitively and epistemologically deep relations with the tools which they implement. Rule-based design (of which programming is but one form) exemplifies the kind of epistemologically rich interface that allows humans to creatively design their task environments in order to effect a *re*-presentation of the material and tasks that populate that environment. Xenakis was one composer who understood the significance of rule-based design to a modern aesthetics, and applied rule-based principles in all of his work — whether actually using a computer or not.

Acknowledgments

I would like to thank Agostino Di Scipio for his helpful comments regarding the initial draft of this paper. This paper is dedicated to Paula Pribula-Hamman.

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