UC San Diego
UC San Diego Electronic Theses and Dissertations

Title
An Endless Ladder: The Preservation of Digital Interactive Artworks

Permalink
https://escholarship.org/uc/item/71r4h2hv

Author
Ponce, Jason

Publication Date
2022

Peer reviewed|Thesis/dissertation

eScholarship.org Powered by the California Digital Library
University of California

UNIVERSITY OF CALIFORNIA SAN DIEGO

An Endless Ladder: The Preservation of Digital Interactive Artworks

A dissertation submitted in partial satisfaction of the
requirements for the degree Doctor of Philosophy

in

Music

by

Jason Ponce

Committee in charge:

Professor Miller Puckette, Chair
Professor Morana Alac
Professor David Borgo
Professor Shahrokh Yadegari

2022

Copyright

Jason Ponce, 2022

All rights reserved.

The Dissertation of Jason Ponce is approved, and it is acceptable in quality and form for publication on microfilm and electronically.

University of California San Diego

2022

DEDICATION

This document is dedicated to Gabriel and Mary Beth Ponce, my father and mother. Though I may not have given them much choice in the matter, their early willingness to let me explore the world on my own terms has made all the difference in my life. What things I have seen and done have been made possible by their their bottomless well of love and support. I am so grateful.

EPIGRAPH

Death is always on the way, but the fact that you don't know when it will arrive seems to take away from the finiteness of life. It's that terrible precision that we hate so much. But because we don't know, we get to think of life as an inexhaustible well. Yet everything happens a certain number of times, and a very small number, really. How many more times will you remember a certain afternoon of your childhood, some afternoon that's so deeply a part of your being that you can't even conceive of your life without it? Perhaps four or five times more. Perhaps not even. How many more times will you watch the full moon rise? Perhaps twenty. And yet it all seems limitless. [25]

Paul Bowles

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF LISTINGS

ACKNOWLEDGEMENTS

I am incredibly grateful to Miller Puckette for his scope, his humor, and for letting me find my own way. I cannot imagine anyone else who could have done for me what he has done (especially when that was nothing), or could have supported my work in the very subtle and specific ways that he has.

I have never known a person more deeply, outrageously committed to their purpose than John Luther Adams. Our work together has been all the things I ever wanted as an artist: vital, exacting, deep, mildly impossible. His generosity and trust in me have shocked me at times, and I often find myself humbled before the task of preserving the things we have made so that others might experience them (see literally everything below). During our time afield I have strained to hear the world the way he does, and my relationship with Alaska—already a place of great personal significance—has taken on a renewed grandeur through our kinship.

Finally, to all my dear friends and colleagues with whom I have made art and music over the years: my work with you has always been my best work. In exchange for your love and faith I offer you a lifetime of commitment to our shared dreams, along with a ceaseless wonderment at how I can be so lucky to know you. Thank you.

VITA

2001-2003	Resident Instructor & Composer, Kraton, Yogyakarta, Indonesia
2004	Bachelor of Science, University of California Santa Cruz
2007	Master of Arts, University of California San Diego
2009-2011	Instructor, Dept of Music, University of California San Diego
2010-2022	Founder & Artistic Director, Eidetic Interactive
2018-2021	Data Scientist, Data Analytics and Research Computing, Stanford University
2021-2022	Research Software Engineer, Roche
2022	Doctor of Philosophy, University of California San Diego

FIELDS OF STUDY

Major Field: Music (Computer Music)

Studies in Compositional Algorithms and Audio Spatialization
Professors Miller Puckette and David Wessel

Studies in Digital Signal Processing
Professors Richard F. Moore, Miller Puckette and Shlomo Dubnov

Studies in Music Composition
Professors Roger Reynolds and David Cope

Studies in Interaction Design
Professor David Wessel

ABSTRACT OF THE DISSERTATION

An Endless Ladder: The Preservation of Digital Interactive Artworks

by

Jason Ponce

Doctor of Philosophy in Music

University of California San Diego, 2022

Professor Miller Puckette, Chair

Compared with more traditionally oriented mediums of artistic creation, art that is time-based, technologically specific, site specific, and intended to be "permanent" poses unique challenges when considering its potential longevity. Institutions engaged in holding digital cultural objects must address the same problems of technological obsolescence that have been central within the development of digital technologies generally, as well as similar questions of physical preservation that arise in the conservation of any cultural object. Such

works require rigorous and specific ongoing maintenance while also contributing significant economic stresses to the collecting capacities of the institutions that hold them. John Luther Adams' *The Wind Garden* and *The Place Where You Go To Listen*, with which I continue to be closely involved, face very real and complex problems for their continued existence. Both of these works rely on a computing architecture which, given enough time, will cease to run on any computer without significant translation and redesign. While both works have institutional affiliations, the former as part of the Stuart Collection at the University of California, San Diego, and the latter under the auspices of the University of Alaska's Museum of the North, each demands a continuous allocation of knowledge, resources, and attention that outstrips either institutions' abilities to simply "hold" them as they would more traditional media. Similar questions of conservation and longevity are currently being asked by the Nam June Paik Art Center regarding the future of Paik's *Something Pacific*, and other related works by Paik. In discussing the specifics of my own co-creation of these works, I address the wide array of issues surrounding the genesis and preservation of this type of work, including problems of the very definition of a work's "objecthood", the economic, technological, and cultural forces that threaten our ability to preserve this work, our cultural conceptions of "permanence", and the various philosophical binds encountered by other related artworks.

Introduction

Until such time it is decided that composition as we understand it is a futile pursuit, there is an implicit mandate that composed music be able to be reproduced now and on into the future. Standard Western notational practices exist in part to address this specific problem. But here computer music encounters a dilemma: how does one secure the future of a technological object that is conceived and created in one object-domain but mediated and articulated within another? Stated another way, if due to a scarcity of resources, or the availability of a mediating technology, or for any other reason, a work becomes inseparable from the system with which it was created, what becomes of that work when that system becomes obsolete, broken, or disappears entirely? How are we to conceive of such a work in the context of the machines and processes created after the fact, be they known to us now or yet-to-come, that will be used to interpret and perform repertoire in the future?

My interest in this topic has grown out of my co-creation of several major permanent digital interactive installations.[1] Inherent in the discussion of this

[1] Officially, two of the installations discussed extensively in this paper, *The Wind Garden* and *The Place Where You Go to Listen*, are the work of John Luther Adams. At the same time, it is also true that these works would not exist without my creative contributions, both past and future. This is an issue that must be confronted in the course of making, understanding, and attributing collaborative art, and perhaps especially artworks that rely

work, and indeed all creative work that engages rapidly changing technologies, is the accumulation of both wholly unanswerable questions and questions whose answers are only satisfactory or relevant for a limited time frame. The topics I will discuss here are drawn from questions to which, in my role as collaborating artist and engineer on these artworks, I have been compelled to provide some kind of answer. In some cases I have answered a question knowing that my solution would have only short-lived acceptability. But the imperative to "make it work" demands a certain resourcefulness, and it has been in my own interest to think on both shorter and longer time frames while addressing a single problem within the functioning of a work. This document, therefore, will lean into the accumulation of unanswered and unanswerable questions because sometimes the simple awareness of a question guides an approach. Given my survey of writings on this topic, many of which will be referenced throughout this paper, it appears that only a very niche segment of the population (primarily professional archivists) are engaged with these questions on any level. Our current interactions with digital technologies at large are shaped by our collective engagement (read: via political non-engagement) with overwhelmingly large corporate interests. For our relationship to digital objects to change, these conversations must exit niche circles and become part of a larger conversation, with a level of participation significant enough to push

---

on deeply interactive systems. In all cases, the more inherently collaborative the artwork is, the more "authorship" becomes confounded. It is a particularly pointed question within the creative culture that has grown up at IRCAM [195] and at similar computer music centers using IRCAM as their model for creative collaboration. In my particular case, John Luther Adams would not define me as "author," but I do not believe he would define me as "technician" either. This document will not attempt to untangle the issues of authorship in collaborative work more generally.

back against the prevailing corporatism currently dictating the parameters of our digital lives. This is to say that the questions I accumulate herein effect not only artists working in a digital domain and the archivists trying to preserve their work, but a major segment of the population that engages with digital technologies in their everyday lives.

There are several baseline approaches for dealing with the technological obsolescence of a specific artwork. One approach to the survival of such works is via direct translation. The evolution of computing technology ensures that such translations are commonplace in industry, and we can observe their effects in many areas. In software engineering such a translation is known as a *port*. A software port is a specific kind of transformation applied to code that allows software written for one system or language to run on a different system or language. Since the domains of computer music and software engineering overlap strongly and in multiple ways, the software port is a useful basis for comparison.[2] In other scenarios, following the passage of a quantity of time, it may be required to execute a full emulation of whole machines/systems in software such that the original code can be executed "natively," or without modification on another machine.[3] Both are serious undertakings, both add considerable complexity to the original object, and both occur in computer music on a regular basis.

One well-known and particularly compelling example from computer

[2]For example, the long history of competition between Apple and Microsoft has demanded the porting of several softwares native to a Mac or a PC over to the other platform in order to stay competitive.

[3]For example, via emulation it is possible to run the original Apollo 11 Guidance Computer on a Mac.

music that approaches some of these technical and aesthetic issues head-on is the Pd Repertory Project (PDRP). PDRP, developed by Miller Puckette with Kerry Hagan and Arshia Cont, is a growing library of significant works from the computer music repertory which have been recreated using the open-source Pure Data (pd) platform. In Puckette's words:

> The last 35 years have seen the development of a significant repertory of music involving concert instruments whose sound is enhanced or transformed using live electronics. The realizations of many of these pieces have depended on specific items of hardware or software which, while chosen for their expediency at the times of the premieres of the pieces, will eventually become impossible to find, and in some cases are already becoming scarce...In addition to making it much easier to perform these specific pieces, the project aims to to fill three other useful functions. First, the realizations will serve to document the pieces in a way that will be useful to musicologists. Second, they will serve as a model showing how one might realize pieces involving real-time electronics in a less ephemeral way than is now often the practice. Finally, these realizations should be able to attain a higher level of audio quality than previous ones. [153]

Puckette's observations are echoed more broadly by the organizers of Projet Antony, a group which "inherits many initiatives and research projects initiated in recent years to safeguard the heritage of music using digital technologies":

> The durability of works using real time devices is undermined by the rapid obsolescence of computer programs. Faced with this problem, a few initiatives exist, such as the Pure Data Repository, which makes emblematic works rewritten with relatively durable IT tools available, because they are located in the Open Source domain. International projects, such as the ANR CASPAR project, have provided the expertise of digital data archivists, seeking to apply the recommendations of the OAIS in the fields of music. They make it possible to perpetuate file

> formats, document technological devices, develop an organology of electronic instruments, ensure the playability of the electronic musical instrument and preserve audio and video documents of public performances. The Gamelan or ReKall projects have enabled the development of tools to document the genesis of works. The MUSTICA and then Sidney environments developed at IRCAM, for their part, focused on archiving geared towards the possibility of continuing to play works. [8]

Puckette's final line is noteworthy, as it acknowledges how the evolution of computing and audio hardware inevitably affects and changes the realization of musical works. It is an open question as to how much of the idiosyncratic sound of Max Mathew's GROOVE system is itself integral to the music produced with it during the late 1960s, but in the same sense that a guitarist might prefer the sound of a tube amplifier, or a recording engineer might make creative use of analog distortion, it is clear that that amount must be non-zero.

Personally, I find it difficult to imagine the significant works of, for example, Emmanual Ghent or Laurie Spiegel[4] without the specific machines that helped bring them into existence. Like a cello in a Bach suite or a pipe organ in a Buxtehude prelude, the technologies for which the music was created is part of the music in a fundamental sense.[5] Antoine Vincent, Bruno

[4]"Emmanuel Ghent (1925-2003) was a pioneering composer of electronic music and a psychiatric practitioner, researcher, and teacher...In the 1960s, Ghent pioneered the concept of electronic music by adapting a computer system, initially designed to synthesize the human voice, to instead synthesize music." [105] Laurie Spiegel (b.1945) "is known worldwide for her pioneering work with several early electronic and computer music systems...(her) best known works include her 1970s music, created on computers at Bell Telephone Labs, early work (c. 1980) in the online transmission of digital music, a realization of Kepler's Harmony of the World that went up on the Voyager spacecraft's golden record, and Music Mouse—An Intelligent Instrument for Macintosh, Amiga, and Atari computers." [127]

[5]We have long accepted the sonic result of porting Bach's keyboard works to the technology of the piano, while simultaneously understanding that these were not Bach's sounds. For

Bachimont, and Alain Bonardi (the last a Projet Antony organizer) already articulated this problem in 2012 not just as a technical hurdle to be overcome, but a hurdle which, if not overcome results in the direct loss of a particular cultural heritage, namely that of contemporary computer music:

> Among the numerous transformations brought about by digital technology, one of the most worrying concerns the conservation of contemporary musical heritage which is threatened, some works having already disappeared, for lack of tools allowing them to be replayed while avoiding technologies whose obsolescence is getting faster and faster: we can cite *Atlantys* by Tristan Murail, initially composed for two Yamaha DX7 synthesizers, whose performance in concert at Radio-France in 2009 was canceled because the devices had become obsolete and unreliable; it hasn't been reassembled yet. Note that certain practices have taken this obsolescence into account by presenting themselves as ephemeral; improvisation using live-coding is defined by nature as a phenomenon to be experienced in the moment, without sustainability.[6] [188]

Yet even though many of the machines of an earlier era of computer music, such as the Yamaha DX7, may be increasingly difficult to find and work with, or have vanished altogether, it is of course possible to recreate these

those performers actively engaged in this porting, this perhaps falls under Puckette's notion of attaining "a higher level of audio quality than previous," with harpsichord enthusiasts becoming culturally relegated to the niche of "historical performance."

[6]Original: "Parmi les nombreuses transformations entraînées par le numérique, l'une des plus préoccupantes concerne la conservation du patrimoine musical contemporain qui est menacé, certaines œuvres ayant déjà disparu, faute de représentations permettant de les rejouer tout en s'abstrayant des technologies dont l'obsolescence se fait de plus en plus rapide : nous pouvons citer Atlantys de Tristan Murail, initialement composée pour deux synthétiseurs Yamaha DX7, dont l'exécution en concert à Radio-France en 2009 a été annulée à cause du matériel devenu obsolète et peu fiable ; elle n'a pas encore été remontée pour le moment. Notons que certaines pratiques ont pris en compte cette obsolescence en se présentant elles mêmes comme éphémères ; ainsi l'improvisation faisant appel au live-coding se définit par nature comme un phénomène à vivre dans l'instant, sans pérennité."

works for modern audiences by understanding and replicating the technical processes behind the sound (as in the case of the Pure Data Repertory Project), by emulating the hardware itself, or by other means. Writing about the Faust (Functional Audio Stream) environment, Yann Orlarey has said:

> The long-term preservation of musical works using real-time computing devices is a complex problem, in part because the mere preservation of computer codes is not sufficient. Indeed, the libraries on which these source codes are based, the software that interprets or compiles them, the computers and the operating systems that make them work, are themselves subject to evolution, or even disappearance. In fact, there is a form of tension, almost irreconcilable, between the constant need for novelty and evolution of the tools of creation and the stability necessary for the long-term preservation of works that use these same tools. To try to resolve, at least partially, this tension, we suggest integrating the issue of preservation into the design of creative tools. Creative tools must become preservable, in the sense that they must be able to give a precise, human-readable description independent of any machine, of what they do, of their semantics.[7] [135]

Romain Michon describes Faust as, "a functional programming language specifically designed for real-time signal processing and synthesis. Faust targets

[7]Original: "La préservation à long terme des pièces musicales faisant appel à des dispositifs informatiques en temps-réel est un problème complexe dû, pour partie, au fait que la simple conservation des codes informatiques n'est pas suffisante. En effet, les librairies sur lesquelles s'appuient ces codes sources, les logiciels qui les interprètent ou les compilent, les ordinateurs et les systèmes d'exploitation qui les font fonctionner, sont eux-mêmes soumis à évolution, voir à disparition. De fait, il existe une forme de tension, presque irréconciliable, entre le besoin permanent de nouveauté et d'évolution des outils de création et la stabilité nécessaire à la préservation à long terme des œuvres qui font appel à ces mêmes outils. Pour essayer de résoudre, tout du moins partiellement, cette tension, nous proposons d'intégrer la question de la préservation dès la conception des outils de création. Les outils de créations doivent devenir préservables, au sens où ils doivent être capables de donner une description précise, humaine lisible et indépendante de toute machine, de ce qu'ils font, de leur sémantique."

high-performance signal processing applications and audio plug-ins for a variety of platforms and standards. The core component of Faust is its compiler. It allows [one] to 'translate' any Faust digital signal processing (DSP) specification to a wide range of non-domain specific languages such as C++, C, JAVA, JavaScript, LLVM bit code, etc." [114]

This is of course not to say that portability is not an issue elsewhere. There are valid comparisons to other technological objects, though the significance of the interplay between object, production, and replication diverge at certain points. Film, for example, must always be concerned with evolving formats and changing distribution channels. Today a film may be shot on film stock or on high-definition digital video, presented in a multi-channel auditorium or on a home television (or laptop, or phone), transcoded to various digital formats, reproduced on portable media or streamed over the Internet to be viewed in a browser. All of these format iterations exist in the service of the dissemination and preservation of the object, which arguably arrives to the viewer more or less intact. But film diverges from musical presentation in that it is not performed as such. In this way, I would argue that film is distinct from recorded musical performance, which is often a representational object, and not strictly the art object itself. A film has no other form than that form that was recorded; the *recording* of the actions of the film is the artistic object itself. Therefore, whereas musical performance that was once live or fully acoustic can be recreated as a new live or fully acoustic performance,[8] film necessarily must

[8]The relationship between in-person music making and recordings of music performance come up throughout this paper. Some of the complexities around the specific idea of "liveness" in musical performance are discussed further in Section 2.2.1

have its medium ported while maintaining the objecthood of the media as it was originally fixed. The effects of transformation, iteration and replication hold little allure for the filmmaker, as each iteration represents real, calculable loss in terms of control, quality, and in some cases, revenue.[9] Nor is it likely many filmmakers relish the idea of subjecting their work to the generations of digital compression and downsampling required to reproduce their efforts on portable devices.

What unites PDRP, Faust, and Projet Antony, and even more broadly focused digital culture projects such as Rhizome.org however, is a common conception of the digital artwork as situated within a particular frame of time that is contemporaneous with the tools used to create the artwork. By "situated" I mean, the artwork was conceived according to or within the limitations of technologies that were (presumably) state of the art at a particular time, and that it was given a performance that was finite in length around the time of its inception and creation. Vincent *et al.* put the finest of points on this: "What could be the goals of preservation? That open question does not ask for a single response...The first obvious objective is to offer the possibility of replaying the object preserved, that is, being able to *re-enter* it."[10] [188] The emphasis is my own, as it highlights the conception that the artwork is necessarily a thing of the past to be remade.

---

[9] See the Institute for Policy Innovation's report on movie piracy: "The True Cost of Motion Picture Piracy to the U.S. Economy." [170]

[10] Original: "Quels peuvent être les objectifs de la préservation? Cette question ouverte n'attend pas une unique réponse, mais nous nous limiterons aux aspects que nous étudions actuellement. Le premier objectif évident est d'offrir la possibilité de rejouer l'objet préservé, c'est-à-dire être capable de le ressaisir."

What if the performance of an artwork is ongoing in perpetuity, or at least across several generations? Or put another way, what if an artwork is not an idea that was locked to a particular time, performed at a particular time, and then put on a shelf of sorts, to be later dusted off, re-booted, and re-performed? And further, what if the work of art is not only intended to be continuously performed (it is intended to be continuously performing), but that performance is intrinsically tied to the environment in which it is situated? Orlarey's "irreconcilable tension" is doubly recast as a problem inherent within the life of the artwork itself.

Chapter 1

Future Ages May Be Forgiven For Concluding That The Main Focus Of Our Society Was Computer Games[1]

My creative practice over the last decade has forced me to engage at a very granular level with the topics discussed in this paper, so it is fitting that a discussion of problems facing digital art preservation generally be grounded by those specific pieces with which I have interacted directly, pieces I have worked at length to understand, to co-create, and to conserve. The three works that will be discussed in most detail are *The Wind Garden* (2017), *The Place Where You Go To Listen* (2004), both by John Luther Adams, and *Something Pacific* (1986) by Nam June Paik. In the case of the two works by Adams, I have assumed the role of co-creator, designer, engineer, programmer, project manager and all-around problem solver (i.e. the first line of defense in the

[1] The title of this chapter is in fact a quote drawn from Marc Weber's article, "Self-Fulfilling History: How Narrative Shapes Preservation of the Online World" in Information & Culture, Vol. 51, No. 1, 2016. [190]

conservation battle); in the case of the Paik, I have been commissioned, per the artist's wishes, to re-imagine the next iteration of that work in an updated medium. While articulating some of the overarching problems facing those engaged with preserving digital arts, I will also illustrate particular points with reference to other major works, the nature of which compel an engagement with the same types of imaginative problem solving.

All three of the "case study" pieces on which I have worked currently exist within the protectorate of museum collections. *The Wind Garden* and *Something Pacific* are part of the Stuart Collection at UC San Diego, and *The Place Where You Go Listen* is part of the permanent collection of the University of Alaska's Museum of The North in Fairbanks, Alaska. A central problem faced by all institutions working with their uniquely limited resources is how to decide what pieces merit "collecting," but I do not intend to get into a discussion around determining such merit, of which works are worthy of the efforts needed to conserve them: these three works have already been deemed worthy of conservation by reasonably stable and well-funded institutions. In the case of *The Wind Garden*, the creation of the piece was also commissioned by the collection that holds it. I will say, however, that in making such determinations, curators and conservationists have increasingly complex factors to weigh as more and more art is created in the digital realm: taking under your aegis a realtime generated, site-specific sound installation that exists for the sake of its ability to interact with the environment in which it is situated is a wildly different undertaking from holding either a marble statue, an old Pac-Man console or a fixed digital video. The decision to take up a realtime generated, site-specific sound installation is a decision to engage in a very non-theoretical and long-term struggle with Orlarey's "irreconcilable tension."

1.1 Objects

Throughout this discussion I will discuss multi-modal, live-generated installation works and their constituent parts (i.e. software, hardware, processes, algorithms, interfaces, sounds, etc.) as specific kinds of techno-cultural *objects*. Doing so allows me to situate them within a larger cultural framework of practice and production that will be important for a discussions about what computer musicians actually do. I will make liberal use of *object* in order to discuss different aspects of my specific areas of interest, even as those areas differ enough as to require rather specific shades of meaning. For example, I may present an existing work from a variety of media repertories as specific kinds of cultural *objects* at large, or refer to computer hardware, software or systems as "technological objects." My somewhat contingent conceptualization of *object* is intentional.

In constructing my own usage of object, it should be acknowledged in advance that use of the word already has a strong presence in the literature of music discourse and criticism, and within various philosophical and theoretical areas that are commonly adjacent. While these usages tend to be specialized and carry very specific meanings, they nevertheless remain useful here because aspects of those formulations continue to inform my own meanings in different ways at different times. In this sense I hope that the contingency of my definitions of "object" proves an asset, trading a portion of specificity for an interdisciplinary breadth more suitable for grappling with such multi-faceted subjects.

Idiomatic usage of object is particularly prevalent in the case of aesthetics and critical theory, appearing, in different guises, within the work of cultural theorists like Slavoj Žižek, Levi Bryant, and Graham Harmon, and features prominently within the various other branches of what has become known as Speculative Realism. As a recently fashionable "ism," Speculative Realism seems to have a surprisingly indistinct center. In his "Resources on an Emerging Discipline," Eric Phetteplace writes,

> Speculative Realism is difficult to define: like the hodgepodge of divergent theories falling under the label Postmodernism, it is less an internally consistent set of ideas than a diverse group of theories unified against a common adversary. Speculative Realists and their allies are combating what they call "correlationism," or the belief that all existence is reducible to the human experience of existence. Thus they claim, against theorists as varied as Immanuel Kant, Jacques Derrida, and Karl Marx, that there is a world outside of the mind, language, and economic forces. The exact nature of this world, however, is the source of much dispute. [143]

Phetteplace continues, "Due to the lack of authoritative resources, many of the most useful research sites related to Speculative Realism are of an informal nature, such as blogs, discussion lists, and individually maintained content lists, but they are all consistently maintained and of high quality." Nevertheless, from this grey place has emerged a vibrant collection of theoretical offshoots, including a resurgence of interest in Levi Bryant's Object-Oriented Ontology—a frame that is at least partially responsible for the critical narrative that is shifting the conversations museums and other collecting entities are having about their primary curatorial items of interest. After the wave of conceptual immateriality that characterized works like Sol LeWitt's ephemeral wall drawings (made to be painted over), and Martin Creed's *Work No. 227: The Lights Going On and Off*, in which a light in a room is turned off and on at five second intervals, there has been significant curatorial pressure over the past decade to hasten back to the more commodifiable and lucrative realm of physical objecthood. [148] To this point, when discussing his relationship with prominent art collector Charles Saatchi in an 2003 Time Out interview, artist Jake Chapman quipped, "I'm happy to acknowledge the prostitutional relationship between [Saatchi's] money and our objects." [54] Similarly, the 2016 Switch House/Blavatnik addition to the Tate Modern, funded by Russian oligarch-philanthropist Len Blavatnik, is largely dedicated to film, photography, sculpture and other objects squarely in the material domain. So while there may be no real consensus about what is meant generally by "object," the term has considerable resonance within both theoretical and consvervationist communities,[2] and this may be usefully applied in our discussion.

Meanwhile, this debate is generating thought and discussion that at times feels very relevant to the concerns of music studies. Žižek's critique of Levi Bryant's Object-Oriented Ontology, for example, rejects Bryant for indulging in a "premodern enchantment of the world," a sentiment which could function

[2]Furthermore, despite the acrimonious tone of some of these arguments, there are voices at the periphery arguing these parties are actually more aligned than they appear to one another. See Sterling Hall's (2012) self-published article, "Resonating Ontologies: The Illusory Nature of the Confrontation Between Žižek's Ontology and Speculative Realism" for one such analysis. [74]

at least as well as a modernist rallying cry prefiguring the abandonment of 19th century romanticism. Similarly, Žižek's own implementation of objecthood, while not expressly musical in nature, at times appears to echo Adorno's own attempt to reconcile the relationship between musical subject and substance. Žižek states,

> ...subject is not just split like every object between its phenomenal qualities (actualizations) and its inaccessible virtual in-itself; subject is divided between its appearance and the void in the core of its being, not between appearance and its hidden substantial ground. It is only against this background that one can understand in what sense subject effectively "is" an object. ([198] p.187)

Versus Adorno, writing specifically on the topic of subject in music:

> The separation of subject and object is both real and semblance. True, because in the realm of cognition it lends expression to the real separation, the rivenness of the human condition, the result of a coercive historical process; untrue, because the historical separation must not be hypostatized, not magically transformed into an invariant...The image of a temporal or extratemporal original state of blissful identity between subject and object is romantic, however; at times wistful projection, today just a lie. ([4] p.246)

Elsewhere, aesthetic conceptualizations of objecthood frequently rely on the representational aspects of music, and are often held up by an implicit agreement that the musical score exists as a kind of pure representation. Forwarding this point of view in the body of musicology literature are theorists Nelson Goodman and Roman Ingarden [69], who both believe that an unambiguous connection must exist between notation and performance for a work of music to exist in a "legitimate" sense. The works discussed at length later in this document directly question any such unambiguous connection. In his book *The Work of Music and the Problem of its Identity*, Ingarden leverages this idea to reject much of John Cage's output after 1950 as not, in fact, being music. [85] This is, incidentally, the period when Cage began relying heavily on aleatorics, chance operation, and graphical notation—all techniques which challenge the absolutism of formal Western notation and result in what Ingarden calls a "weakening" of a work's musical identity. Goodman and Ingarden's suggestion that indeterminate musical objects—and by extension improvised or generated music—may not *exist* in the same way as notated music might seem like a logical conclusion at which to arrive when assuming a formalist type/token musical ontology. But this paradigm not only rejects or ignores important aspects of Cage's indeterminate works, but is also unable to account for what many musicians and improvisers know and understand intuitively: the "existence" of a musical work lies at least as much within the momentary act of its production as it does within any system of formalized representation. This suggests new kinds of musical objects at work whose interrelationships are inadequately described by the classical type/token semiotic model.

The "musicking" of Christopher Small [171] and the social economics of Jacques Attali [11] also inform my definition of object, as they in their own ways represent music-making as a multitude of historically rooted, economically informed, socio-political practices. Small writes,

> ...a musical performance is a much richer and more complex affair than is allowed by those who concentrate their attention exclusively on the musical work and on its effect on the listener.

> If we widen the circle of our attention to take in the entire set of relationships that constitute a performance we shall see that music's primary meanings are not individual at all but social... [171]

In this way the gestalt of a piece is a conversation between co-creating agents, adorned with a multiplicity of histories and distributed through time and place via the simple act of performance.

While I do not dispute that a formalist project of musical ontology can be valuable or that it might be applied usefully somewhere, I wish to depart from that here in favor of generative music processes, musics that are perpetually in the process of *becoming* [48]. Such music can represent a non-objectivist ontology of music that anchors the music within a network of practice and relation rather than aesthetics or metaphysics. In writing of objects and presuming clarity, my purpose is not to deconstruct or interfere with the term as it functions within any existing body of literature or research community, nor is it to promote a kind of musical epistemology that relies upon structures of difference, although, as I will discuss below, structures of difference must play a vital role in preservation efforts generally. I use it instead as a special semantic container that provides space for, or even encourages, intellectual flow between areas of study, that allows for imagination as well as rigor, and that mindfully hybridizes the diverse taxonomies that comprise the study of music and other time-based arts.

Interaction as we understand it here can be thought of as a family of technologies fundamentally enabled by other technologies, which are themselves fundamentally bounded by that which is available. Computer memory, CPU cycles, platforms, frameworks, networks, programming paradigms—in fact all the "objects" that are the raw materials of the technology artist—are the products of market forces that possess their own internal logics, and which may or may not be concerned with how the objects they produce are ultimately utilized. Certainly there are some benefits to this arrangement, since increased throughput, higher bandwidth and falling prices mean lower points of entry and fewer constraints for the artist. But, as shall be explored later, problems arise quickly at the nexus of corporatization, personal privacy, and creativity.

Technological Objects

It is a performer's job to hold up cultural objects for the scrutiny of others. In this sense, the "holding up" may be particularly evident when using computers to make music, since often what is being held up in performed computer music (intentionally or not) are the products of arbitrary internal design decisions, be they good or bad. Performativity, embodiment, instrumenthood, control, interface—these are all deeply representational aspects of computer music performance that rely on design decisions made well in advance of any public presentation. How does one articulate sound? How are metaphorical constructs such as the body, or the wind, or earthquakes represented? How closely or distantly does one orient oneself toward the historical prototype of "instrument"? What is shown to the audience and what remains hidden? These representations shape the narrative of "music made with computers," and how that narrative is communicated. They are, in essence, a discourse of their own, capable of bestowing or complicating meaning.

In Adorno's numerous essays on what he calls the "paradox of musical reproduction," he wrestles with this problem at length before ultimately concluding that representation can only fail the work. Implicit in his usage of language like "reproduction," "representation," etc. is Adorno's assumption that the work enjoys a kind of ideal existence (typically via the score) before and beyond any attempt to realize or interpret it. My goal here is not to delve into the nature of musical representation in general, or the score in particular; what is of interest here is musical action, specifically the representational interactive action that results in the creation of musical objects when using computers.

The nature of the technological object too has changed. What was once singular, localized, and possessed has become interconnected, distributed, and shared. Social media platforms, for example, present a specific kind of object to the user in the form of the platform itself (the app, the interface, the very social relevancy of the tool) and also the individual messages those platforms mediate, yet all are meaningless outside of their ability to interconnect with other similar objects. This also holds true for the underlying computer code that enables these kinds of objects. The *object oriented* model of programming specifies that programmers focus on the creation on logical groupings or *classes* of code called *objects*, which contains properties (attributes), methods (functions), data, and even other objects. Organizing code in this way ensures that it can be scaled and reused easily, and is an effective paradigm with working on large, complex projects that involve many developers and are targeted at a large numbers of users.[3]

[3]Although it is widely used, object oriented programming is only one paradigm for software development. *Functional* and *procedural* styles are also prevalent, for example, and have growing communities with vocal advocates.

The remarkable penetration of technology into so many different facets of modern life and the ways in which our interactions with each other perpetually seem like they cannot possibly become more mediated indicates a shift in the significance and meaning of what it means to be interactive. Margaret Morse writes:

> ...the primary ideological assumption about technology is that it should work. No wonder the term "interactivity" presupposes a fait accompli—that links in network of connections have been successfully made. However, unintentional failures of interactive hardware and software and of the humans that design and employ them occur at every level of cybersociety from AT&T down to the artists who toil, often collaboratively, as pioneers in labor intensive new media.[4]. The term interactivity thus refers to a state that is after or incognizant of painful effort and myriad unsuccessful, broken and invalid connections and attempts to interact that simply don't work. ([116] p.22)

Meanwhile, it can also be said that the depth of the state-of-the-art in human-machine interaction is largely due to the enormous influx of resources and research from private/public and corporate/academic institutions during recent decades, which requires rapid iteration, thereby ensuring that computing hardware and software are perpetually moving targets. As such, many of the central issues in interactive computer music are less "solved" than they are "approached" at any given time, according to the exigencies and affordances of that specific moment. Thus when viewed as a technological object, we find this kind of music falls into a very specific category of cultural production: one in which its objecthood is assured while its permanency is not. Since one

[4]For a larger discussion of this specific topic, see Chapter 4

of the primary objects of interest in computer music is often a performance rather than a device or a service, the value that object holds becomes less governed by the principles of obsolescence (graceful or otherwise), and more governed by the principals of capital and cultural production, artistic merit, and/or aesthetic beauty.

1.2 Museums, Libraries, Archives

> The decorations of the polished surfaces of the walls ought to be treated with due regard to propriety, so as to be adapted to their situations, and not out of keeping with differences in kind. In winter dining rooms, neither paintings on grand subjects nor delicacy of decoration in the cornice work of the vaultings is a serviceable kind of design, because they are spoiled by the smoke from the fire and the constant soot from the lamps.
>
> Vitruvius Pollio, *The Ten Books On Architecture*

> In 290 BC, Ptolemy I, in an effort to collect diverse global literature in a single place, established the first known museum in Alexandria. This museum consisted of a library, collections of artifacts relating to the nine muses, and facilities for research and teaching.
>
> Carrie Stumm, "Preservation Of Electronic Media In Libraries, Museums, and Archives"

As stated, the three case study pieces I will discuss are part of museum collections. Historically, music, as a time-based art form, has not fallen under the purview of museum activities, which have traditionally focused on more tangible media: media that has a fixed objecthood and also a fixed cost/value structure attached to it.

If one chooses to hire a group of musicians to entertain at a banquet of nobles, one is choosing to engage with a time-based art form (music) for perhaps a couple of hours (minus union-stipulated breaks). If one chooses to have the ceiling of the banquet hall in which the players will perform painted, one is choosing to live with the work of a specific artist for several years, or perhaps the rest of one's life. This carries with it an intrinsic sense of "an investment" to be protected (that which is not to be spoiled by smoke), whereas the hiring of musicians is by comparison a well-chosen, but singular application of disposable income, and the smoke of the charred suckling pig filling the room only adds to the enjoyment of the music (the creation of an ephemeral experience), even though it is also spoiling the new fresco (ruining a long-term investment). "Cost" for a museum is not only the cost of commission or acquisition, but of ongoing maintenance. The fresco that was poorly chosen for application in the "winter dining room" has a higher cost than the same fresco more wisely chosen for application in the sitting room. Likewise, media with a fixed objecthood inherently requires less maintenance than media with a dislocated objecthood.[5]

And of course, time-based art forms have until recently been largely

[5] In attempting to calculate such a cost, William Real, the former Director of Technology Initiatives at the Carnegie Museum in Pittsburgh, provides the following laundry list of potential costs: producing archival masters of audiovisual components, future periodic migrations of the masters to newer formats, producing successive generations of presentation media formats, acquisition of successive generations of presentation playback equipment, storage for the archival master (possibly off-site), acquisition of redundant equipment for later use as spare parts, in-house or outside expertise for diagnosis and repair of electronic components, bringing the artist (or artist's representative) for future re-installations, in-house expertise to maintain the piece while it is on view, in-house staffing costs, special documentation of the piece, and software maintenance (including reprogramming or program emulation). ([154] p.222)

outside the scope of museum conservation.[6] What preservation concerns have existed, therefore, within the field of Western concert music have necessarily focused on objects that can be saved for their historic value (scores, examples of historical instruments, the letters and other personal effects of composers), and objects that can be capitalized upon (published scores and sets of performance materials, recordings of performances of works, proprietary software like Max/MSP etc.).

1.2.1 The official view on museum conservation

Because the works being discussed herein are part of formal collections, and formal collecting is not a comparably developed component of modern musical creation relative to the visual arts, it may be useful in this context to understand the common view of collecting institutions (i.e. museums) toward conservation. The International Council of Museums Committee for Conservation (ICOM-CC) describes conservation thus:

> The activity of the conservator-restorer (conservation) consists of technical examination, preservation, and conservation-restoration of cultural property: Examination is the preliminary procedure taken to determine the documentary significance of an artifact; original structure and materials; the extent of its deterioration, alteration, and loss; and the documentation of these findings. Preservation is action taken to retard or prevent deterioration of or damage to cultural properties by control of their environment and/or treatment of their structure in order to maintain them as

[6] More remarkable than the building of the Philips Pavilion and installation of Varèse's *Poème Électronique* and Xenakis's 11 channel *Concrète Ph* inside the Brussels World Fair in 1958, is that the entire thing was demolished just one year later. [183] Granted, the pavilion was never conceived of as a "cultural object," it was entirely a commercial undertaking to promote the Philips corporation.

> nearly as possible in an unchanging state. Restoration is action taken to make a deteriorated or damaged artifact understandable, with minimal sacrifice of aesthetic and historic integrity. [131]

And for further clarity of terms, Michele Cloonan points out that "Preservation usually refers to the overall management and care of collections, while conservation is the treatment of individual items or collections of items." [36]

In the early days of digitization within museum culture, Sonia Kaytal notes that the view was that digital technology could be used to "better" preserve a physical collection and to allow broader access to the collection:

> As museums are increasingly viewed as spaces for civic engagement and education, they have moved from concentrating on objects to stories, and from collections to audiences. As a result, their objectives have moved beyond mere display of artworks to encompass conservation, digital cataloging, and archiving, in addition to building a number of possibilities for user participation...The museum no longer houses a static collection of objects, but rather a set of possibilities for human experience and participation between museum, artist, and user. [90]

Kaytal's implication, certainly, is that there has been a 1-1 transfer from physical object to representational digital space, that the digitization of physical work can give that work a prolonged life and in so doing, provide audiences broader meta-access to objects.[7] However, none of the works discussed herein submit to such simple re-classification of object domain, but rather expand the notion of museum-cum-set-of-possibilities perhaps even further than at the time of Kaytal's writing. Purely digital representations of multi-modal work could be

[7] Katyal discusses at length the clandestine laser scanning and subsequent 3D printing of the Bust of Nefertiti as punk counter transference of culture. ([90] p.1112)

created, but if they were to be created, they would be just that: a diminished representation (or documentation) of the original in the same way that a recording of a live performance is not itself the live performance.

The "property" oriented focus of the ICOM-CC definition is immediately problematized as one moves away from considering the conservation of physical objects via digital means and into wholly digital space. Francis Marchese, co-director of the Pace Digital Gallery at Pace University, points to how time-based digital art confounds the industry-wide boiler-plate stance articulated by the ICOM-CC:

> Traditional conservation practice thus focuses on an artwork as an integrated physical whole, the integrity of which must be preserved. Change is defined as a process that will deleteriously affect the stability of an artwork, moving it away from its original reference state and altering its identity.
>
> Time-based digital artwork does not fit this definition because change is an intrinsic part of its nature. Museum conservators in charge of maintaining time-based media, that is, artwork whose aesthetic experience evolves over time, realize this and are attempting to expand the conservation paradigm to accommodate digital art. [108]

This sentiment is echoed by Fernando Domínguez Rubio in his discussion of Nam June Paik's *Untitled* (1993),

> "...in contrast with more traditional artworks, like oil paintings, the preservation of media-artworks is not based on their capacity to be stabilized, but on their capacities to move and to change. These artworks only survive if they are continually migrated to different technological platforms." ([161] p.636)

Rubio defines such works as "unruly," as they not only demand reconsideration of the materials used to sustain them, but throw into chaos the traditional relationships between curators and conservationists in the process of defining meaning. This problem began to come to the fore long before digital technology started to confound the idea of holding and caring for "an enduring object." As Klaus Weschenfelder points out, "Many artists work performatively, context-related, and in various media...This leads to the fact that the Fluxus movements can be documented but not exhibited."[8] ([192] p.132) The same holds true for Cage's aleatoric works mentioned above. A set of instructions for a set of actions that may manifest in wildly different performative actions upon repeated execution occupies the same unruly realm of objecthood by only the thinnest of conceptual threads. This is analogous to the transformation of objecthood that results in holding and caring for obsolete instruments. Of course, at least with regard to physical objects it may be that some meaning is lost when we put, for example, a historic harpsichord on display in a museum, but at least we seem to be in agreement on the nature and meaning of the loss, as well as whose role it is to work through the problems that this presents, and even the tools used to address those problems.

1.2.2 Infinite variation

We lack sufficient historical distance compared to the speed of technological obsolescence in order to determine which of the countless models within micro-generations of, for example, analog synthesizers (a generation, here,

[8]For an intensely in depth look at these topics, see *Digital Art Conservation*, produced by ZKM Karlsruhe, and edited by Bernhard Serexhe. [169]

being vastly shorter than a human generation), are most worthy of preservation. Vincent *et al.*, in citing the unavailability of two functioning DX7s in order to perform Tristan Murail's *Atlantys* (1985), stake out a philosophical territory along the lines of:

> Murail is an important composer who has created a body of work that is significant to the history of Western Art Music $\Longrightarrow$
>
> Murail composed a piece using two DX7 synthesizers $\Longrightarrow$
>
> $$\therefore$$
>
> We should preserve the Yamaha DX7 in order to be able to reproduce a specific work by Murail.[9]

The DX7 occupies a particularly fascinating place in the history of musical instruments vis-à-vis technological objecthood, as this device was both a doorway into what would become a generationally defining soundworld, and a significant bridge between the academic enclave and the larger forces of global market capitalization. When it was released in 1983, the DX7 became one of the world's first digital instruments to achieve substantial commercial success, dramatically outselling widely-used analog workhorses like the classic Minimoog.[10] Yet while the DX7 itself enjoyed this success, it was the synthesis *algorithm* behind it that has survived far beyond the materiality of the original device, or any other specific implementation of the algorithm. The DX7 uses

[9]They state outright that they are only concerning themselves with works that have been requested for additional performance by presenters, but the logic thread remains, regardless of from where the impetus to remount a piece originated.

[10]The DX7 was one of the best selling synthesizers in the early years of digital music making. ([184] p.317)

what was then a novel synthesis technique called *frequency modulation synthesis* (known commonly as FM), invented at Stanford University by John Chowning in 1967. Chowning's algorithm is described by

$$x(t) = A(t)cos[\omega_c t + I(t)cos(\omega_m t + \phi_m) + \phi_c] \tag{1.1}$$

where $A(t)$ is a time-varying amplitude function, $I(t)$ is the modulation index, ω_c is a carrier frequency, ω_m is the modulating frequency, and ϕ_m and ϕ_c are arbitrary phase constants. Idiosyncrasies resulting from the physicality of the instrument notwithstanding, this equation represents the true objecthood of the Yamaha DX7.

After American manufacturers failed to recognize the technique's potential, Chowning's algorithm was licensed to the Japanese company Yamaha in 1977, and it (the algorithm, not the device) went on to become one of Stanford University's highest earning intellectual properties. ([184] p.6) As digital music synthesizers have proliferated over the decades, the kind of eccentric musical objecthood represented by the arrival of the DX7, in which the utility of the instrument is entirely separated from its form, is now taken for granted. While one may choose to invest in an expensive controller that produces no sound of its own, as with all digital musical devices it is the integrated circuit, or chip, from which all sound issues, and the chip is cheap, digitally agnostic, and ready for mass production.

Given that the advance of technologies that produced something like the Yamaha DX7 is driven by market demand, and the survival of any one corporate entity producing these technologies calls both for wide, buoyant

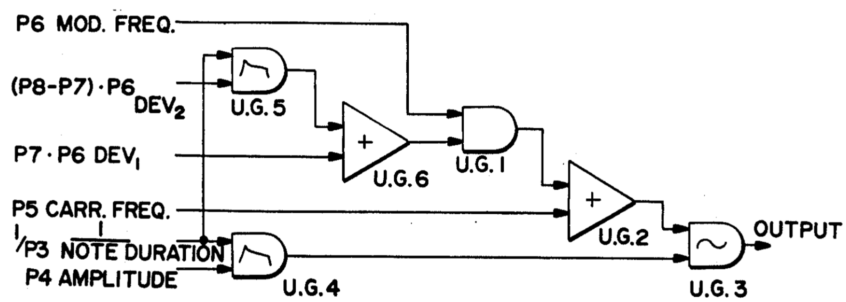

Figure 1.1. Block diagram from US Patent 4018121, filed 1977: John Chowning's frequency modulation synthesis. [35]

sales and constant innovation of models to be sold, it is useful to filter the enormous glut of potential individual pieces of technology considered for saving by focusing preservation efforts on specific works that call for those pieces of technology. And in fact, attempting to predict that a specific work of art, or a specific technology *will be* meaningful to future generations is surely a futile pursuit.[11] That Radio-France concert producers find it important to re-perform a work by Tristan Murail now is sufficient motivation to solve the apparent endangered DX7 problem. Perhaps a subsidiary result of their efforts would be that a physical set of DX7s would make their way into a museum or archive-type of collection somewhere, which could then be called upon in the future should others also want to perform this piece.

There is some irony in the fact that "the DX7" can be considered more an algorithmic object than a physical object, and as such available to be remade by anyone with the ability to apply Chowning's equations. It is not an object

[11] See above re: demolition of the Philips Pavilion.

that demands "freezing" in order to be re-accessed, nor is the sound it creates somehow "less authentic" if it does not emerge from the plastic body of the instrument manufactured by Yamaha. It remains unclear why, therefore, the Radio-France concert producers chose not to perform Murail's *Atlantys* when they were unable to source two functioning DX7s. As mentioned earlier, while the materiality of the instrument retains a certain cultural power, the core functionality of the instrument can be reproduced entirely in software in a few minutes' time. Within the context of a musical performance, the value of the object lies in its ability to create a particular sound, not in the embodiment of the object.

There are a small handful of organizations taking the opposite approach, not focusing on individual works, but like the Svalbard Global Seed Vault[12] simply trying to amass as many examples of variations on technologies before they are gone: the Morris Museum in Morristown, NJ maintains the Murtogh D. Guinness Collection of 750 historic mechanical musical instruments and automata [118] and The Electronic Music Education and Preservation Project, a slightly more rogue private collection, bills itself as an "educational center and multi-media production studio," in Harleysville, PA. [53] The objects represented in these two institutions could be used to string together an idiosyncratic narrative thread of a certain stripe of music technology from the mid 1800s up to the digital age, at which point EMEAPP declares itself

[12] In 2017, the "failproof" seed vault flooded when permafrost unexpectedly melted. The Norwegian government spent 20 million Euros refurbishing the storage unit to protect from future flooding. [30] Imagine an economic and cultural landscape wherein a national government committed 20 million Euros to the preservation of a variety of analog synthesizers.

uninterested in the "homogenization" of sound caused by the advent of digital technology.[13] [46]

In line with the guidelines of the ICOM-CC and understanding that use degrades the object, the holders of these collections of historical instruments do not make them accessible for regular ongoing performance. These objects have shifted their object-domain as well, but in a direction away from utility: they have transitioned from being a thing that facilitates music making (a tool to make art) into self contained sculptural art-objects. One can refer to recordings to know what Jimmy Hendrix's wah-wah pedal sounds like, but one cannot compose for it, cannot use it in live performance now, even though, in a seemingly unlikely set of circumstances, we know exactly where that specific pedal is (Harleysville, PA). Unlike the DX7, the key technology of which has transcended its physical objecthood, a piece of technology like Hendrix's pedal has become locked in its own materiality, relinquished its technological potential; it is no longer an "instrument" as it once was. In this regard, these collections are like other collections of historic technologies: museums devoted to airplanes, trains, automobiles, apparel, or dolls. These objects might very well be singularly beautiful, as in the case of the Metropolitan Museum's 17th century Italian harpsichord [126], but the objects themselves were not originally conceived as decorative or sculptural art-objects (or perhaps only secondarily

[13] These are both obscure examples, to be sure, but it was only in 2019 that the Metropolitan Museum of Art held its first exhibit on the "Instruments of Rock-n-Roll," featuring a collection of instruments (mostly famous guitars) brought together from private collections, and from the collection of the Rock-n-Roll Hall of Fame. Aside from the DJs they must annually hire for the Met Gala, this is the closest that forward looking institution has come to engaging with electronic music. [125]

so), and so there is an embedded disconnect for the contemporary observer.

Figure 1.2. Late 17th century Italian harpsichord held in the Metropolitan Museum of Art collection, a gift of Susan Dwight Bliss, 1945. Public Domain image courtesy of the Museum. [126]

When one engages with a fresco on the ceiling of a room in which it was originally painted, one engages with the full nature of that object: it has no other potential within it. When one engages with an antique train, or baroque hurdy-gurdy, there is a missing layer of potential engagement. The observer is left to wonder what it would feel like to be clattered along, or to grind out melodies. Despite being put on display, such objects have transmutated beyond the form that produced the very interactions that made them significant and worth preservation, like displaying the paintbrushes Michaelangelo used to paint the Sistine Chapel.

1.3 Digital Art Conservation

It would, today, be broadly cliche to point out that the rapid advancement of electronic and digital technologies over the last 60 years has resulted in the similarly rapid growth in areas of art-making that hybridize traditional forms with new technologies. Only recently, however, have practitioners and conservationists begun to think seriously about the implications for the future of a preserved culture as a result of the extreme ephemerality of the medium of digital art-making.

Writing in 2004, Carey Stumm observed, "While preservation standards for some nonelectronic mediums have been established based on research and shared information between groups of professionals, the preservation of electronic media now being collected by cultural heritage institutions has only begun to be addressed." ([178] p.40) In 2007, Richard Rienhart noted that

> "traditional museological approaches to documentation and preservation because of their ephemeral, documentary, technical, and multi-part nature and because of the variability and rapid obsolescence of the media formats often used in such works. It is not feasible for the arts community to keep the original equipment and software in working order over the centuries and industry has no incentive to continue producing old parts or to keep all new equipment backward compatible indefinitely." [156]

In 2012, Perla Innocenti observed that most of the collected knowledge around preserving digital art had been of a survey nature and pointed out, “So far, the theoretical aspects of the problem of digital art preservation and digital curation have been examined without much grounding, particularly in experimentation, and not responding to the specific theoretical and methodological dilemmas posed by digital art (e.g. transience, emergence, and lack of fixity).” [86] In 2013, Christopher Prom wrote, “Why have most archives failed to effectively address electronic records issues? The reasons are many, but in the end the typical answers are that ‘digital preservation is hard,’ and ‘we don’t have enough money to do it properly’.” [152] In 2020, Johannes Goebel, former director of ZKM in Karlsruhe and Director of the Experimental Media and Performing Arts Center in Troy, NY wrote: “After a decreasing interest in the challenges of archiving digital data between 2010 and 2015 nourished by the notion of “the cloud” holding “everything forever,” a renewed interest in the question of the longevity of the physical bits that hold digitally encoded information has risen.” ([65] p.33)

Stumm defines five fundamental strategies for conserving electronic media: System Preservation (maintaining a phonograph machine), Refreshing (e.g. copying one electronic tape onto another), Migration (i.e. “porting”), Emulation (e.g. PDRP), and Encapsulation (i.e. enveloping the work within its metadata). This last strategy, encapsulation, is not actually a technique for maintaining the work itself per se, but a strategy to ensure the possible reboot of the work in some future. The goal here is to compile all of the ancillary information about the work (photos of the work, instructions for rebuilding the work, etc.) such that a faithful re-rendering could exist.[14] ([178] p.43) And despite a lack of standardization such as exists for physical art conservation, there is near universal agreement on the need for such thorough documentation of digital work.[15] Francis Marchese likens the need for documentation of digital and time-based art to the documentation practices of software development:

> Pip Laurenson, Head of Time-based Media Conservation at the Tate Museum, has proposed a redefinition of conservation practice to accommodate time-based media, so that conservation becomes the means by which an artwork's essential properties are documented, understood, and maintained. Its aim is the preservation of the artwork's identity, so that it may be displayed in the future as different possible authentic installations. For Laurenson, the identity of a digital work should be considered as a collection of properties which include: the artists instructions, approved installations intended to act as models, an understanding of the context in which the art was made, and the degree to which the artist specifications reflect his or her practice at the time the art was created. For a 26th century conservator this means that if the standard methods of digital art conservation (e.g., migration and emulation) eventually fail, then the preservation strategy of reinterpretation, that is, the process of recreating part or all of the artwork utilizing this extended documentation, can be invoked.[16] ([108] p.303)

He also elaborates the types of documentation that would be necessary in order to adequately understand in some distant future the nature of a contemporary digital art work, including information about architecture and design, technical

---

[14] See Section 1.4 for more discussion on Johannes Goebel's attempt to create a digital time capsule using M-Discs.

[15] See also Conway [40], Conway [39], and Lobley [103].

[16] See also Pip Laurenson's full discussion of the topic. [102]

information including source codes, interfaces, embedded commentary, and end user manuals, possibly including instructional videos.[17] He conjectures that for curators of the future, "Artwork selection will not only be based on its importance to the canon, but also the availability of resources (e.g., staffing, time, funds) required for its installation." ([108] p.306) Given the DX7 example cited above, that future is now.

Goebel relates the problems brought into the spotlight by digital art to the problems of trying to recreate any time-based art work that lacks adequate documentation of the original performance. Regarding a set of commissioned pieces for a mechanical stage built at ZKM, he notes, "What we are left with today, only three decades after these new works were performed, are elements of the mechanical stage sitting in some depot of a museum, the digital data controlling the recreated stage in the three works being lost or inaccessible due to just having been lost or because of obsolete software and hardware, and video documentation of the performances potentially still being somewhere...or not." ([65] p.28) What all of these actively practicing conservators are speaking to is the reality that the digital and time-based work we are creating now will not simply continue to exist on its own without ongoing concerted effort.

It is perhaps interesting to conjecture that the tradition of Western European art music developed as it did in no small part *because of* its reliance on transmission of idea via score—via physical object, rather than simply by way of oral traditions of teaching and learning. Despite contemporary assertions that a score is an intrinsic part of concert music (Adorno/Ingerbord/Goodman), no

[17] See also: Bollacker. [23]

musician living and working in the pre-20th century would mistake “a score” for “music.” But without this ever-growing record of sets of notational instructions, European music surely would have developed along a different path. The scantily notated pre-19th century scores with which we are all familiar (those that are totally devoid of dynamic indications or tempo markings) points to the notion of a score as being closer to mnemonic device for short-term recall of a particular musical assemblage, rather than an object oriented toward long-term preservation of a precisely repeatable musical ritual, or as Goebel describes it, a prescriptive method of how music would go:

> In the 9th century a development started in the western part of Europe, which—as many musical notations—began as a mnemonic system, documenting how words were to be sung. This freezing out of time went into a different direction in the following centuries, when the notation was not capturing “the old” and preserving tradition, but rather it was being used in a prescriptive way: it communicated to musicians what and how to play what was put down in writing. ([65] p.6)

The score is not just foundational to the analog art of western concert music making, it is indeed a set of instructions, a type of users manual, a blueprint for remaking repeatable sound constructs. We study scores as though “they are music,” but the score is itself a form of *documentation*. Digital work may or may not demand such hyper-specific documentation in its initial creation, but if a piece is to have a future life, we must think like composers working in a standard notational practice.[18] It is true that a score is not yet

[18] Perhaps the real genius of Stockhausen’s *Elektronische Studien* is not the sound world they articulated, but the fact that Stockhausen devised an effectively new-but-familiar graphical score language to make such ephemeral phenomena precisely repeatable.

at the level of a simulacrum for actual sounds that a modern recording of an acoustic performance is, but then, a recording does not instruct us as to how a thing gets made. It would take an exceptional and highly trained musician (or several) to realize a performance of Beethoven's 9th Symphony working only from a recording. Thorough, multi-level documentation is everything.

1.3.1 Digital cultural heritage

As I noted above, we are still in the very early stages of coming to terms with the implications of our new reality, and the practices this reality demands of us.[19] Calling attention to a "preservation paradox" based on a conundrum at MoMA with regard to Nam June Paik's *Untitled* (1993), Rubio observes:

> While it is possible to successfully store, preserve, and display cultural artifacts produced centuries and even millennia ago, preserving cultural artifacts produced just a few decades ago poses a formidable, often insurmountable, challenge...Only two decades after being produced, *Untitled* already runs the risk of becoming irremediably lost as a result of its dependence on largely outdated technologies. The original 1993 *Untitled* was based on U-Matic decks, CRT monitors, analogical live-feed cameras, and a player piano running on a floppy disc. By the time it was first exhibited at MoMA in 2004, many of these technological components were already obsolete and had to be replaced by newer technologies. ([161] p.635)

Rubio goes on to describe the difficulties involved in attempting to remount *Untitled* in 2011...leading to his paradox:

> The museum thus faced an interesting dilemma. It could "freeze" the artwork as it was in 2011, thus leaving *Untitled* as Nam Jun

[19] See: Rosa [158], Muller [119], Muller [120], Borndigital [121], and Neal [122]

> Paik last modified it and abstaining from making any further modification. This option would secure the authenticity of the artwork, but at the cost of sentencing it to a sure death, as most of the technologies required to run *Untitled* were already malfunctioning or obsolete. An alternative course of action would be to keep *Untitled* alive by constantly migrating it to newer technological platforms. This solution would imply altering *Untitled*'s form and potentially its meaning, thus giving rise to questions about its authenticity and authorship since the museum would be effectively usurping Nam June Paik's role as author of the artwork. ([161] p.635)

The importance (cultural and economic) of authenticity will be discussed later. Beyond the consequences for the specific museum of "de-authenticating" a specific work of art, there is widespread agreement that these questions are urgent because we are dealing with the collective "cultural heritage" of our time. Beyond maintaining the aura of authenticity within specific pieces, we are working to ensure something of the experience of living and knowing and making in this time is available to future generations.

In our post-communist/post-colonial era of social nativism ([144] p.862) we have cultivated a knee-jerk reaction for framing "culture" as nation-specific, or otherwise "tribe"-specific within a nation. However, music employing digital technologies, and the digital recording of digital and non-digital art is not an issue that is specific to one nation or tribe within a nation; it is truly a collective cultural heritage. UNESCO,[20] the recognized leader in issues of trans-national

[20]Invoking UNESCO is fraught. The mission of the organization, which was chartered by the United Nations in 1945, is: "to build peace through international cooperation as it is the only way to build bridges between nations. Therefore, as a laboratory of ideas, UNESCO seeks to offer a broad range of expertise in the fields of Education, the Sciences and Culture." [186] "Heritage" (i.e. "culture") is just one area of the organization's "expertise" within this broader mission of "peace building." In the height of the Cold War, the United State

cultural heritage discusses a "heritage" of digital technology thus:

> Digital heritage is made up of computer-based materials of enduring value that should be kept for future generations. Digital heritage emanates from different communities, industries, sectors and regions. Not all digital materials are of enduring value, but those that are require active preservation approaches if continuity of digital heritage is to be maintained.
>
> Heritage is explained in UNESCO documents as "our legacy from the past, what we live with today, and what we pass on to future generations." A heritage is something that is, or should be, passed from generation to generation because it is valued. [185]

Projet Antony also takes the explicit stance that digital music making is a form of "cultural heritage," writing this into the mission of the organization: "to safeguard the heritage of music using digital technologies." [8] It is not accidental that Projet Antony invokes "cultural heritage" as such. Like the museological focus on the preservation of unchanging physical objects, accepted notions of "cultural heritage," which emerged from agreements made at The Hague Convention, have also maintained a property-oriented focus:

---

withdrew from participation in UNESCO citing issues of UNESCO's extraneous politicization of "virtually every subject" and its exhibition of "a hostility toward the basic institutions of a free society, especially a free market and a free press." [149] In American political speak, this is a pretty thinly veiled way of saying that the organization would not do as it was told by the United States. Long after the Cold War had ended, the U.S. rejoined UNESCO in 2002, at which time first lady Laura Bush stated, "UNESCO, an institution born of a yearning for peace that survived years of war, can now help achieve peace by spreading the values that will help defeat terror and lead to a better and safer world: education, tolerance, respect for all human life and respect for each other's differences." [182] American exceptionalism and the country's perpetual wars on communism/terrorism aside, there simply aren't other organizations with similar international support, cooperation, funding and reach out there. So...here we are.

> ...the growing body of international instruments and other texts relating to cultural heritage was driven by contemporary concerns and intellectual fashions, further illustrating lack of a single set of well-established principles underpinning this body of international law. There exists a difficulty of interpretation of the core concepts of "cultural heritage" (or "cultural property") heritage of mankind and as yet no generally agreed definition of the content of these terms appears to exist. ([20] p.62)

Attempting to ascribe a similar legal weight to a particular software program developed (perhaps outside of a capitalist framework) for a particular performative end, while noble on the part of Projet Antony, only complicates the attempt to reach a broader understanding of what is worthy of protection and preservation as "heritage." Is it imaginable that we could reach a consensus that a particular program in a particular programming language demands similar international legal considerations as, say, the Hagia Sophia or the temples of Angkor Wat? This urge to equate modern ephemerality with sturdy, old-fashioned physicality while confusing accepted understandings of property and heritage is no doubt partially born of the fear of irretrievable loss of the potential cultural artifacts of our time, and the simultaneous fear on the part of creators that the broader world is largely unaware of the potential for such a loss.

1.4 A Digital Dark Age

> "Historical materials simply don't survive by accident the way they used to."
>
> Marc Weber, "Self-Fulfilling History"

“Imagine a printed book losing the printer’s ink over less than a decade.”

Johannes Goebel, “The Computer as Time Machine”

Figure 1.3. Inside the 1958 Philips Pavilion, from a series by Foundation Le Corbusier

The Rosetta Stone, the Dead Sea Scrolls, the Lascaux cave paintings, the Terracotta Warriors, as well as Ötzi and King Richard III were all discovered by accident.[21] In a hundred or a thousand years, what will be left from this time

[21] Richard III, being a king, was probably never intended to be lost in the first place, but in the case of Ötzi, it’s safe to say that he had no intention of being discovered 5000 years

for people to discover? Perhaps a thin resinous layer of concrete and plastic around the globe, a new reference stratum that will allow future archaeologists to date things as before or after the 20th and 21st centuries. Yet such a stratum will convey little about our times and our lives other than, "was here."

Urged on by our awareness of impending global bio-collapse, the disappearance of vast swaths of cultural heritage is a hot topic across academic disciplines and science fiction writing. We have many actual historical references that demonstrate both our ability to amass objects of cultural import, and our simultaneous will to mangle such collections and demolish such objects[22], as though all of humanity is engaged in a permanent game of building sand castles on a tidal beach. Not only is the shift away from physical objecthood alarming when considering the durability of "objects," it is perhaps even more troubling to note that in the present moment, an incomprehensible quantity of our knowledge has been entrusted to safe keeping by commercial technology enterprises. Even self-proclaimed "cultural institutions," which would probably be the first to admit they are not institutions of computer science, rely on the services of commercial enterprises in order to maintain their objects of cultural import.

> The cycles of obsolescence in hardware and software, driven by the economic system, are so short that even for the lifetime of an individual it is hard to keep the bits in place to restore them into the time of our perception, our seeing and hearing, whenever we

after his death, and I would suspect that even 5000 years ago, murderers weren't too keen on having their victims hauled out for scientific inspection. Ötzi just happened to fall in a time and place that preserved him. [93]

[22]The Library at Alexandria was largely destroyed during Julius Ceaser's campaign in 47 BC. If parts of it were left standing, they were certainly gone by CE 270. [5]

> want. And finally, we may want to keep the bits—representing what we deem important—under our own control. Delegating the storage to "the Cloud," to a system and business model we have absolutely no control and say over, may be good for present-day accessibility purposes, but we don't own the physical representation of the bits in the Cloud. The Cloud takes no responsibility for data loss. ([65] p.6)

Two recent examples from industry illustrate this. In February of 2017, Amazon S3, the distributed data storage arm of the suite of cloud-based tools collectively known as Amazon Web Services, or AWS, experienced a roughly four hour outage. During this time none of the world's web services that relied on S3, even in part, were functional.[23] Unsurprisingly, this included a number of other key AWS services, along with Amazon's own websites, which had the curious secondary effect of making it impossible for Amazon to announce the outage to the rest of the world using its own platform, or provide timely updates to Amazon's millions of customers. What ensued from the end user's point of view was that a large portion of what is commonly known as "the Internet" suddenly disappeared. Social media platforms, streaming services, travel booking websites, financial platforms, image hosting, messaging services

[23]"This is by no means an exhaustive list of things that fell over or were wobbly today, due to the S3 downtime, but here's a start: Docker's Registry Hub, Trello, Travis CI, GitHub and GitLab, Quora, Medium, Signal, Slack, Imgur, Twitch.tv, Razer, heaps of publications that stored images and other media in S3, Adobe's cloud, Zendesk, Heroku, Coursera, Bitbucket, Autodesk's cloud, Twilio, Mailchimp, Citrix, Expedia, Flipboard, and Yahoo! Mail...Readers also reported that Zoom.us and some Salesforce.com services were having problems, as were Xero, SiriusXM, and Strava. Another reader reports being unable to order coffee because the Hey You app was broken." [124] "The four-hour AWS outage caused S&P 500 companies to lose $150 million, Cyence, a startup that models the economic impact of cyber risk, estimated, a Cyence spokeswoman said via email. US financial services companies lost $160 million, the firm estimated." [179]

(even services operated by other huge competing corporations like Apple), and many other mechanisms by which regular people interact with each other all just...weren't anymore.

What such experiences reveal, besides perhaps the extent to which our modern daily lives rely on a technology developed by the US military in the 1960s[24], is how the notion of distributed data, often pitched as a panacea to the problems of data preservation, is a problem that aside from obviously being unsolved, remains murky and misunderstood behind the world-shaping forces of giant corporations like Amazon and Google. Amazon widely advertises S3 as an "eleven nines" class of service, referring to the number of significant digits that describe S3's data reliability. In a brilliant stroke of misdirection, Jeff Barr, Amazon's "Chief Evangelist" promoted the high "durability" of data stored in S3 in an apocryphal blog post from 2010. In it Barr defines durability as:

> "the probability that the object will remain intact and accessible after a period of one year. 100% durability would mean that there's no possible way for the object to be lost, 90% durability would mean that there's a 1-in-10 chance, and so forth...the durability of an object stored in Amazon S3 is 99.999999999%. If you store 10,000 objects with us, on average we may lose one of them every 10 million years or so. This storage is designed in such a way that we can sustain the concurrent loss of data in two separate storage facilities." [14]

It should be noted that Barr's evangelism here is targeted at the *durability*

[24] ARPANET was the first wide-area packet-switched computer network, developed in 1969 with funding from the US Department of Defense. It was created as a means of maintaining communications between strategic sites throughout the United States in the event of a nuclear war. It is the earliest incarnation of the suite of technologies that would eventually become known as the Internet. [104]

of Amazon's data, which is not the same as *availability*. He claims that S3's distributed data model is capable of sustaining concurrent losses across data centers, and while that may be true this redundancy did nothing to prevent the massive outage nearly seven years later. It turns out that eleven nines worth of data integrity is without any meaning or value at all if that same data is not available when it is needed. Further, Amazon's post-mortem of the event identified the root cause of the outage as an error in a configuration file that was edited by a *human*—the now infamous "$150 million typo." [76] This is perhaps the best possible illustration of how poorly understood the collision of digital culture is with the infrastructure that affords it, and how fundamentally different the concerns are for the entities at either end of the data pipeline. It may also have been one of the first times this matrix of cultural and economic forces entered the minds of the general public, as the incident was widely reported in the mainstream media.[25] Naturally, the online public absorbed and reacted to the experience in the manner to which it has become accustomed, by posting snarky commentary on Twitter:

[25] That is, non-technical news sources, and popular mom and pop news outlets

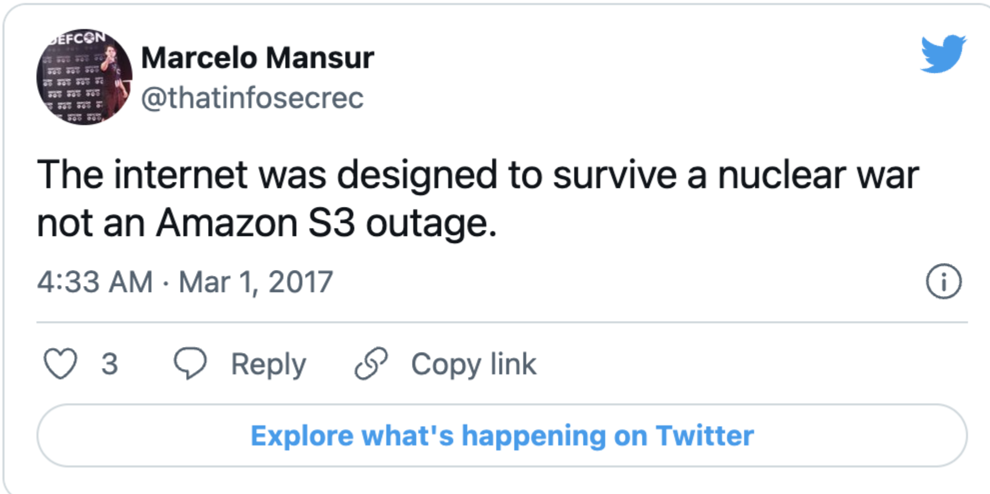

Figure 1.4. Snarky tweet 1 from the fallout of the 2017 AWS S3 outage

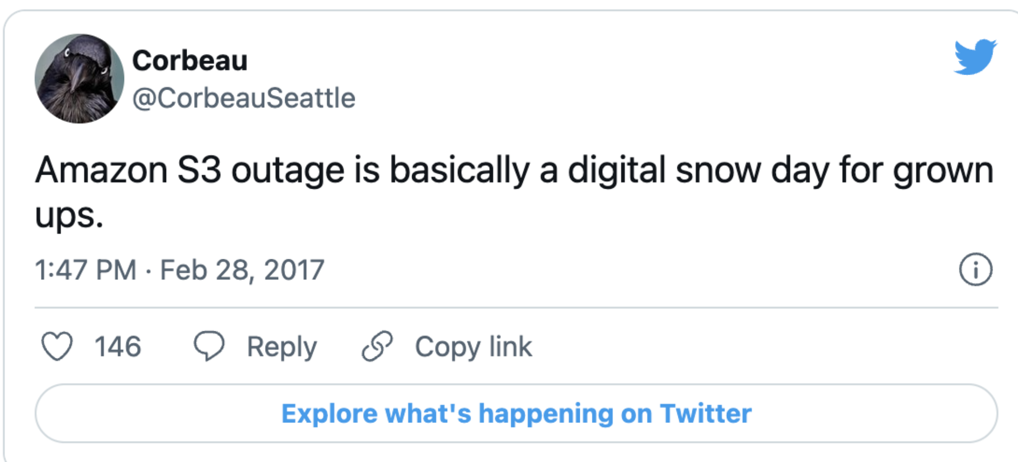

Figure 1.5. Snarky tweet 2 from the fallout of the 2017 AWS S3 outage

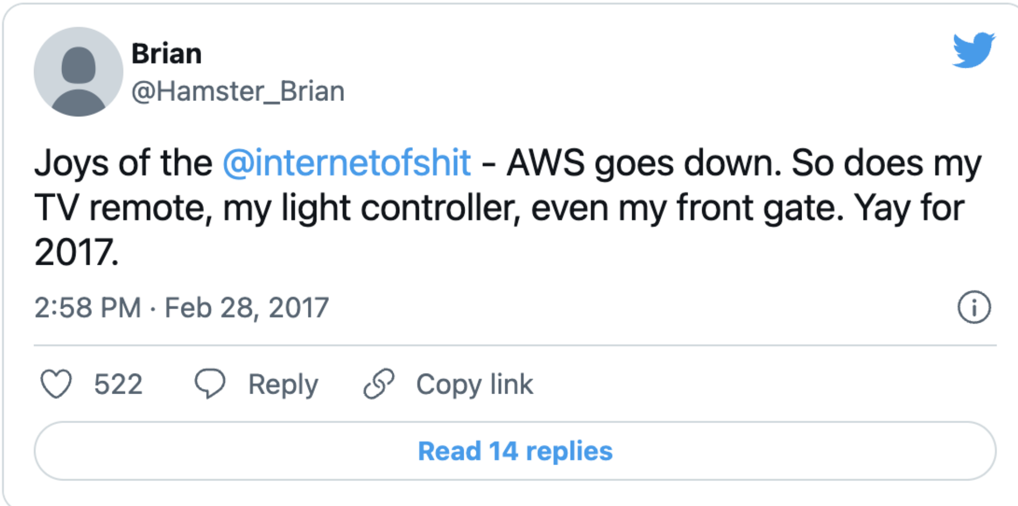

Figure 1.6. Snarky Tweet 3 from the fallout of the 2017 AWS S3 outage

A second example is offered by Backblaze, a major current player in the cloud-based data backup space. Every year the company publishes an exhaustive report of its internal rates of drive failures, broken down by manufacturer. Presumably, the purpose of these reports is to highlight how low these rates are (often well under 1% per manufacturer), and to thereby showcase their expertise in thinking about and understanding this kind of digital failure. But with a small steps back it becomes evident that while a $< 1\%$ failure rate might seem low, given that Backblaze also trumpets of managing nearly 2000 petabytes of data, the actual byte count for potentially lost data is disturbingly high, well within the scope of a major "digital darkening." [7] Backblaze and companies like it stay in business by building out very expensive redundant systems to mitigate what would otherwise be business-shuttering losses, such that even multiple simultaneous drive failures do not necessarily translate into irretrievable data lost for the customer. Backblaze's business model is therefore based on 1) the fact that digital data is inherently vulnerable, and 2) their elaborate network of redundant systems is addressing the impossible problem of digital data preservation better than anybody else.

Backblaze Hard Drive Failure Rates for 2021

Reporting period 1/1/2021 thru 12/31/2021 inclusive. For drives models in service as of 12/31/2021.

MFG	Model	Drive Size	Drive Count	Avg. Age (months)	Drive Days	Drive Failures	AFR
HGST	HMS5C4040ALE640	4TB	3,429	66.92	1,188,017	19	0.58%
HGST	HMS5C4040BLE640	4TB	12,703	62.37	4,647,157	39	0.31%
Seagate	ST4000DM000	4TB	18,611	74.37	6,856,981	339	1.80%
Toshiba	MD04ABA400V	4TB	97	79.32	35,781	2	2.04%
Seagate	ST6000DX000	6TB	886	80.85	323,390	1	0.11%
HGST	HUH728080ALE600	8TB	1,124	44.85	397,463	7	0.64%
Seagate	ST8000DM002	8TB	9,718	62.63	3,554,465	142	1.46%
Seagate	ST8000NM0055	8TB	14,334	52.82	5,253,943	214	1.49%
Seagate	ST10000NM0086	10TB	1,192	50.07	436,951	27	2.26%
HGST	HUH721212ALE600	12TB	2,600	27.04	946,710	7	0.27%
HGST	HUH721212ALE604	12TB	13,138	9.40	3,305,589	26	0.29%
HGST	HUH721212ALN604	12TB	10,818	32.95	3,951,844	52	0.48%
Seagate	ST12000NM0007	12TB	1,324	25.80	2,799,888	154	2.01%
Seagate	ST12000NM0008	12TB	20,201	21.13	7,340,502	218	1.08%
Seagate	ST12000NM001G	12TB	12,171	13.84	3,770,446	54	0.52%
Seagate	ST14000NM001G	14TB	10,738	11.10	3,054,188	86	1.03%
Seagate	ST14000NM0138	14TB	1,611	12.86	586,327	77	4.79%
Toshiba	MG07ACA14TA	14TB	38,214	14.28	11,617,844	245	0.77%
Toshiba	MG07ACA14TEY	14TB	462	11.81	153,659	7	1.66%
WDC	WUH721414ALE6L4	14TB	8,408	12.81	2,951,046	35	0.43%
Seagate	ST16000NM001G	16TB	10,861	7.74	1,606,863	49	1.11%
Toshiba	MG08ACA16TE	16TB	5,985	3.57	320,260	8	0.91%
Toshiba	MG08ACA16TEY	16TB	2,367	8.52	573,726	11	0.70%
WDC	WUH721816ALE6L0	16TB	1,767	5.06	256,533	1	0.14%
		Totals	**202,759**		**65,929,573**	**1,820**	**1.01%**

Backblaze

Figure 1.7. Backblaze hard drive failure report. [13]

Yet what is interesting here is not Backblaze's public boasting, or the kaleidoscope of data that is their annual crash report.[26] Instead, the very existence of such reports, and the ways in which they are publicized and promoted, reveal a deep underlying anxiety about just how precarious our larger digital moment really is. Failure is near, they seem to be saying, and not just your failure, dear incompetent customer, but ours too. We know this so well that our entire business model teeters atop this fact. And so, even outside the guardian walls of the academic citadel, even beyond the nurturing embrace of the museum with its explicit mandate to preserve, and even when backed by the bottomless mine of Silicon Valley venture cash, the problem of digital preservation remains fraught and unsolved. This reality stands in some contrast to Backblaze's marketing copy, which refers to its data arrays as "vaults" and its drive pools as "tomes"—carefully chosen words that evoke an object permanence previously reserved for extant artifacts of antiquity, which have the curious (and very analog) property of being able to preserve themselves. Jonathan Sterne relates this directly to audio technology:

> As it goes for media in general, so it goes for sound recordings and digital sound recordings in particular. Consider the following broad categories of issues in the preservation of digital music "documents" encountered by archivists: digital music documents exist in varying formats, which may correspond to scores, to audio recordings, or "control formats," such as MIDI or MAX/MSP algorithms that are essentially performance instructions for computers. The storage media themselves are unstable. Even if an old hard drive or disc were properly preserved, its "readability" is an open question, given the wide range of software and operating

[26]For more information than is included in the above table, see: https://www.backblaze.com/blog/backblaze-drive-stats-for-2021

> systems in use at any given time. Even then, issues of intelligibility arise: much of what makes digital audio work today relies upon some kind of "metadata," whether we are talking about the names of songs and albums in CDDB or the information on preferred tracks and takes in a multitrack recording.
>
> One can only imagine the lamenting historian's horror at this state of affairs. The world is populated with an unprecedented number of recordings, yet they exist in countless different formats and with seemingly endless preservation problems. It's cruel. We have made recordings more portable and easier to store than ever before, but in so doing we have also made them more ephemeral. Most of them will be lost to posterity, and despite the efforts of archivists, there is really not much we can do about it. [176]

Both *The Wind Garden* and *The Place Where You Go to Listen* run on commodity hardware: Mac computers handle logic, interaction, and synthesis (and lighting in the case of The Place), Linux servers handle data acquisition, data pipelines, ETL, and various backend services, and Raspberry Pis, the current iteration of low-cost, system-on-a-card style computers, handle random bespoke tasks in both installations. For example, in *The Place Where You Go to Listen* I have employed a Raspberry Pi specifically to provide an ethernet bridge between the synthesis machine (Mac) and the serial (RS-232) data streaming from the roof-mounted anemometer at the Museum of the North. At an immediate level, the pieces are monitored and maintained over commercial Internet services. The issue is that these machines and services will only continue to exist so long as they are profitable to commercial entities whose interests could not be further from the interest of the cultural entity making use of these tools.[27] More on this in section 1.5.

The idea of the Digital Dark Age emerged around 1996/1997,[28] and was simultaneously used to refer to the loss of data perceived to have been stored permanently, but also to a very presciently predicted wealth gap that would emerge between those with Internet access / prowess / ability to continually adapt and accelerate their use of it, and those without.[29] [66] The idea became enormously popularized around 2015 when Google VP Vint Cerf gave a talk to the American Association for the Advancement of Science about the potential for even one of the wealthiest companies in the history of humanity to suffer a catastrophic loss of data.[30] [106]

Noting that "the longer the preservation period, the more we must assume lack of specific knowledge of the content and its structure and semantics" by future investigators, Cerf outlines a set of considerations for digital preservation that essentially map to the considerations being put forward by museum conservators about maintaining their own collections. These considerations include:

---

[27]Also see Bollacker [22], Jeffrey [88], Kuny [99], and Panos. [141]

[28]The Long Now Foundation puts the inception of the term at 1996. [162]

[29]In his exceptional book *Capital and Ideology* Thomas Picketty points out the dramatic increase in the wealth gap in Russia in the handful of years following the collapse of the Soviet Union, which also happens to coincide with the widespread emergence of internet commerce. ([144], p.21)

[30]The constant personal interaction that we have with corporate giants such as Google and Amazon makes it difficult to remember that extremely large companies can and do fail, and have done so even in our own lifetimes (e.g. Lehman Brothers). If Yanis Varoufakis is correct (see section 1.5) that in the last few years we have begun a transition from late-stage capitalism to a new techno-feudalism, wherein central banks print money to float enormous corporations through challenging times, there may be fewer such failures of companies in the near future. On the scale of a slightly longer time, however, failure is inevitable. Who among us has a robust memory of interacting with the Dutch East India Company?

- Digital object structures, representations, vocabulary and standard terminology (schema, OWL, ...)
- Identifier spaces, registries, resolution mechanisms
- Digital Object Architecture, CNRI
- Standard, rigorous ingestion processes
- Metadata (about the data, provenance, authenticity, calibration, ...)
- Legal frameworks for preservation (copyright, patents, licensing, special treatment for preserving bodies)
- Business Models for extended, long term operation [33]

Cerf adds, "The solution is to take an X-ray snapshot of the content and the application and the operating system together, with a description of the machine that it runs on, and preserve that for long periods of time. And that digital snapshot will recreate the past in the future." [62]

This idea is being explored in a more immediately local capacity by the Experimental Media and Performing Arts Center in Troy, NY. Johannes Goebel has undertaken an effort to document the time-based work that has been done in that space over the last decade. The current best solution is to store as much information about each work on M-Disc DVDs (roughly 4GB per disc, with larger studies of pieces being broken up over several discs). Goebel refers to this process as creating a "digital time capsule." ([65] p.35) EMPAC's is a true conservation effort for time-based art. Unlike in Cerf's thought experiment, EMPAC is not attempting to make all of our current active interfaces accessible into the future, but simply to build a robust enough record of time-based art making that these works are accessible and knowable in the future. Thus, the technology they have settled on is not concerned with porting or emulation; it is instead simply a container suitable for archiving extensive metadata about time-based artworks. The specific container they have chosen is the optical disc, a more robust medium than earlier generation DVDs. "For the time capsule, we have identified the so-called M-DISC DVD as the only optical storage medium currently available and supported by everyday commodity technology that does not require environmental control beyond what is comfortable for human life." ([65] p.45) Goebel goes into great detail about the specific properties of the M-Disc DVD that make it best suited to their current efforts, but summarizes EMPAC's interest thus:

> Barry Lunt, one of the inventors of the M-DISC, pointed out to me that all information humanity stores up to now depends on contrast, with one property of material being differentiated from another through contrast. This is as simple as it is fundamental. (Certainly contrast is basic for all human perception, but the focus here is on the encoding of what is to be taken out of time, to be kept beyond the very moment of immediate perception). Text, numbers and drawings written or printed on paper depend on the contrast between the paper and ink. If the contrasts (sic) fades over time by the paper aging and the ink losing its color, we may not be able to read it any longer. Letters or images engraved in stone may disappear slowly through weathering, until we cannot interpret any more contrasts in the surface of the material. ([65] p.46)

While these problems are widely understood within the computer science community, the wider public is still only perhaps peripherally aware of the fragility of the system. Writing in 2015, a self-proclaimed “pioneer of Glitch art” Michael Betancourt wrote,

> As digital objects do not degrade with time; they will not disappear over time. The limit for a digital work is not based on its physical demise, but rather on its availability within contemporary technology. Older digital works are only “lost” because the technological support for accessing them vanishes: the digital work, theoretically, endures and can be retrieved at some future time. Digital reproduction then becomes not only an inherent characteristic of digital objects, it is also their means to effective immortality. ([19] p.45)

The idea that digital objects “do not degrade” is a pleasant fantasy reminiscent of the early advertisements for the venerable compact disc, in which people were shown using them as drink coasters, or hurling them like a discus across the room to friends as a way of illustrating how permanent and indestructible the new digital format was, compared to vinyl or tape. Similarly, believing today that your favorite digital format will survive even as long as the compact disc leaves you only a short digital skip away from disappointment. It is regrettable that glitch artist Betancourt in 2015 seems to have been unaware of fellow glitch artist Yasunao Tone, whose work in the 1980s specifically explored the volatility and degradation of digital media, and whose music inspired an entire generation of electronic musicians and sound artists. [177]

In 2022, we are quite possibly in the midst of a wide-scale digital shedding event. Given the appearance of writable CD-Rs on the commercial

Figure 1.8. Vintage advertisement for a Sony CD player implying digital permanence

marketplace in 1991, and the 20-50 year readability lifespan of the information on those objects (depending on quality of manufacture, and quality and speed of writing at the time of recording), [87] it is very likely that individuals who did not migrate the information on home-written CD-Rs to another format are, at the time of this writing, already in the process of losing that information. It is also very likely that, because the exterior plastic of CDs is highly durable, there could be a widespread lack of awareness that the material substrate that actually stores recorded data[31] degrades several orders of magnitude faster than the casing of the disc itself. The surreptitious vanishing of everything

[31]Typically aluminum or gold foil and dye, both of which are susceptible to deterioration with exposure to sunlight, among other unstable characteristics.

deemed worth backing up in 1991 does not alone constitute a "digital dark age" on the scale discussed by Vint Cerf, but it hints at our ongoing vulnerability to unanticipated loss. Unfortunately for us, as well as for future generations, there is almost no way to know what will be lost from that particular generation of storage media, nor the scale of the loss until some future moment when we awaken to realize that none of our CD-R archives from that era can be read by a computer and are indeed lost forever. Have we entered into a 'digital dark age" without knowing it? We cannot know. In the same manner that it is unlikely the people alive in 850 A.D. viewed their time as "dark," we would not now view ours as such either. We appear to be living in an extraordinarily vibrant time of creation, complete with vast and comprehensive records of the things we have made. The unanswerable question is if it will continue to appear that way to future generations.

1.5 Techno Feudalism

> "...keeping what one wants to keep—under one's own control, in one's own home, organization, institution large or small – has become next to impossible without constant care and funding."
> Johannes Goebel, "The Computer as Universal Time Machine"

I began Chapter 1 by framing a work of art as an investment. For a museum, wherein a significant part of the revenue stream that keeps it operational comes from a combination of foundation grants, ticket sales, and individual donations, all of which are cultivated based upon the items held in the museum collection, this is a very direct and overt way of understanding an art piece. It may be that museums have taken up a particular mantle of cultural stewardship within our society, but it is an expensive mantle to maintain, and one that because of its relationship to revenue generation, can only exist within the dominant economic structure.

Consider the debacle of the financially beleaguered city of Detroit, which, in 2013, was bankrupt and reaching a crisis point following the 2008 financial collapse. Detroit has gone through several rounds of white flight: after World War II, again in 2000 when the city ended a rule mandating that city employees live within city limits, and yet another as the city was working through the very bankruptcy crisis caused largely by the previous rounds of flight to the suburbs.[32] [6] The city began discussing selling off items in the Detroit Institute of Art (DIA, for short, but not to be confused with Dia) in order to meet its financial obligations, but:

> Officials from suburban counties have warned that if the city's bankruptcy managers sell any assets in the Detroit Institute of Art (DIA)—whose collection includes a self-portrait by Van Gogh, a 27-panel fresco by Diego Rivera and works by Rembrandt and Matisse—they will cut their contributions to its funding. The combined income from three counties surrounding the city is worth $23m a year to the museum, a sum that represents almost 75% of its operating budget...The contract between the counties and the institute stipulates that it should be operated in accordance with professional museum standards. These include a clause saying that the proceeds of art sold must be used to buy more art. [111]

[32]Every time wealthier residents left the city, the city lost enormous amounts of tax revenue. In 2014, the city cut the pensions of retired city workers, exacerbating again the problem of abandoned houses that continues to plague it. [70]

To summarize: the people who chose not to participate in the cultivation of a living urban culture within Detroit decried the potential "loss of culture" were the city to sell off the large repository of European art that is sitting in the middle of the city they left, the same city which, technically, owns the art.

Just as is the case with every single other cultural institution in the United States, direct governmental support for the museum dwindled through the late 20th century.[33] The property tax revenue flowing to the museum from the surrounding suburbs was not a defacto position, it was a decision that had to be approved by a special vote in those counties in 2012. Yet it was *after* this vote to increase public funding to the DIA that the city invited Christie's Auction House to appraise the entire collection.

> As Annmarie Erickson, the institute's chief operating officer, put it to me on Friday, "The more price, value and sale are discussed, the more palatable it becomes to people, the less shocking." Ms. Erickson also pointed out that if major works were sold, the buyers most likely able to afford them would be private collectors from Russia, China or the Middle East. [173]

Ultimately, the sale did not take place.

Entertaining the idea of selling off the DIA collection to raise huge amounts of cash did not arise in a vacuum. The city needed only glance over to the East Coast to see the potential fundraising ability latent within its collection. In New York City, the art market is staggering:

[33] As a broad economic indicator, the real-number budget allocation for the National Endowment for the Arts has been nearly flat for the last forty years. In 1978 its budget was $123,850,000, and in 2020 was $162,250,000. [57] When adjusted for inflation, the budget in 1978 would be worth around $520,000,000 in today's dollars, meaning that despite apparent stability, the budget has shrunk by about 75%. [194]

> The US has been one of the strongest markets of the past decade, leading the global recovery of sales after the global financial crisis in 2010, with strong growth up to 2015. The market declined by 16% in 2016 as political uncertainties and a lack of high-end supply led to a deterioration in sales growth. However, the decline was short-lived and sales rebounded to reach a historic peak of just under $30 billion in 2018, twice the annual global growth rate, and a 31% increase in value over two years. In 2019, despite aggregate dealer sales maintaining positive momentum, a significant contraction in the auction sector (due to a reduction in the volume of very highly priced works on sale) brought the US market's value down 5% year-on-year to $28.3 billion. Despite this decline, the value of US-based art sales in 2019 was still its second highest level in history. Values have also grown by just over 130% since their low point in 2009, more than twice the rate of any other market, including China (61%) and the UK (42%). It is estimated that New York has accounted for at least 90% of the value of sales in the US market in most of the last 20 years. [110]

At least since Benjamin's seminal essay on modern art [16], we have been engaged with a philosophical struggle over how to keep works of art tethered to a value. At the same time, though, we have witnessed a very tangible explosion in the valuation of art pieces, and their overt conversion into investment commodities. The New York art market is essentially now a minor branch of the New York Stock Exchange. Was the City of Detroit's proposal culturally short-sighted or was it a recognition that certain art pieces are in fact commodities? If the city had a stash of gold bouillon sitting in a large building downtown, would the public outcry over selling it have been the same, or would it have been hailed as a shrewd fiscal decision to save the city? The presence of the art in the DIA has done nothing, after all, to turn the tide of the city's 70 year population exodus; what, then, is the cultural significance of this work beyond its financial value?

Benjamin's thesis that uniqueness is the thing that makes a work of art valuable still holds: Basquiat's *Untitled* (1982) would not have sold for $110 million if there were ten of them, all deemed "authentic."[34] Literally any human with an Internet connection can view any of the several hundred thousand digital representations of *Untitled* simply by performing a Google search for it, but only one person can hang the 72 $\frac{1}{8}$" x 68 $\frac{1}{8}$" canvas in their home. And so, the economy of art mirrors the larger economy: if "aura" is that which contributes to the skyrocketing value of a specific art piece, then the distribution of "aura" must necessarily be limited to a tiny fraction of all available art pieces in order for any one of them to achieve extraordinary valuation. To take the Democratic Socialist view, the top one tenth of 1% of art works are imbued with greater "aura" than the collective bottom 90%, quite regardless of their "authenticity."

This phenomenon is coupled with an ever deepening struggle on the part of individual artists to uphold the aura within their own art, because it is within its aura that its real value is located. For living artists, this entails cultivating a cult of personality: cultivating a Warholian aura of themselves so that anything they may produce may be similarly imbued. For those vast

[34]"Basquiat generated $439.6 million at auction in 2021, the most ever for the artist—and second only to Pablo Picasso." [92] "Generated" may not be quite the right word here. Perhaps: "caused the transfer of," since several people merely traded dollars for canvas, and no actual wealth was made new by the canvas.

warehouses of art pieces that do not command sums on par with Basquiat, marketplaces have moved swiftly to create structures bent on value extraction on a large scale. A mere twenty years ago, it was possible for record companies to sell individual reproductions of recorded music at scale, and for musicians to make a small fractional profit from those sales of physical representations. In the last twenty years, we witnessed the end stage of Benjamin's problem of mechanical reproduction. Reproductions of works lost *all* value in their ubiquity. This coincided with a near perfect crossfade within the marketplace: the idea of capital in music reproduction shifted from the mechanical reproduction and dissemination of copies of individual works to the amassing of enormous digital collections.[35] Tech giants turned themselves into mega-collectors able to turn profits by granting access to the broadest possible pool of always-available recordings. One can almost draw a straight through-line from Napster, which launched in 1999 to the great dismay of record companies for its ability to undercut corporate profits[36], to Spotify (launched in 2008) as the legal corporatization of the same activities as Napster. [180] If Napster was a revelation in the potential for ubiquity of access, Spotify was the capitalist revelation in the new commodification of ubiquity. An individual either pays for access to everything, or there is access to nothing. The "subscription model" has almost entirely replaced the concept of the individual sale of a digital product, and this paradigm has encroached even into niche creative domains

[35]In 2022, Spotify boasts managing "over 82 million tracks, including more than 3.6 million podcast titles." [174]

[36]Napster quickly went bankrupt in 2001 from lawsuits over the murky legality of its file sharing. [21]

such as photo and video editing, writing, 3D art, and music notation.[37]

All of this is to say that no entity in need of money to operate can ignore what is happening more broadly in the art market and in the economy generally. This is especially true when we are discussing digital art, as whether or not its creators intend, they are contributing to the enrichment of the holders of what Yanis Varoufakis describes as "command capital." As Varoufakis points out:

> Meanwhile, digital platforms have replaced markets as the locus of private wealth extraction. For the first time in history, almost everyone produces for free the capital stock of large corporations. That is what it means to upload stuff on Facebook or move around while linked to Google Maps...It is not, of course, that traditional capitalist sectors have disappeared. In the early nineteenth century, many feudal relations remained intact, but capitalist relations had begun to dominate. Today, capitalist relations remain intact, but techno-feudalist relations have begun to overtake them. [187]

Johannes Goebel agrees:

> The role the Church once played about 1000 years ago as the controlling body in the era of Europe's first universities is now being taken over by multinational companies through data collection, data mining, and structured accessibility...The holders of power over technology, its development, production and distribution, are the new holders of tradition parallel to the Western European Medieval era, when the holder and gatekeeper of knowledge, its

[37]This discussion could rightly begin to move towards issue of copyright and a comparison between the implication of the idea of "moral rights" attributed to visual artworks by the Visual Artists Rights Act of 1990, as compared to some of the more incomprehensible music copyright lawsuits brought in recent years decided on the testimony of "forensic musicologists" [137], and with the aid of "problematic legal tests (that) lead to...uninformed, subjective jury decisions." ([164] p.290) Suffice to say that the legality around platforms' blanket copyright statements is murky, at best, and the idea of "moral rights" listed in VARA do not extend in the same manner to art objects not specifically listed in that act. For the sake of continuity, I will not be exploring such minutiae here. For the original VARA text, see U.S. Code § 106A - Rights of certain authors to attribution and integrity. [1]

passing on and controlling access, was The Church. ([65] p.7)

Goebel's description of the great lengths needed to create a digital time capsule, quite simply a digital record of work that has been created at one arts institution, is illuminating. It is easy enough to hang a Basquiat on the wall and trust that the work will still be there in several decades or generations, and maintain the same potential to hold value. As I distinguished above, performance activities have never had the potential to hold such value. And by their very nature, we can only cultivate records of performance activities; a record of a thing is never as valuable as the thing itself. Goebel writes:

> A performance, or time-based event in general, does not accumulate value over time, it cannot be used as long-term investment by just having it stored away and waiting for time to pass and "the market" increasing its value. The return on investment in time-based arts is transactional in direct relationship to each individual human's moment and time spent with the work, as the work moves through its own time with the time of the individuals watching, listening, and interacting. Ticket prices to museums do not influence the value of the still art displayed. Ticket prices, cost for prepackaged media, or fees charged for time-based experiences are solely dependent on the very moment of desire of audience members or participants to share time with what will meet their senses, and the financial calculation and market analysis of the artist, presenter, producer or distributor. ([65] p.19)

As evidenced by the need to stockpile massive quantities of digital works in order to profit off of them by controlling access to a collection, it is obvious that digital works fall into a similar "valueless" category.

The blockchaining of individual works of art, in addition to being rife with potential for fraud[38], could be a tool to restore a modicum of "authenticity" and aura to digital creations. In the same way that we "agree" that digital representations of currency hold value, we "agree" that the open-for-inspection nature of the blockchain record allows us to establish and agree upon the provenance of a particular iteration of a digital work, and understand that a specific iteration of a digital work has a particular value that is more significant than other iterations of the same. As with any marketplace, desirability takes over in determining actual market value, but prior to the advent of blockchain, there was in fact no hope of assigning any such value. However, the blockchain marketplace is still a commercial enterprise. Just because we have a more precise means of tracking a single digital instantiation does not remove the record itself from the same potential perils that face any work existing in The Cloud. In both cases, we are trusting corporations to continue to exist, and to continue to invest in the maintenance of the machines keeping the record. As Kaytal points out, "Control and ownership of these technologies seldom coincide with that of the cultural heritage that they preserve." ([90] p.1114)

On this topic, we find ourselves at something of a philosophical dead end. As evidenced by the DIA conundrum, the mere presence of a large collection of quantifiably valuable cultural objects is not enough to alter the social patterns unfolding around them. These social patterns make it more difficult to keep these objects present and safe from deterioration. And digital objects are inherently without value because they lack aura. Registering them

[38]...fraud being the most delicious and ever-present dark side of the art market, worthy of several dissertations on its own.

in an open-platform database may re-endow them with some kind of aura, but the medium in which they are contained is just as subject to the a potential digital dark age as the works themselves. Museums, tasked with preserving cultural creation and faced with a billowing explosion of work in the digital domain have to determine which objects are worth attempting to hold on to, given increasingly limited resources, and while maintaining collections of physical objects as well, whose value they must ensure in order to continue to explore work in the digital domain.

These dilemmas are further exacerbated by the fact that it is nearly impossible even to "own" the computer hardware you have already invested in.[39] This is perhaps one of the most insidious aspects of Varoufakis' techno-feudalism: in nearly every digital act we commit, we are performing labor for and thereby contributing to the enrichment of a large corporation. We are also doing so by means of a tool we thought we owned, but in fact has been leased to us for a finite period. According to Varoufakis, this is part of the process of the broader cultivation of "command capital":

> Standard capital comprises produced means of production. Command capital, in contrast, comprises produced means of organising the means of industrial production. Its owners can extract huge new value without owning the means of industrial production; merely by owning the privatised informational networks that embody command capital.
>
> Command capital, to be more precise, lives on privately owned networks/platforms and has the potential to command those who

[39]During the writing of this paper, *The Wind Garden* suffered a second catastrophic failure resulting from the curious and problematic new forms of "ownership" emerging from the modern technical landscape. See Section 3.4.10 for a discussion of the incident.

> do not own it to do two things: Train the machines/algorithms on which it lives to (A) direct our consumption patterns; and (B) directly manufacture even more command capital on behalf of its owners (e.g. posting stuff on Facebook, a form of labour de-commodification).
>
> In more abstract terms: Standard capital allows capitalists to amass surplus exchange value. Command capital, in contrast, allows techno-lords (i.e. Jeff Bezos, Elon Musk, et al.) to amass surplus command value. Command value? Yes: Any digital commodity has command value to the extent that its buyer can use it to convert expressive everyday human activity into the capacity to train an algorithm to do two things: (A) make us buy stuff, and (B) make us produce command capital for free and for their benefit.
>
> In the language of Marx's political economy, the magnitude of command value contained in any digital commodity is determined by the sum of: the surplus value of the commodities it makes us buy (see A above) + the labour time socially/technically necessary for us to produce a unit of command capital (under B above), to be appropriated instantly by the techno-lords. [115]

In the strictest sense of the word, Apple no longer "owns" the computer it has sold the Stuart Collection, but it does own the ability to allow that computer to communicate with other computers. Apple's manipulation of this reality is deeper than the "planned obsolescence" of, for example, 1950s refrigerators, as GE wasn't actually going around to people's homes and removing air compressors from them. Varoufakis' reference to Marx's political economy is a useful frame through which to consider the situation, but the scope of what is occurring now has significantly outstripped Marx's understanding of tools and their relationship to laborers. Marx recognized the transformation of hand tools into machines as one of the central problems of the industrial revolution: "The special tools of the various detail workmen, such as those of the beaters, cambers, spinners, etc., in the woollen manufacture, are now transformed into the tools of specialised machines, each machine constituting a special organ, with a special function, in the system," ([109] p.264) but his suppositions about the usefulness of tools only extend up to the point that the tools themselves have been worn down by the user and demand replacement:

> "...every year a part of these instruments of labour perishes or reaches the limit of its productive function. It reaches, therefore, in that year, the time for its periodical reproduction, for its replacement by new ones of the same kind. If the productiveness of labour has, during the using up of these instruments of labour, increased (and it develops continually with the uninterrupted advance of science and technology), more efficient and (considering their increased efficiency), cheaper machines, tools, apparatus, etc., replace the old. The old capital is reproduced in a more productive form, apart from the constant detail improvements in the instruments of labour already in use." ([109] p.424)

In order for *The Wind Garden*, which went live in 2017, to survive only to 2022, the Stuart Collection must lease new tools, and commit a not insubstantial amount of money to the recreation of the platform on which the piece runs. Similarly, in the very near future, the Lord Microstrain accelerometers used to collect data in *The Wind Garden* will also be obsolete in that they will no longer communicate with the rest of our hardware stack; even if they still technically function, this company has no economic imperative to keep these backwards compatible for our obscure artistic purposes. The money the Stuart Collection spends to replace these still functioning but rendered useless tools could be devoted to the building of the Collection's own cultural capital, to the commissioning of new work, to the collection of other pieces that would continue to expand its institutional aura. Instead, the Stuart Collection is forced to "pay rent" on its own capital to a more powerful and very-non-governmental manager of capital.

1.6 Many Hands

> "I know now that there is an army of people equipped with the interest, knowledge, and skills to prevent it (and we are training more every day!), I feel confident in saying that there will very likely be #nodigitaldarkage."
>
> Heather Ryan, "#nodigitaldarkage"

We may fundamentally rely on commercial technologies and enterprises for preservation, but the effort of preserving is not limited to a handful of atomized centers of wealth. This may be the primary difference between our current time and most attempts to preserve the libraries and knowledge centers for all of analog history. The very impulse to digitize vast physical collections that emerged in the mid-1990s was not just a result of the (perhaps questionable) idea that the objects would be immortalized outside of their corporeal stature, but that the information contained therein would be spread beyond a single physical incarnation. When the Library of Alexandria was destroyed, there was no backup copy in Constantinople. It is possible that a catastrophic loss of physical computing technology in one part of the world could be remedied by way of technologies in another part of the world, but given the examples above about Backblaze and Amazon, we would need a significantly different approach to data dispersal than is currently in place.

Of course, as noted in the differences in complexity between Cerf's hypothetical and very complex web X-Ray thought experiment and Goebel's actual but very simple growing time capsule, preserving regularly accessible data is not the same as preserving a cultural heritage. As we are still very much in the throes of trying to work out how to preserve digital culture, efforts by what I will refer to as "pop-up preservationists," which in my reading would include the developers of Projet Antony (who, like the rest of us, rely upon massive corporate technological infrastructure but are acting outside of its command-capital aims), may in the future turn out to be as important as the efforts made by more formalized and better funded institutions like UNESCO or Google. Rhizome.org, for example, "advocates for social memory for Internet users and networked cultures by ensuring ongoing access to digital artifacts in our care; supporting free and open source software tools that foster decentralized and vernacular archives; and building partnerships and relationships with community groups and organizations who share our goals."[40] The long-running UbuWeb, while not working to keep technologies functioning into the future, has become an important archive of experimental art practices spanning several genres and media.

> Founded in 1996, UbuWeb is a pirate shadow library consisting of hundreds of thousands of freely downloadable avant-garde artifacts. By the letter of the law, the site is questionable; we openly violate copyright norms and almost never ask for permission. Most everything on the site is pilfered, ripped, and swiped from other places, then reposted." [67]

[40] See also: Archiving the Avant Garde, The Avant Garde Project, Open Culture, Archiving.org, IMSLP/Petrucci Music Library, variablemedia.net, and still-water.net. Siegfried Zielenski refers to these projects as "an-archives" and also cites Montevideo, NIMK Amsterdam, Videobrasil, the Moscow Theramin Center, and others. ([196] p.102)

But even they acknowledge the fragility of the undertaking. “It’s amazing to me that UbuWeb, after fifteen years, is still going. Run with no money, Ubu has succeeded by breaking all the rules, by going about things the wrong way.” [68]

Being more ad hoc than major commercial or governmental undertakings, such pop-up preservation activities are, however, also fraught. As Goebel points out: “Decentralized organizational structures which are “just human centered”—societal, political, or cultural in contrast to “just financially driven”—often fade out as the founders of the first generation start to die, a sustainable succession has not been put in place, and funding becomes an issue.” ([65] p.40) As Marc Weber pointed out in the quote at the top of this chapter, “Future ages may be forgiven for concluding that the main focus of our society was computer games. These [objects]—with strong hobbyist and professional communities collecting them—are better preserved than many other kinds of digital materials.” ([190] p.6) Weber’s point is, of course, that so many individuals are engaged in the act of keeping old video games accessible, that this is perhaps (not-ironically) the thing that will most likely “be found” in the future, simply by nature of a critical mass of activity. Some of these organic, “unofficial” efforts of conservation approach museum-quality levels of curation and completeness, and frequently involve similarly organic (crowdsourced) channels for funding and support.

A notable example of this community is Joel Hopkins, the Australian gamer who currently holds the world record for the largest video game collection,

Figure 1.9. Joel Hopkins' video game collection

at more than 40,000 titles. In a video posted to YouTube that has gathered nearly four million views, Hopkins gives viewers a tour of his vast collection, moving through room after supermarket-sized room filled with shelves of games, game consoles, and collectables, many of which are decades old and made by companies that no longer exist. [80] At one point in the tour Hopkins stops in the hallway "hub" that connects the different rooms in his collection, and explains that this is where his "retro collectables" are stored. While an exciting electro-funk track plays in the background, Hopkins pauses before a shelf and gestures with pride at one of his "most treasured collectibles." It is a Yamaha DX7 keyboard—a gift, he explains, from the Japanese gaming company Sega. It is an extraordinary moment. Yet it is unclear whether Hopkins is aware of the cultural significance of his keyboard outside of its somewhat oblique connection to video games, or if he is cognizant of the ways in which his specific acts of collecting have transcended his own niche interest. And this is, perhaps, the most revealing and fascinating aspect of this video.

Figure 1.10. Joel Hopkins presents his prized DX7

> "...the new hyper-inegalitarian narrative that has taken hold since the 1980s is not ordained by fate. While it is partly a product of history and of the communist debacle, it is also a consequence of the failure to disseminate knowledge, of disciplinary barriers that are too rigid, and of insufficient citizen appropriation of economic and financial issues, which are too often left to others." ([144] p.966)

If it is useful to consider Varoufakis' narrative regarding the contemporary transformation of capitalism in order to better understand the dynamics in which institutional preservation efforts are compelled to operate, perhaps it is equally useful to consider Thomas Picketty's call to a renewed participatory socialism in this context as well. By simply deciding not to leave preservation efforts in the hands of others but engaging in whatever small ways may be at our disposal (as clearly demonstrated by Hopkins), we are contributing to the preservation of our culture. The unintentional effect of Joel Hopkins' video game obsession is that the probability that a physical example of the Yamaha DX7 will exist for the next thirty or forty years increases. As Picketty points out, dissemination, not concentration, is key. Assuming there are "Joel Hopkins" all over the world (an assumption verified by a simple Google search for "video game collectors," which brings up YouTube how-to's, chat forums, conferences, Reddit threads etc. all geared to supporting a kind of "Hopkins-multiverse" of game preservation) each of which is amassing an individual concentration of video games, the collective result is an almost inconceivably massive dissemination of video games and ancillary bits of obsolete technologies. In such a scenario, issues of emulation and porting may then, become questions of taste rather than issues of dire necessity. If as a society of listeners we have come to accept the sound of "porting" the keyboard music of Bach from harpsichord to piano, it is not only because of the durability of piano construction compared to that of the harpsichord, but also at least in part because of the sheer quantity of pianos that exist in private homes all over the world.

Chapter 2

Unruly+

Recalling Rubio's formulation "unruly" as it pertains to time-based art and the difficulties of preserving and maintaining it, the two pieces by John Luther Adams discussed herein might be considered *unruly+* as they not only face the same technical hurdles and eventual demand for porting technologies, but the works themselves are conceived to be ever-changing. Such an ingrained mutability forces a reckoning with the constitution of the work. What is it that the museums are working to conserve exactly? How shall this be accomplished? The problems I have been compelled to address, while very much related to concepts of digital archiving and preservation are even more artistically urgent. The museums that hold these two works by John Luther Adams are not engaged in the storage of a digital art piece for potential future retrieval; they are engaged in the process of keeping a time-based musical performance functioning for an indefinite duration. In the case of both works by Adams, the works are:

- site-specific

- computer music based
- time-based, in at least two senses of that idea

Each of these aspects demands general consideration.

2.1 Site-specific Work

> The correct density should allow for surprising, emergent moments of spatial melody...these will be most common closer to the north and south ends of The Crossing.
>
> The piece should breathe. Use *floor* and *scale* judiciously. Too much volume destroys what should be a delicate and reaching experience. Too much scaling corrupts the natural respiration of the grove.
>
> At times (but not at all times), it should be possible for an inattentive passer-by to move through the grove and not realize he/she/they are inside a sound installation.
>
> Listening with intention should be rewarded.
>
> Walking with intention should be rewarded.
>
> Jason Ponce, *The Wind Garden Technical Manual*

This section will not provide an exhaustive analysis of site-specific work, as such exhaustive analyses are themselves discrete dissertations. My aim here is simply to address a few salient points as they relate to considerations of preservation, and will eventually inform the discussions of *The Wind Garden* and *The Place Where You Go To Listen.* In 2001, William Real proposed that in dealing with digital installation art, the conservator not follow a specific set of guidelines, but undertake a process of interrogating the work, asking such questions as, "In what ways might an installation change in future iterations, while at the same time retaining its authenticity?", "What risks to the future integrity of an installation should be anticipated?", and, crucially for our purposes, "In what ways is an installation more like a performance than an object?" ([154] p.214)

At least part of the reason for Real's approach may be that, as Tatja Scholte points out, "There is no particular art movement or art form called 'site-specific installation art'." ([166] p.42) Therefore, there is no prescribed objecthood to study and from which to develop a concise list of shared characteristics and conservatory approaches. Complicating this is the fact that in its original incarnation, site-specific art as a practice was a reaction against the physical confines of the museum (i.e. those institutions that are now working to preserve this kind of work.) "By working directly with the conditions of the site, artists gave expression to their aversion to the ideology of the white cube."[1] ([166] p.44)

[1] See also Scholte [167]

> Site-specific work in its earliest formation, then, focused on establishing an inextricable, indivisible relationship between the work and its site, and demanded the physical presence of the viewer for the work's completion. The (neo-avant-garde) aspiration to exceed the limitations of traditional media, like painting and sculpture, as well as their institutional setting; the epistemological challenge to relocate meaning from within the art object to the contingencies of its context; the radical restructuring of the subject from an old Cartesian model to a phenomenological one of lived bodily experience; and the self-conscious desire to resist the forces of the capitalist market economy, which circulates art works as transportable and exchangeable commodity goods - all these imperatives came together in art's new attachment to the actuality of the site. ([100] p.86)

In this intrinsic tie to locationality, Rosalind Krauss proposes that site-specific art is in fact a modern-day descendent of ancient practices of sculpture. In pre-modern times, sculpture was similarly locked to a place:

> The logic of sculpture, it would seem, is inseparable from the logic of the monument. By virtue of this logic a sculpture is a commemorative representation. It sits in a particular place and speaks in a symbolical tongue about the meaning or use of that place. The equestrian statue of Marcus Aurelius is such a monument, set in the center of the Campidoglio to represent by its symbolical presence the relationship between ancient, Imperial Rome and the seat of government of modern, Renaissance Rome. Bernini's statue of the Conversion of Constantine, placed at the foot of the Vatican stairway connecting the Basilica of St. Peter to the heart of the papacy is another such monument, a marker at a particular place for a specific meaning/event. ([96] p.33)

Curiously, even though they are to some degree both intentionally "housed inside" museums, *The Wind Garden*, and *The Place* are both deeply site-specific in that they are responsive to the environment in which they are situated (more will be said on this topic later). Traditional time-based arts (music, dance, theater) on the other hand are fundamentally placeless, and phenomenologically occupy the uniquely slippery world of semi-ungraspable experience shared by deep-sky objects.[2] Musical practices have historically developed as a result of the environments in which they tended to be situated, and a wing of acoustic archaeology has grown around analyzing, for example, sound diffusion in Gothic cathedrals and Etruscan tombs,[3] in order to better understand the specific relationship between space and the music performed in those places. Yet Gabrieli's *Sacrae Simfoniae* can be performed in any venue to similarly pleasing effect. Yes, the piece is better understood if a modern venue has the potential for antiphonal placement of instruments (the most prominent architectural quality of St. Mark's Basilica that contributed to their composition), but the pieces will work without antiphonality. And on the other side of that relationship, the reverberation time of St. John the Divine in New York City is substantially longer[4] than the 1.8-2.2 seconds that is understood as the ideal range of reverberation time for orchestras performing 18th and 19th century music [72], but the New York Philharmonic has presented 29 annual Memorial Day concerts there anyway, including, most recently, music

---

[2] Faint deep sky objects, such as, for example, globular cluster Messier 56, first identified by Ptolemy in the 2nd century, which is part of the constellation Lyra and located in the so-called "Gaia Sausage," are better viewed through averted vision. If you look directly at such objects, the lack of rods in the center of the eye makes them appear to vanish. [73]

[3] See for example: Howard, Moretti, "Sound and Space in Renaissance Venice: Architecture, Music, Acoustics." [81], and: Girón, Galindo and Gómez-Gómez, "Assessment of the subjective perception of reverberation in Spanish cathedrals." [64], and: Oroleva, Barnard, "Sound properties in pre-Roman Etruria: an archaeoacoustic analysis of the Etruscan tomb space." [136]

[4] The reverberation time of The Cathedral of St. John Divine is widely reported to be around 8 seconds. [107]

by Mozart and Schubert. [132] People attend these concerts, and given that there have been 29 of them, apparently enjoy them.

Imagining an orchestra playing Schubert in a space with an 8-second reverberation time leads me to ponder artistic identity crises more generally: I would propose that all arts have undergone an identity crisis over the last 100 years as a result of the various confluences of world war, cold war, Western economic flourish, and the parallel rises of commercial computing and globalism. Yet compared to something like the idea of "sculpture," music continues to be, at its core, organized compression waves in air, even if those compression waves are unrecognizable because of the architectural environment in which they are propagated. To illustrate this, consider these two contrasting examples of classic installation work: attempting to understand Maya Lin's *Storm King Wavefield* (2007-2008) as belonging to the same "category" of work (i.e. site-specific sculpture) as Richard Serra's hotly contentious *Tilted Arc* (1981) is perhaps not only an intellectually flawed undertaking, but wholly useless in terms of considering barriers to the ongoing existence of either work. The primary danger to Lin's work is soil compaction and subsequent erosion [32], but the downfall of Serra's was public outcry over use of urban public space. To wit, Real's recommendation for interrogating aspects of the specific work at hand.

Speaking to the anti-establishment urge inherent in early site-specific undertakings, Jennifer Mundy notes of *Tilted Arc*, "The sculpture was finally removed on 15 March 1989. Cut into three parts, *Tilted Arc*—or, rather, what remains of it—is stored in a warehouse. The artist regards the work as destroyed because it is removed from its intended site. He also noted that, in disregarding his argument and considering the work as movable, the General Services Administration had made the work 'exactly what it was intended not to be: a mobile, marketable product'." [117] But Serra's stance may have been unique as time, market forces, and preservation efforts imposed themselves upon older generations of such work:

> In the recent past, however, as the cultural and market values of works from the 1960s and '70s have risen, many of the early precedents in site-specific art, once deemed so difficult to collect and impossible to reproduce, have reappeared in several high-profile exhibitions, such as "l'art conceptuel, une perspective" at the Musee d'art moderne de la ville de Paris (1989), "The New Sculpture 1965-75: Between Geometry and Gesture" (1990), and "Immaterial Objects" (1991-92), both at the Whitney Museum. ([100] p.97)

It is curious to imagine that in the unruly realm of site-specific work, *some* preservation efforts may actually run counter to what would be in accordance with the artist's wishes. In such cases, what are the weights of aura and authenticity in the work relative to their value (cultural or economic) for the museum?

2.2 Computer Music

Although certain aspects of computer musicking clearly fall into the category of pure research (mathematics, compositional algorithms, acoustics, psychoacoustics, etc.), the performance practices of computer music occupy a more diffused spectrum of activity. This spectrum ranges from "laptop music," to the creation of hyperinstruments (realtime sonic transformational interactions with acoustic instruments[5]), improvisation (which also includes live coding), etc. These various practices are realized using a variety of standard electroacoustic techniques like realtime processing, score following, various synthesis processes, etc. When computer musicking transitions from pure research to performance, however, the computer itself moves into the domain of performative-object, and presenting it in this way reveals a number of embedded questions that were discussed briefly in the introduction: in a computer music performance, how is the body represented? How tightly or loosely is a presentation of computer music linked to traditional notions of instrumenthood? How has the performer approached the question of interface and considered that which should be shown to an audience vs. what should remain hidden? These questions speak to a complex collision of practices, and make a strong argument that "computer music" (like "site-specific art" discussed above, or "time-based art" discussed below) might occupy generally a similar "unruly" territory as Rubio's installation works.

[5]The MIT Media Lab has an entire division devoted to the development of hyperinstruments. They define the phenomenon as such: "The Hyperinstruments project creates expanded musical instruments and uses technology to give extra power and finesse to virtuosic performers. They were designed to augment a wide range of traditional musical instruments and have been used by some of the world's foremost performers (Yo-Yo Ma, the Los Angeles Philharmonic, Peter Gabriel, and Penn & Teller). Research focuses on designing computer systems that measure and interpret human expression and feeling, exploring appropriate modalities and content of interactive art and entertainment environments, and building sophisticated interactive musical instruments for non-professional musicians, students, music lovers, and the general public." [101] However, as a general term, I would apply it to any circumstance of using computer technology to somehow enhance the sound of a natively acoustic instrument.

2.2.1 Interface

Unruliness in computer music arguably begins with the concept of *interface* which, in this context, can mean a number of different but related concepts, including:

- Interface between performer and computer
- Interfaces between technical systems
- Interface between performer and audience

Musician's interface (interface between performer and computer)

The human-machine interface in computer music is one of the more widely explored aspects of computer music performance and, interestingly, one aspect that is known and discussed both inside and outside the (usually academic) communities that create and present computer music. The problem of embodiment inherent in computer music breaks the historical contract of concert music presentation, in which it is expected that physical (musical) gesture be meaningfully linked to resulting sound, and has led to a kind of crisis as performers and audiences struggle to understand and adapt to what both *looks* and *feels* like a lacuna between body and sound.

All musical instruments must have an interface of some kind. This interface imposes certain actions and behaviors upon the instrument, and is responsible for abstracting away certain sonic or material properties of the instrument in order to support musical expression by a performer. It is not important, for instance, that a cello player understand the structural or acoustic properties of spruce or maple in order to master the cello. Nor is it particularly important for a piano player to understand the intricacies in the complex hammer-throwing mechanism that is engaged between the striking of the key and the striking of the string. In both cases, the performer is tasked only with mastering a set of physical motions required by the interface, which is then judged as more or less successful according to the sound produced by the instrument. Computer music instruments also demand that the performer master a set of physical motions and gestures in order to create sound, but digital instruments differ from acoustic instruments in that unlike the fixed interfaces to a cello or a piano, which have remained more or less unchanged for several hundred years, the interface to a computer music instrument is a highly arbitrary and individualistic piece of design. Two people tasked with producing their own interface to the same computer music object will not produce the same thing, and as an "instrument" it is easy to imagine that one could be "good" (discoverable, sensitive, articulate, etc.), and the other "bad" (obtuse, confusing, leaden, etc.), or both good and bad for different reasons, depending on which principles of design are being discussed. Therefore, there is an important cognitive layer that must be imposed upon technical systems that are to become musical instruments, a layer which is highly sensitive to extramusical design paradigms.

There is no doubt that computer music embodiment and interface are deep and complex questions, and I will not not attempt a comprehensive discussion of the subject here. Instead I will quote Bob Ostertag's summary of the issue from his article, "Why Computer Music is So Awful," which he penned after being invited to sit on the computer music jury at the particularly high-profile and well-funded Ars Electronica festival:

> Despite years of research and experimentation, however, there is still no new instrument sufficiently sophisticated to allow anyone to develop even a rudimentary virtuosity with it. I believe that this failure is rooted in the premise that the problem lies in inadequate controllers. The bigger problem is this: What exactly are we going to control with these controllers we would like to invent? The performance software I have made does not require much data input to play. On the contrary, it requires very little. I might spend a whole performance making changes of very fine gradation to just a few variables.
>
> If I had some really wild controller that doesn't exist now but that I could dream up—such as a big ball of a mudlike substance that I could stick my hands into, squeeze and stretch, jump up and down on, throw against the wall and wrap around my head, resulting in a variety of parameter streams that would be seamlessly digitized and fed to the computer— even if I had such a thing I don't know how I would use it. I have no software that could use all that data and I don't think anyone else does either. The problem is inherent in the very concept of the music: if we are "playing" by intervening in ongoing automated processes, then most of what is going on requires no input from the performer, and subtle interventions on the performer's part are more likely to add compositional coherence to the result than big, dramatic ones. [138]

Ostertag's conundrum appears to be the central problem addressed by Sam Pluta's 2012 doctoral dissertation: "Laptop Improvisation in a Multi-Dimensional Space." [145] "A summary of the argument is that by creating a multi-dimensional environment of Sonic Vector Spaces and implementing a method for quickly traversing that environment, a performer is able to create enough information flow to achieve laptop virtuosity." Pluta's performance life as a laptop improviser speaks to his own virtuosity with the performance software and controllers he has developed for himself, but we are not yet in a collective place where any one person's creation addresses Ostertag's problem generally. Given all of the economic forces discussed throughout this paper, we may never be in such a place.

Interfaces between technical systems

Depending on the type of computer music instrument that is desired, there will be a greater or lesser number of internal interfaces at work. Internal interfaces here are defined as technologies or methods that are not exposed to the audience *or* the performer, by which one layer of a computer music instrument is made to communicate with another. A partial list of typical computer music layers which require interfaces include:

- data/storage, where the interface could be a relational or time-series database, and a query language
- controllers/data, where the interface could be OSC or MIDI
- synthesis/voicing, where the interface might be a polyphony construct (poly or poly~), or an ADR envelope
- time/synchrony, where the interface could be NTP, a click track, or

SMTPE timecode

- logic/control, were the interface might be a software delivery mechanism between a computation and an articulation

- object/object, where the interface might be any programming construct that allows for high-level modularity or interoperability

I would again defer to Ostertag, who summarizes the challenges faced by a computer musician in dealing with the quantity and complexity of internal interfaces while creating a new work:

> ...it appears that the more technology is thrown at a problem, the more boring the results. Composers may begin with a musical idea but get lost along the way in the writing of the code, the troubleshooting of the system, and the funding to make the whole thing possible, then fail to notice that the results do not justify the effort. [In computer music] the merits of the works done with cutting-edge versus commonplace technology are certainly opaque to the uninitiated, and often discernible only to those who have invested time and effort acquiring expertise in the very same technology. [139]

Each node of internal interface offers the possibility for good or bad design decisions, and it is within the management of these "opaque" interfaces that many computer music projects go careening into "so awful" territory, as the sheer bulk of the time spent on the creation of many computer music projects ends up concentrated in this realm to the detriment of the other elements of the work. As Ostertag rightly points out, more technology does not necessarily equate to more interesting results. What it does necessarily equate to, though, are more internal points of interface, more design problems to be solved. In *The Wind Garden*, one of the (more problematic) internal interfaces of the piece was the SQL database that sat between data acquisition and synthesis (see section 3.3 and the ensuing discussion), with SQL queries and Java mediating between. As discussed, this interface aged very poorly and was eventually eliminated, but the process of managing, eliminating and ultimately rebuilding a replacement interface constituted several major chunks of project time. Developing an effective and appropriate alternative demanded keeping the aesthetic priorities of the piece, as defined by John Luther Adams, as a layer of guiding thought while I worked on internal interface problems that sometimes felt only tangentially related to the sound production goals of the full work.

It is possible that the omnipresence of these kinds of problematic internal interface issues is actually an endorsement for the IRCAM model of collaboration between "composers" and "engineers" working together on a project. Although this model problematically ossifies the hierarchic social structures of composer "stars" and anonymous, nameless engineers (as well as the compensation structures enjoyed by those two categories), the division of creative labor is actually useful. Somebody must be responsible for keeping an eye on the trail of breadcrumbs that will lead back from the dark forest glade of technical interiority so that we have a cultural object ready to hold up at the end of the day, and not just an evidential series of solutions to technical problems that are irrelevant outside of the context of a particular piece of music, i.e.: solutions to problems that are so obscure that nobody cares about having them solved.

Interface between performer and audience

> Digital musical instruments bring new possibilities for musical performance. They are also more complex for the audience to understand, due to the diversity of their components and the magical aspect of the musicians' actions when compared to acoustic instruments. This complexity results in a loss of "liveness" and possibly a poor experience for the audience. [18]

In reviewing several touchstones of contemporary media studies (for example, Philip Auslander's *Liveness*, originally published in 1999 and re-issued in 2008), one senses that the authors' struggles to make logical order of an increasingly chaotically mediated world of blended digital and analog experience have become hopelessly dated. The parabolic upturn in the degree to which individuals' lives have become mediated over the last decade (the ability to live broadcast from a cell phone, for example), renders quaint the anxiety over what used to seem like the conflicting nature of "live" versus "recorded" performative acts. Auslander cites The Doors putting a live performance on hold in 1967 to watch themselves on a televised (not live) broadcast ([12] p.10). Paul Sanden, writing in 2012 describes a scenario in which a band performs along with pre-recorded elements in a "live" performance and questions the nature of "liveness" within that performance, and the degree to which an audience understands that it is not, strictly speaking, completely "live." ([163] p.2) These questions may have felt urgent a decade ago, but feel somewhat less urgent in the face of social media ubiquity, when at nearly every moment, somebody somewhere is "live-streaming" some aspect of their daily life.

Somehow, though, despite this phenomenon, there continues to be a dissatisfying realm of interface between performer and audience in the presentation of computer music. To better grasp this, it may be better to consider James Gibson and Michel Chion. Gibson's model of "cognitive affordances" [63] appears frequently in the growing discourse around computer performance and interface, and this concept has come to encompass both human-machine interfaces and also the interface between performer and audience (what I refer to as a "historical contract" above). As stated in Chapter 1, it is a performer's job to hold up cultural objects for the scrutiny of others. Computer music is particularly unruly in this regard due to its highly interdisciplinary nature and the fact that the typical musicking discourse between performer and audience is complicated by many of computer music's defining aspects. Put simply, in a fully acoustic concert, part of the experience of observation includes observation of the physical connection between performer and object of performance. This basic notion drove the development of many precursors to and early forays into hyper-instrumentalism, for example Boulez's *Dialogue de l'hombre double* (1985), Manoury's *Pluton* (1988/89), Davidovsky's *Synchronims* (1963-2006), or even Luigi Nono's intentionally less technically slick *Sofferte onde serene* (1976) and *La lontananza nostalgica utopica futura* (1988). In their own way, each of these pieces activates a perception game for the audience in their use of electronic elements to confound the perception of sound source. But as one moves away from the rarefied world of hyper-instruments to computer music more generally, observations of the physical act of performance slip from playfully confounding to utterly baffling.

If we think of a concert presentation as a narrative following the logic of Don Ihde's "Embodied" model, the story of a concert performance always looks like this:

> The player picks up the instrument (having learned to embody it) and expressively produces the desired music: Player $\Longrightarrow$ instrument $\Longrightarrow$ Sound. In Embodiment cases, the soundmaking instrument will be partially symbiotically embodied. (Player-instrument) $\Longrightarrow$ sound. ([84] p.95)

Obviously, performing with a laptop destroys such a cleanly articulated structure of embodiment. In his seminal book, *Audio-Vision* (1994), Michel Chion writes at length about the ways in which film sound works with or against cinematic narrative structure, and the many possible forms of play between diegetic sound (sound that is a direct result of action within the narrative and action of the film) and nondiegetic sound (sound that is applied to the film but does not arise from within the film-world). "Sounds can be situated at different narrative levels, such as conventional background music (nondiegetic) and synch dialogue (diegetic)." ([34] p.67) I would propose that the principal disconnect in the interface between performer and audience in computer music concertizing is the result of 1) the *disembodiment* of physical gesture to perceived sound and 2) the manner in which this disembodiment seems to render all of the sound as performatively "nondiegetic", or otherwise acousmatic.

I would argue that humans have a general sense of the acoustic properties of objects based on a lifetime of both intentional and unintentional observation. Nobody sitting in a concert hall would observe a row of sousaphones lined up on stage before a performance and imagine that the sounds that are to come will resemble a kazoo choir. But everything about the computer is non-discernable from an audience standpoint. One cannot look at a computer and guess what kind of sounds will come out of it. We all know that *all* sounds *could* come out of it. The music of both Skrillex and a live-coding concert originate from the same on-stage performance objects. Similarly, the gestures of a computer musician are essentially invisible to an audience (typing being hidden by the screen of the computer), and lack direct acoustic consequence. In a Skrillex concert there is no attempt to (or necessity) to equate physical action to sonic result, as that dramatic narrative is replaced by stage spectacle. The attempt at didactic expression during a live-coding performance may keep alive the embodiment narrative somewhat, but the performance as a whole subsequently suffers musically from what Ostertag described as "inadequate controllers." This phenomena cannot be discussed purely as a shifting (or breakdown) of embodiment structures, or purely as a problem of computer music existing in a permanent state of the non-diegetic; it is a problem that exists at the intersection of these phenomena.

This intersection of confusions is a much deeper root problem intrinsic to the act of performing computer music than any problems that may still be lingering in society's relationship to ''liveness" or other mediated acts, performed or not. Regardless of whatever new realms of meta-verseification are to come in the next decade, the basic breakdown of the historic contract of live performance that occurs in the performance of computer music will not go away.

Interfaces between computer music and institutions

Looking back at a thing like the Philips Pavilion, a thing most of us alive and engaging with computer music practice today never actually experienced, it feels like a promise was being made along the lines of, "(Thanks to the Philips corporation), in the future we will all have flying cars." That is, in the future, we will all have multi-channel sound fields situated within elegant and intriguingly built environments to play with. The practice of computer music since then has developed along the lines of assuming that if you build it inside the computer, external access (to physical spaces, to financial and other technical resources, etc.) will come. In reality, computer music is made predominantly within the highly limited scope of universities, and performed or presented at universities or similar institutions via academic conferences, often to very limited and specialized audiences.[6] Sources of funding often ensure that research agendas at computer music centers are set by administrators and not necessarily by composers or artists, and while interests may at times overlap, these relationships are certainly fraught. [24] Similarly, the tools and methods of producing such music make it difficult or impossible for composers to develop work anywhere else but within these highly specialized labs or studios which are, again, almost always attached to large institutions.

The environment in which we now operate is not so different from the most nascent days of the field, when composers were compelled to flock to places like the WDR Electronic Music Studio in order to realize such work.

[6] See section 5.2 for more on new music and subculture.

Places like The Center for New Music and Audio Technology (CNMAT), and the Studio for Electro-Acoustic Music (SeaM), satellites of The University of California Berkeley and The Bauhaus University in Weimar, Germany, respectively, are both results of and reactions to the institutionalization of computer music. While CNMAT presents a relatively unencumbered community of high-performance audio researchers and composers that stands somewhat apart from the UC Berkeley School of Music, SeaM offers something rarely seen in the United States: its "loudspeaker orchestra" is a computer music composition studio that gathers high-performance, high-directional audio with a large array of unpaired and uncalibrated loudspeakers of varying quality and orientation, all presented to the composer as options for creative diffusion of audio. And both of these somewhat niche communities stand in further contrast to the similarly rarefied world of the highly-funded and well-tuned multi-channel speaker arrays like the Birmingham ElectroAcoustic Sound Theatre (BEAST) at the University of Birmingham, UK, or the Wavefield Synthesis array at Rensselaer Polytechnic Institute's EMPAC. Needless to say it is impossible to develop work for any of these studios outside of the spaces themselves. Composers wishing to create works for any such spaces must somehow align, or interface, themselves with the institutions that support them, and then physically go there—all of which presents significant barriers to entry and access.

On the other hand, *audiences* experience multi-channel sound fields every time they go to the movies, or attend popular stage spectacles like *Cirque du Soleil*. Just as we should be wary of entrusting all of our long-term data storage to commercial enterprise, we should be equally wary of entrusting our imaginations and our will to create to the same. But we are living in a nearly impossible paradox for would-be computer musicians. All potential audiences are accustomed to movie theater level audio performance, and they also, generally, have access to portions of the same tools (computers and software) that allow anyone to be a computer musician. This creates a disconnect on the part of anyone who has opened Garage Band and also attended a Pixar movie, imagining, perhaps, that there is a neat linearity between the two for anyone who chooses to spend enough time twisting virtual knobs in Garage Band.[7] But as we know, the creation of unique computer music objects depends not just on interfacing with the computer and building internal interfaces within the computer, but on the ability of the musician to interface with an institution capable of supporting and realizing the total work. Imagine if every pianist possessed only the action of the piano, and only a select few with access to an institution with fully built pianos, or with enough personal resources to build one themselves, would be able to hear the results of their physical practice on the keyboard.

2.2.2 Design and technical debt

Unruliness in computer music is not limited to the various concepts of interface. The practice of computer music occurs primarily outside the typical structures of corporate software development and so is far less "shaped"

[7] Anecdotally, I would argue that even many virtuosic and highly trained musicians in other domains of music making fall into this category of disconnect. Naming names is, of course, highly distasteful.

and "regulated" in terms of code standards, maintainability, and general best engineering practices. There is also far less of a mandate to manage code in such a way that it can be easily understood, worked on, and expanded upon by others, as would be required by a team of software engineers working on the same codebase. As Morse observed, it is safe to say that with respect to the underlying code of a computer music object, the principal assumption behind it is that "it should work." And for the purposes of one or two or twenty concerts, code that "works" (that is, code that does not crash mid-show; lights on, everybody out) may perhaps be sufficient. Matters complicate quickly, however, with sound art or performances that are designed to occur over years, or decades. In these cases the "technical debts" incurred by poor design or bad practice can balloon rapidly, overwhelm maintainers, deplete budgets, and eventually threaten the very existence of the work. Kruchten, *et al.*, define technical debt as:

> The metaphor of technical debt in software development was introduced two decades ago by Ward Cunningham to explain to nontechnical product stakeholders the need for what we call now "refactoring." It has been refined and expanded since, notably by Steve McConnell in his taxonomy, Martin Fowler with his four quadrants, and Jim Highsmith and his colleagues from the Cutter Consortium with their model of the impact of technical debt on the total cost of ownership. From the original description—"not quite right code which we postpone making it right—various people have used the metaphor of technical "debt" to describe many other kinds of debts or ills of software development, encompassing broadly anything that stands in the way of deploying, selling, or evolving a software system or anything that adds to the friction from which software development endeavors suffer: test debt, people debt, architectural debt, requirement debt, documentation debt, or just an amorphous, all-encompassing

software debt. [61]

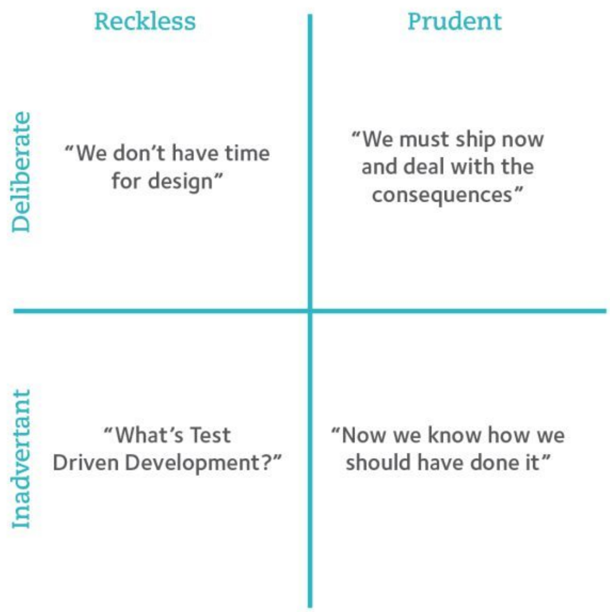

Figure 2.1. Martin Fowler's four quadrants of technical debt [97]

Computer music objects are by definition abstractions and thereby complications of musical idea. This is why when using a computer music object to perform music *design* becomes crucial. At stake are agency to the performer, transmissibility or "portability" from the perspective of the audience, and simple raw utility, all of which are the products of design decisions that are made (or not made, as the case may be) prior to the moment of presentation. Design decisions at all levels affect the end result. For example, in the case of a musician improvising with a computer, a decision has to be made about what specific parameters of the core technical system to expose to the performer (agency, utility), and, equally important, how those parameters should be articulated by the performer (transmissibility, portability) during the moment of production. As discussed above, interface becomes the primary mediating layer between musical intention and reception.

The parameterization of musical intention is described by its own design paradigms. Data structure design can facilitate or encourage the evolution of an instrument, or it can hobble future development and freeze an instrument in place like a living fossil. Careful logical separation of data flow, storage, processing, gating, state, interface and other technical subsystems might make the difference in whether an instrument is able to survive the equivalent of a digital extinction event. To wit, what happens when Apple decides it is no longer profitable to allow their machines to be used for general purpose computing,[8] or when Cycling '74 finally drops Java support in Max/MSP, or when Pd no longer compiles?[9] A living example of the importance of good

[8]The threat to what is referred to as "general purpose computing," or the ability to use a computing device for an arbitrary purpose, is real and troubling. As manufacturers pivot away from those objects formerly known as "computers," and as software becomes increasingly enmeshed in the hardware that supports it we have witnessed an exponential increase in corporate investment in "devices." Devices, while perhaps presenting a veneer of being generally-purposeful, are in fact walled gardens, with highly controlled and corporatized classifications of rules and rubrics for the kinds of computing that is authorized to be performed on them. Producing applications for the ubiquitous iPhone, for example, requires an active developer account with Apple, and all code must be submitted to Apple for approval prior to being made available to the public via Apple's sole channel of distribution. And of course any software sold through Apple's software marketplace nets a return to the developer less Apple's 30% cut off the top. Unsurprisingly, the revenue generated from Apple's software marketplace for mobile devices is enormous, exceeding $85 billion in 2021. [31] Apps can and do get rejected by Apple, and it is not uncommon for apps that were once blessed by Apple to become deauthorized with no explanation and no recourse to the developer. This is further confounded by Apple's boilerplate policy to deny users the ability to upgrade, service, or repair hardware that they have purchased and ostensibly own. The repair of a broken device becomes, therefore, another service to subscribe to, and thereby another source of revenue for the manufacturer.

[9]See the discussions in Section 2.3.3, "The Problem of Long Long and Indefinite Time: The Clock of the Long Now" for an analog elaboration on this idea, and Section 3.4 for a case study discussion of how this exact problem imperilled *The Wind Garden*.

early design choices and thoughtful parameterization in computer music is discussed at length in Section 3.4, "Specific Issues in Conservation of *The Wind Garden*," in which I describe how a poor early decision to use SQL to warehouse and deliver inbound data introduced latency, needless complexity, relentless problems, and ultimately made the work very difficult to maintain. These problems led to a deep and expensive redesign of the work that I performed in 2016.

Open source is certainly one potential solution to this problem, and this is exactly why open source computer music tools like Pure Data and SuperCollider will almost certainly survive longer and remain useful longer than their commercial cousin Max/MSP. However, even though the last decade has seen increased adoption of free open source software and hardware among the general public, the true democratizing power of open source tools is not that they can be obtained and used for no cost; the true value is that these tools make their own source code available to all, to be forked and modified by anyone for any specific need or purpose. Still, the ability to take advantage of the merits of this framework is limited to individuals who have the skills and training to develop and build software,[10] a relatively small group of specialists that in no way represents the general public. Even the venerable Linux operating system, the open source marvel with all of its corporate backers, slick "usable" distributions, and global legions of contributing programmers, has to date claimed only 2.3% market share, largely due to issues of perceived accessibility for non-technical users. [155] And of course market share directly

[10]See [37] for Marisa Leavitt Cohn's discussion of "unruly" code over time.

effects whether or not companies that make popular and widely-used software packages (Adobe Photoshop being a classic example) decide it is worth the time and money to port their products to Linux.

In the end, the cultivation of a rich body of computer music literature (and thereby the critical mass needed for large-scale efforts to preserve it) is perpetually under attack by the imposed decay of innovation. The cello and the piano have such a deep body of literature because the instruments themselves have remained stable for such a long period of time, which has allowed for the separation of labor around the performance practice. The relative stability of the technical design allows for the development of a positive feedback loop within the cultivation of the artistic practice. This feedback loop subsequently allows for the cultivation of expertise in each area within it. Luthiers, continuing to make subtle refinements to the otherwise unchanged design of a cello body are not expected to play like world-class cellists, and the world-class cellist is not expected to carve their own cello. Neither is expected to set down on paper predictive musical ideas in a universally accepted language, nor are they expected to be expert in the preservation of the artistic results of the practice of playing the cello. In the realm of computer music, a new instrument is created for nearly every piece of music in that even if there are similarities of interfaces and design structures with other computer music works, the specific set of decisions for a specific work is unique to the purpose of the piece at hand. Along with perpetual commercial development, this forever-being-built scenario prohibits the possibility of developing a stable body of collective literature that can be pointed to, that can be gathered, which can accumulate cultural weight, which can be preserved.

2.2.3 Paralinguistics and computer code

In my discussion of *The Wind Garden* in Chapter 3, I state that I am a strong advocate of including printed code in written documentation. For individuals used to working with computer code the idea of conserving that code by printing it out may seem off-point, or anachronistic. Yet doing so solves a couple key problems. One is perhaps more obvious: committing code to paper improves the chances of that code surviving on into the future due to its simple materiality. It may be found, perhaps tens or even hundreds of years later, on a shelf or in a ruin, and be understood by an educated reader—even if just in part. This is unsurprising, as computer code, in the form of text written in a given programming language, shares many features of spoken language. In producing code, computer programmers engage in a form of structured discourse that has, like spoken language, a catalog of embedded grammatical and syntactical rules, conventions for punctuation, and methods for logical operation and comparison. So while the understanding of a rediscovered code-artifact-object written in a lost programming language may at first be rudimentary, with some study it can be expected that the full meaning of the code would eventually be revealed. Writing about the discursive properties of code as it relates to intellectual property law, Brian Fitzgerald writes:

> Software which acts as the customising agent of information technology has become so integral to our daily lives that I am moved to conceptualise it as a form of discourse which in turn informs my understanding of how the law might regulate software. Software provides us with a framework for understanding

> and knowing; it is a representational framework. At the most basic level software in object or source code is seen to be a literary (discursive) text for the purpose of copyright law. Software though is much more than a literary text—in a broader and more abstract way software is seen to be a mode of understanding or a methodology for constructing meaning: it is part of the architecture of knowledge.[11] [56]

Code as Language

Below is a fragment of Java code used in *The Wind Garden* which tracks the position of the sun from hour to hour and from month to month in order to provide coefficients for filtering and synthesis. Even this fragment, though obviously only one small part in a much larger, more complex system, is capable of conveying meaningful intent to a reader:

Listing 2.1. Java code fragment from *The Wind Garden*

```java
private void calcHA(double lat, double lon, int year, int month
    ,
int date, int hour, int min, double sec)
{
// sec is type double for calculations
// declare calculated things
double day, JD, T, minTime, time_offset, tst, sha, theta,
    cosPhi,
exoatmElevation, refractionCorrection, te, H, A;
int TZ = 0, DS = 0;

// calculate astronomical times
day = date+(hour+(min+sec/60)/60)/24;
JD = calcJD(year,month,day);
T = calcTimeJulianCent(JD);
minTime = calcEquationOfTime(T);
time_offset = minTime-4*(-lon)+60*(TZ-DS);
```

[11]See also Friedrich Kittler's classic article, "There is No Software." [94]

```
tst = hour*60+min+sec/60+time_offset;
sha = tst/4-180;
if (sha < -180)
{
  sha += 360.0;
}
theta = calcSunDeclination(T);
cosPhi = Math.sin(Math.toRadians(lat))*Math.sin(Math.toRadians(
    theta))
+Math.cos(Math.toRadians(lat))*Math.cos(Math.toRadians(theta))*
Math.cos(Math.toRadians(sha));

// exoatmospheric elevation angle
exoatmElevation = 90 - Math.toDegrees(Math.acos(cosPhi));

// rudimentary refraction correction
if (exoatmElevation > 85.0)
{
refractionCorrection = 0.0;
} else
  {
  te=Math.tan(Math.toRadians(exoatmElevation));
  if (exoatmElevation > 5.0)
  {
    refractionCorrection=58.1 / te - 0.07 / (te*te*te) +
    0.000086 /(te*te*te*te*te);
  }
  else if (exoatmElevation > -0.575)
  {
    refractionCorrection=1735.0 + exoatmElevation * (-518.2 +
    exoatmElevation * (103.4 + exoatmElevation * (-12.79 +
    exoatmElevation * 0.711) ) );
  } else {
    refractionCorrection = -20.774 / te;
  }
  refractionCorrection = refractionCorrection / 3600.0;
}
// refraction-corrected elevation angle
H = exoatmElevation + refractionCorrection;

// calculate azimuth (note correction from degrees W of S)
A= Math.toDegrees(Math.atan2(Math.sin(Math.toRadians(sha)),Math
    .cos(Math.toRadians(sha))*
  Math.sin(Math.toRadians(lat)) - Math.tan(Math.toRadians(theta
    ))*
  Math.cos(Math.toRadians(lat))))+180;

//right to left order
```

```
outlet(1, A);
outlet(0, H);
}

private double calcJD(int iyear, int month, double day)
{
double JD, A, B, dyear;
if(month <= 2)
{
  iyear = iyear-1;
  month = month+12;
}
Integer bigiyear = new Integer(iyear);
dyear = bigiyear.doubleValue();
A = Math.floor(dyear/100); // note cast of year
B = 2 - A + Math.floor(A/4);
JD = Math.floor(365.25*(iyear + 4716)) + Math.floor(30.6001*(
   month+1)) + day +
B - 1524.5;
return JD;
}
```

Interestingly, at least a few of the dominant computer music programming platforms, specifically those like Pure Data and Max/MSP, which fall into the "dataflow" programming paradigm, break (or at least deeply complicate) the paralinguistic relationships computer code has with its resulting musical objects. This breakage is due to the trade-offs in preservability these platforms accept in order to represent musical idea in a way that is 1) visual, 2) conducive to rapid prototyping, and 3) accessible to non-engineers. The result is a highly intuitive and human-oriented set of tools that produce files ("patches") in a format that is extraordinarily volatile from a preservation standpoint, defy the benefits of software version control, and are essentially unreadable in their fundamental state (text). Consider the following code fragment for Karlheinz Stockhausen's *Mantra*, as represented as a text/patch file in Miller Puckette's Pd Repertory Project:

Listing 2.2. Fragment from text/patch representation of Karlheinz Stockhausen's *Mantra*

```
#N canvas 329 127 614 368 10;
#X declare -path ../lib -path -path pdrp-lib .;
#N canvas 476 50 240 278 reset 0;
#X obj 41 24 r reset;
#X msg 41 64 \; ring1-pitch 0 \; ring1-p2 0 \; ring1-plus 0 \;
   ring1-minus
0 \; ring2-pitch 0 \; ring2-p2 0 \; ring2-plus 0 \; ring2-minus
    0 \;
ctl-select1 0 \; ctl-select2 8 \;;
#X connect 0 0 1 0;
#X restore 16 340 pd reset;
#X floatatom 429 233 5 0 0 0 ring1-pitch ring1-pitch-set ring1-
   pitch
;
#N canvas 29 52 754 708 audio-works 0;
#X obj 160 169 hilbert~;
#X obj 347 81 * 0.25;
#X obj 347 103 mtof;
#X obj 403 151 line~;
#X obj 351 200 *~;
#X obj 351 222 *~;
#X obj 347 125 * 0.206825;
#X obj 160 277 *~;
#X obj 238 283 *~;
#X obj 359 55 unpack;
#X obj 159 195 complex-mod~;
```

```
#X obj 160 144 r~ input-signal1;
#X obj 162 582 hilbert~;
#X obj 323 479 * 0.25;
#X obj 323 501 mtof;
#X obj 385 547 line~;
#X obj 348 574 *~;
#X obj 162 613 complex-mod~;
#X obj 162 556 r~ input-signal2;
#X obj 451 78 * 0.25;
#X obj 451 100 mtof;
#X obj 501 153 line~;
#X obj 451 122 * 0.206825;
#X obj 493 55 unpack;
#N canvas 360 84 582 506 pitbis1 0;
#X obj 189 468 outlet~;
#X obj 190 444 line~;
#X floatatom 45 224 0 0 0 0 - - -;
#X obj 44 308 moses;
#X floatatom 233 271 0 0 0 0 - - -;
#X obj 74 333 - 1;
#X text 266 272 bottom of current jitter interval (0-126);
```

There is little here that could benefit somebody who is trying to understand *Mantra*. Indeed, these kinds of techno-musical objects approach meaninglessness without the original software that interprets them. Acknowledging again that small code fragments do little to impart a sense of the larger whole, and acknowledging also that it is perhaps a stretch to refer to these patch/text representations as "code," the contrast to Listing 2.1 is still certainly striking:

gone are the "language" qualities seen in standard text-based programming languages, gone is the readability/scrutability of the text, gone is any hope that should this text be discovered at some distant time in the future that it might be mined for sense or semblance of the culture it once represented. Certainly, dataflow languages do their best never to expose end users to these kinds of textual representations of patches. Nevertheless, this is how they exist as files, ensuring that without a compiled and working copy of Pure Data the significance of these files will almost certainly be lost to time. Of course, what you do get in exchange for this lack of preservability is a dramatic increase in human usability, as shown in in Figure 2.2.

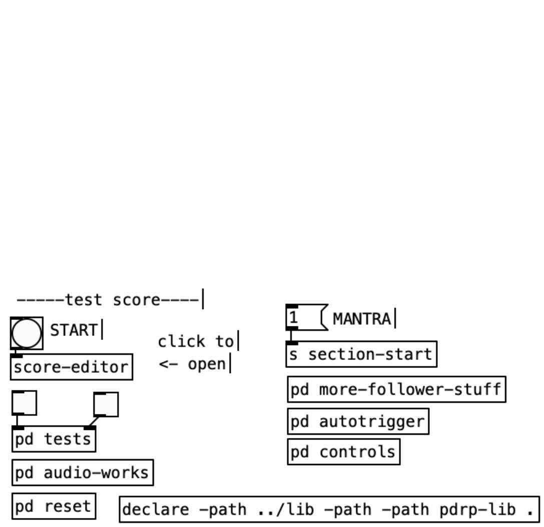

Figure 2.2. Karlheinz Stockhausen's *Mantra* represented as a Pd patch

Code as Speech

Another culture-bearing aspect of computer code is its capacity to represent political speech. The democratization of software represented by the open source software movement is one example, but the ubiquity of software in all areas of modern human life means software's expressive capacities undoubtedly reach a level of "voice" not so distinct from human speech. Addressing the issues of "code as speech," the US Second Circuit court agrees:

> Communication does not lose constitutional protection as "speech" simply because it is expressed in the language of computer code. Mathematical formulae and musical scores are written in "code," i.e., symbolic notations not comprehensible to the uninitiated, and yet both are covered by the First Amendment. If someone chose to write a novel entirely in computer object code by using strings of 1's and 0's for each letter of each word, the resulting work would be no different for constitutional purposes than if it had been written in English. The "object code" version would be incomprehensible to readers outside the programming community (and tedious to read even for most within the community), but it would be no more incomprehensible than a work written in Sanskrit for those unversed in that language. The undisputed evidence reveals that even pure object code can be, and often is, read and understood by experienced programmers. And source code (in any of its various levels of complexity) can be read by many more. Ultimately, however, the ease with which a work is comprehended is irrelevant to the constitutional inquiry. If computer code is distinguishable from conventional speech for First Amendment purposes, it is not because it is written in an obscure language. [79]

Accordingly, there is a rising call to include code in the category of "protected speech." Daniel Bernstein, a computer scientist at the University of Illinois at Chicago, brought such a First Amendment claim against the US State

Department after they classified his new encryption software package Snuffle (along with all printed documentation, conference papers, etc. that included source code) as a "munition," and barred its export under International Traffic in Arms Regulations (ITAR). It is worth quoting at length the opinion given by Ninth Circuit Appeals Court when the case was dismissed and source code was granted protections as expressive speech:

> ..."code," at least as currently understood by computer programmers, refers to the text of a program written in a "high-level" programming language, such as "PASCAL" or "C." The distinguishing feature of source code is that it is meant to be read and understood by humans and that it can be used to express an idea or a method. A computer, in fact, can make no direct use of source code until it has been translated ("compiled") into a "lowlevel" or "machine" language, resulting in computer-executable "object code." That source code is meant for human eyes and understanding, however, does not mean that an untutored layperson can understand it. Because source code is destined for the maw of an automated, ruthlessly literal translator—the compiler—a programmer must follow stringent grammatical, syntactical, formatting, and punctuation conventions. As a result, only those trained in programming can easily understand source code. Also important for our purposes is an understanding of how source code is used in the field of cryptography...By utilizing source code, a cryptographer can express algorithmic ideas with precision and methodological rigor that is otherwise difficult to achieve.
>
> ...we conclude that the challenged regulations allow the government to restrain speech indefinitely with no clear criteria for review. As a result, Bernstein and other scientists have been effectively chilled from engaging in valuable scientific expression. Bernstein's experience itself demonstrates the enormous uncertainty that exists over the scope of the regulations and the potential for the chilling of scientific expression. In short, because the challenged regulations grant boundless discretion to government officials, and because they lack the required procedu-

> ral protections set forth in Freedman, we find that they operate as an unconstitutional prior restraint on speech. [98]

In the case of digital artworks, and especially digital artworks that are expected to survive many years into the future, the analog preservation of source code is a valuable method by which to communicate a specific kind of *intent* to a future reader, even as spoken or written language struggles to do so, and even if it is no longer possible to run or compile that code. A comprehensive approach to digital preservation must avail itself of all available methods, and while this chapter—and in fact *all* written descriptions of *The Wind Garden*—may be a few years behind what is actually running in La Jolla, all effort has been made to provide a robust and comprehensive rendering of what has been done, and—equally important—how Adams intends for this artwork to *feel* when it is encountered. The notion of composing and preserving feeling within interactive artworks is explored more in our discussion of *The Wind Garden* in Chapter 3, but it is worth stating here that "feeling" as I use it here is certainly not about defining the subjective experience of the artwork. It applies only to the guiding design principles and artistic intentions behind the artwork when it is being created, and, for our purposes here, during future efforts to preserve such a work over time.

2.3 Time-based Art

> "Time-based arts is not a genre."
> Johannes Goebel, "The Computer as Universal Time Machine"

Returning to Vitruvius Pollio's winter dining room, I would conjecture that before the 20th century, there was not much confusion over art that is time-based (lyre playing), and art that is not (fresco, sculpture, etc.). Any modern confusion around the notion seems to be rooted in the very problem that is central to our discussion: digitization of physical objects and museums attempting to "hold" time-based art, as it has been hybridized with arts that were formerly non-performative. Music, dance, and theater may occasionally have been performed in museums,[12] but before the 20th century, it could not ever have been the collecting focus of these institutions. Libraries, archives, and museums held scores, letters, and instruments dislocated from their music-making abilities. What other options existed?

All digital art is time-based art. In Vint Cerf's understanding of the confluence of elements that comprise a digital object, this falls under the category of "executable content." ([33] p.10) In the analog medium, a painted image observed is not time-based, it exists physically, and while it may slowly degrade over a very long time, both it and our experience of it are essentially the same upon repeated encounter.[13] In the digital realm, even a static image undergoes a time-based process in order to be observed, although that process might happen at an imperceptible speed. The manner in which this image content is executed (on a CRT monitor, on a 4k display, via projection) alters our experience of the image (varied color, contrast, brightness, etc.), an alteration that never previously occurred with static images, except of course in

[12] The Metropolitan Museum of Art and The Morgan Library, as two examples, even have highly functioning dedicated concert halls within their buildings for just such purposes.

[13] For a differently nuanced discussion on this, see Chapter 5.

certain unique instances. See for example, Figure 2.3.[14] A digital image is quite

Figure 2.3. The botched 2012 "restoration" of Elías García Martínez's 1930 fresco, *Ecce Homo*, located inside Mercy Church in Borja, Spain

literally recreated every time it is viewed. From a conservational standpoint, the ability to re-render a digital image, insofar as it is "executable content" potentially includes ([33] p.13):

- hardware
- operating system
- dynamically linked libraries
- configuration parameters

[14] And speaking of the economics of museums and the art market: "Cecilia Giménez, the Spanish woman who really messed up when she tried to restore a 19th-century (sic) fresco of Jesus, now wants a piece of the action from the 2,000 or so euros ($2,600) her church has collected from tourists coming to see the ruined artwork." [112]

- language settings
- time zone settings

This is not necessarily a more complex process than, for example, decoding and performing a piece of highly-detailed notated music from the score. That we have a general understanding of how to perform a piece like Baude Cordier's *Tout par compas* from the 14th century *Chantilly Codex* (see Figure 2.4) speaks to our ability both to encode and subsequently decode complex instructions of a language not currently in use.

Figure 2.4. Baude Cordier's *Tout par compas*, excerpted from the 14th century *Chantilly Codex*, Musée Condé [41]

Cordier's score is written with neumes, which would have been in common use at the time, but the organization of the ideas was a novel one for any era, a uniquely ingenious coordination of textual narrative,[15] graphic design, and musical symbology at a time before the idea of a "score" had even entered significantly into musical thinking.[16] Several questions persist in the interpretative decoding of the score, but what is certain is that the outside circle is a two-voice canon, written in soprano clef and the inside circle is an accompanying bass line written in alto clef. The notation uses color to indicate the augmentation of notated rhythmic values. The inner and outer circles begin at the same time from the illuminated letter within each circle. The starting point of the trailing canonic voice, as well as the manner of aligning the texts to the notation is to be discovered by the performers.[17] It is important to understand the difference between those elements in Cordier's score that are intentionally confounding (the circle design and use of color) and those elements that are clear, but of an obsolete language (neumes). It it playfully cryptic, but like any score that has been physically rendered, it is a highly detailed set of instructions set in a language upon which contemporary readers would mostly agree. Our understanding of *Tout par compas* is bound to evolve

[15]"All with a compass am I composed, properly, as befits a round. Three times my circumference enclosed; you can chase me with joy, if in singing you are true to me." [42]

[16]Glenn Watkins points out that Gesualdo's behavior in 1594 of carrying around full scores of his compositions, rather than sets of parts, so as to better impress other notable composers of the day with the clearly legible ingenuity of his harmonic inventions was both highly unusual and intensely annoying. ([189] p.43)

[17]Several interpretations of the score have been published starting with Hugo Riemann's 1905 transcription into modern notation (cited by Bergsagel). John Bergsagel published a new interpretation and transcription in 1972 [17], and more recently, Jordan Alexander Key has made available an unpublished transcription created in 2018. [42]

along with our understanding of ancient notational practices (which is to say that our understanding will become richer). The object of the *Chantilly Codex* will only degrade very slowly over a long period of time, much more slowly than will our understanding of the music evolve, whereas in the digital domain any of the processes discussed above could slip through the executable cracks along the way and be gone forever, taking the entire work with it. Ironically, with the rise of internet archives such as IMSLP, scores like *Tout par compas* themselves have become a time-based art form, "executable content."

One might argue that it is actually our newly heightened awareness of what we have lost along the way that makes it seem like we exist in a perpetual motion of loss, particularly with regard to time-based art practices. And of course we are, and we always have been. It's just that it apparently did not used to bother us as much, or we just did not think of it because access to "everything" "always" simply was not part of human consciousness.[18] In this respect, the practitioners of Western concert music have been willfully deceiving themselves for several hundred years that their art has a preserved permanence profoundly different from the oral tradition of other cultural forms of music making. A similar thing same could be said of the environmental crisis. The executors of the industrial revolution seem not to have been aware that resources are in fact finite, or they were similarly willfully deceiving themselves about the permanence of resources relative to the their actions. After all, who

[18]Just pause to consider for a moment the instantaneous destruction of the 70,000 volume Royal Library of Portugal during the 1755 Lisbon earthquake, ensuing tsunami, and three days of city-wide fires. That was just *one* of the several libraries destroyed that day. The number of dead were on a Hiroshima scale. ([157] p.399)

was tracking the general diminution of a particular resource?[19] The awareness itself becomes a double-edged sword, inflicting (hopefully) a profound sadness at our inability to preserve things lost, but in so doing, perhaps urging us on to projecting our awareness of potential loss over longer time periods.

2.3.1 Thinking in medium long time: Cage's *Organ²* *ASLSP As Slow as Possible*

In the course of this discussion, we must discuss both works that are specifically "time-based" and the manner in which works exist "within time." Both *The Wind Garden* and *The Place Where You Go to Listen* are explicitly time-based (i.e. both actively being created *and* performative), but it is also my fundamental interest to make them both perform for a long time—for as long as possible. In the process of interrogating the relationship between time

[19] In her smash hit about the end of life on Earth, Elisabeth Kolbert writes about several people who have been thinking about and modeling this very problem: "(John) Alroy has used computer simulations to test the 'overkill' hypothesis. He's found that humans could have done in the megafauna with only modest effort...When Alroy ran the simulations for North America, he found that even a very small initial population of humans—a hundred or so individuals—could, over the course of a millennium or two, multiply sufficiently to account for pretty much all of the extinctions in the record. This was the case even when the people were assumed to be only fair-to-middling hunters. All they had to do was pick off a mammoth or a giant ground sloth every so often, when the opportunity arose, and keep this up for several centuries. This would have been enough to drive the populations of slow-reproducing species first into decline and then, eventually, all the way down to zero. When Chris Johnson ran similar simulations for Australia, he came up with similar results: if every band of ten hunters killed off just one diprotodon a year, within about seven hundred years, every diprotodon within several hundred miles would have been gone...From an earth history perspective, several hundred years or even several thousand is practically no time at all. From a human perspective, though, it's an immensity. For the people involved in it, the decline of the megafauna would have been so slow as to be imperceptible. They would have had no way of knowing that centuries earlier, mammoths and diprotodons had been much more common. Alroy has described the megafauna extinction as a "geologically instantaneous ecological catastrophe too gradual to be perceived by the people who unleashed it." ([95] p.222)

and objects made now, it is useful to consider objects and the qualities of objects that have survived to us from the cultural deep past. Cordier's *Tout par compas*, discussed above, is one such object that has survived; it offers a study in potential challenges faced by our ability to decode obscure languages across time, a challenge not dissimilar from the challenges that will inevitably arise in understanding computer code in some distant future. The fact that the relationship between Cordier's notation and a performance of the piece is not wholly transparent, that is, the fact that it demands a certain decoding or "figuring out" may in fact be part of our abiding interest in decoding it. In this respect, it could be considered a historical "success story," in that it has *both* physically survived, and the idea of accessing the music it suggests continues to be intriguing and appealing.[20]

The idea of creating a direct foil out of a historic art object and using it in the design of a contemporary artistic undertaking was at the heart of the decisions surrounding the creation of the ongoing performance of John Cage's *Organ²/ASLSP (As Slow as Possible)* (1987), currently running in St. Burchardi Church in Halberstadt, Germany, and which is intended to run well into the 2630's. "During a discussion of Cage's music in 1993, a German musicologist made an offhand comment about an organ being capable of sustaining tones indefinitely. From that comment came the idea for an

[20]Jordan Alexander Key has also turned his modern-notation transcription into an animated YouTube video (see: https://youtu.be/iaeOWdXM4Pg), which has garnered over 40,000 views. In a world where Psy's "Gangnam Style" has over 4 billion views and is still quite far from the top of the YouTube view list [193], 40,000 is not so many views (...like comparing the population of Grove City, OH to the population of all of Asia...), but the fact that a trifle of a choral piece that is over 600 years old continues to have one Grove City worth of interest is not nothing.

Organ²/ASLSP project." [55] Having noted that, hypothetically at least, the "monster that never breathes"[21] could sound chords forever, the John Cage Organ Foundation could have chosen any length for the performance. Why Halberstadt and why this length of performance?

> Music nerds also knew that the city's cathedral was the home of a very famous organ, created by Nicolaus Faber in 1361, which was "perhaps the first one that had a keyboard like the one we know, separating the octave in 12 semi-tones," says (Rainer) Neugebauer. That year, 1361, was subtracted from the year of the new millennium, 2000, which determined the number of years of the performance: 639. [71]

The "very famous" Faber organ was famous at least partly for having been documented in Michael Praetorius's 1619 *Syntagma Musicum* (see Figure 2.5), which includes an incredibly detailed survey of German organs and other musical instruments of the day. Praetorius notes:

> Such organs were not built in ordinary churches, but rather in large, eminent monastery and cathedral churches. The case of one such large cathedral organ, together with some of its interior components and pipes, can still be seen today (among other places) in the cathedral at Halberstadt. Another such instrument was recently removed from the cathedral at Magdeburg. According to the date that actually appears on it, the large instrument at the Halberstadt Cathedral was first built 250 years ago, and was restored just 120 years ago. ([151] p.97)

Tracing the veracity of Neugebauer's claims about the uniqueness of the build of this organ for its era is outside the scope of this paper. Suffice to point out that Praetorius created the relevant volume of the *Syntagma Musicum* in

[21]...a quip about the organ variously attributed to both Stravinsky and Berlioz...

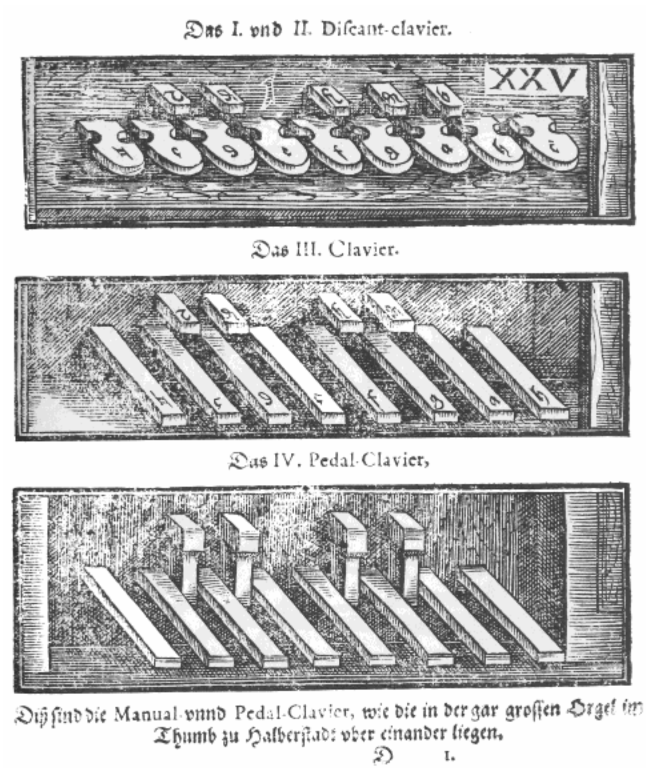

Figure 2.5. Michael Praetorius' diagram of the keyboard and pedals on the 1361 Faber organ in Halberstadt Catherdal. From the 1619 *Syntgma Musicum.* [151]

1619, 258 years after the building of the Faber organ in Halberstadt Cathedral, while we observe Praetorius' record from a distance of 403 years. Neither of these are insignificant quantities of cultural time,[22] and it is certainly a possibility that some details about the organ have suffered during both the stretch from Faber to Praetorius and Praetorius to us. That said, the designers of this performance of Cage's *Organ²* in Halberstadt used both this conceptual historic periscoping to construct a symbolic parameter within which to situate

[22]Just consider that the chronological distance between Praetorius' writing in 1619 and the object about which he was writing was greater than the chronological distance occupied by the existence of the United States.

the performance, as well as an understanding of still-extant organ technologies from that era to design the object of the organ that is at the center of the Cage performance. The Faber organ mentioned by Praetorius no longer exists, but there is still a functioning organ in Sion, Switzerland from 1400, just a generation younger than the Faber organ (see Figure 2.6).

The custom-made organ performing *Organ²* in Halbserstadt's St. Burchardi Church is a simple affair. In shape, it is designed as a modern abstraction of medieval organ design, and the influence of the Sion organ on the shape of the St.Burchardi organ is obvious (see Figure 2.7). A largely decorative housing

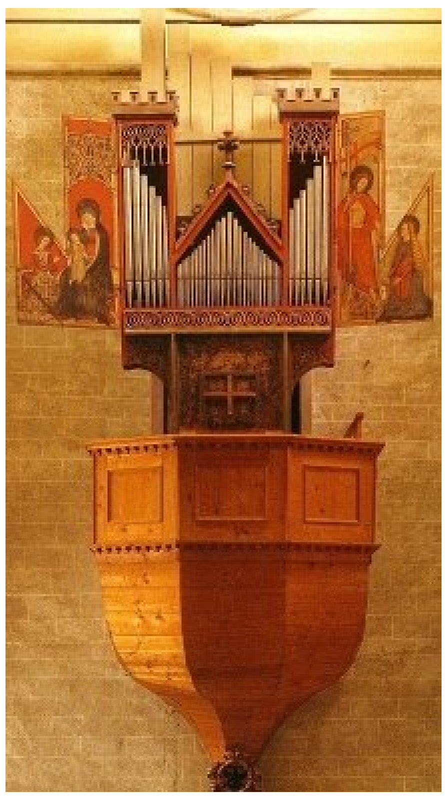

Figure 2.6. This organ, in Sion, Switzerland, which dates from around 1400 is believed to be the oldest playable organ in the world. [45] Public domain photo from Wikimedia.

Figure 2.7. The organ performing John Cage's *Organ²* in Halberstadt's St.Burchardi Church. Photo from the press images of the John Cage Organ Foundation.

for its bellows, which is actually situated in the basement of St. Burchardi, was designed to resemble a manually operated antique organ bellows, also documented by Praetorius in 1619. [55] (See Figures 2.8 and 2.9.) Although a physical construction, this is actually another layer of historic symbolism, as obviously the modern organ, although based on ancient technology, has no need for a manually operated bellows, and such a thing would in fact inhibit the potential for it to sound continuously over long stretches of time. To keep the pitches of the piece sounding for several years, sandbags are hung on keys. [159] Also noteworthy is that the Burchardi organ has very few pipes. New pipes are added as new pitches are called for in the score, meaning that the organ will be built slowly over the performance life of the piece (more will be said on this and the other symbolically derived aspects of the performance in

Section 2.3.3).

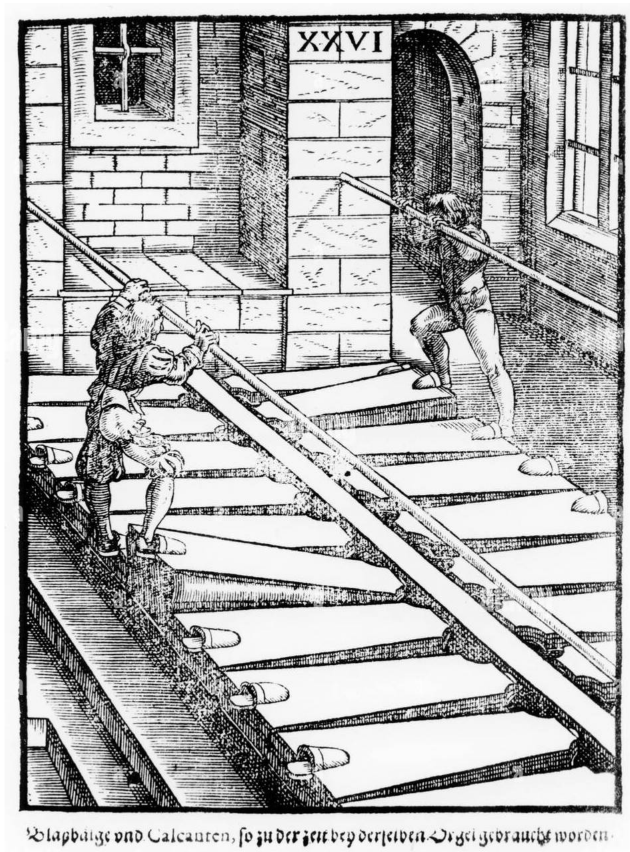

Figure 2.8. Michael Praetorius' diagram of a manually operated organ bellows. From the 1619 *Syntgma Musicum.*

The designers of the Halberstadt performance began the performance of the work on John Cage's birthday (September 5), and in determining when, within the 639 year time frame, chords would change, they set chord-change days always on the 5th of the month in which they occur. If one visits the performance of *Organ²* on any day other than a ceremonial chord-changing day, which draw over 1000 visitors [150], one hears a static chord, perhaps not unlike the sound of being inside an aggressively refrigerated storage room. If

Figure 2.9. The "bellows" constructed for the Halberstadt performance of Cage's *Organ²*.

one returns the next day, the sound is the same. Tables 2.5, 2.6, 2.7, and 2.8 displayed at the end of this chapter show the chord change plan for the first 71 years of the piece, where K = Beginning of tone, P = Pause / End of tone.

Given that Cage's score for the piece is commercially published by Peters, it is simple enough to understand how the piece sounds in terms of its harmony and relative durations of harmonies. For the sake of personal study, one could easily perform a 6 minute 39 second version of the piece rather than a 639 year version of the the piece. What is perhaps of interest is that the score itself presents the *possibility* of creating a "performative time capsule," something in between a painting and a more traditionally constituted music performance—more fixed, less momentary. Thinking in terms of future history, the Halberstadt performance also has an "aura" of connection directly to Cage, performances undertaken in closer proximity to the moment of creation of the artistic object being inherently "more authentic" than those undertaken at a greater distance from Cage. Although Cage was not involved in setting the parameters of this performance, the members of the John Cage Organ Foundation are close enough to the composer that in several hundred years their interpretation of the score will be understood as completely "authentic." Even now, thirty years after Cage's death, there is enough collective memory available to us that we know to take Cage's performance intentions seriously (we have, for example, video of David Tudor playing *4'33"*).[23] In several generations, it is possible that Cage's work *could* occupy the same realm of fringe experiments occupied by things like Satie's *Vexations*, but for now, we know that Cage was wholly and genuinely serious in his efforts to realize his indeterminate scores, and that the effort being made by The John Cage Organ Foundation is sincere, thoroughly considered, and "authentic."[24]

Would the now-anonymous editors of the *Chantilly Codex* ever have imagined that musicians would puzzle over the content of the book 600 years after it was assembled? What if we try to imagine, as the John Cage Organ Foundation has done, a scenario in which we *hope* that listeners will have the opportunity to puzzle over a fantastically idiosyncratic old organ that is "always" playing the same chord, a sonic remnant that is carried forward 600 years from now? I will return to these questions in Section 2.3.3.

[23]See: https://youtu.be/HypmW4Yd7SY

[24]Incidentally, it should come as no surprise that it was Cage who organized the first documented performance of Satie's *Vexations* in 1963, interpreting the score to mean "play the passage 840 times." [168]

2.3.2 Time looping interlude: La Monte Young's *Dream House*

> "If you get permanent paint on your house, that lasts—what?—about a year if you're lucky...We'll see what happens."
>
> La Monte Young [58]

In 2020, the Mela Foundation launched a crowdsourced funding campaign to keep *Dream House* in its current location, on Church Street in New York's Tribeca neighborhood, where it has been located since 1993, and which was $150,000 in debt on back rent. [9] For as existentially critical as this sounds, the conceptual origin of *Dream House* dates back to 1962 the work has had a long history of site changes:

> *Dream House* has been described as "a time installation measured by a continuous frequency environment in sound and light, in which a work would be played continuously and ultimately exist in time as a living organism with a life and tradition of its own." Understood as a durational work to be experienced several times over a lifetime, the first presentations of *Dream House* took place at Heiner Friedrich Gallery in Munich in 1969, Metropolitan Museum of Art in New York in 1971, and the yearlong presentation of *Dream House* at Documenta 5 in Kassel, Germany, in 1972. The 1979–85 iteration *Dream House* at 6 Harrison Street in New York, commissioned by Dia, was followed by MELA Foundation's long-term *Dream House* that opened in 1993 and continues to operate at 275 Church Street in New York today. [58]

In 2015, "Dia Art Foundation[25] announced the acquisition of a unique version of La Monte Young and Marian Zazeela's *Dream House*, titled Dia 15 VI 13 545

[25] To avoid confusion, I will refer to Dia Art foundation as Dia, not to be confused with the Detroit Institute of Art, shorthand: DIA.

West 22 Street *Dream House*. Young and Zazeela created this new iteration in collaboration with their disciple, artist and musician Jung Hee Choi." [58] This is understood as the next iteration in the life of an ongoing work, but for a full generation of interested artists, *Dream House* has been synonymous with its location on Church St.: the decrepit matted down carpet, the specific volume of the sine-wave chord, the experience of getting oneself to Tribeca, the slightly crooked stairway that leads to the third floor, the random variety of volunteers acting as docents, the strange hush of visitors. In the respect that *Dream House* is site specific, these are the specificities of its particular site.

Figure 2.10. La Monte Young's *Dream House* at 275 Church St.

"Dia's acquisition of the artists' Dia 15 VI 13 545 West 22 Street *Dream House* will ensure the conservation and future presentations of this momentous installation," and this effort conforms to Laurensen's notion of conserving time-based art such that "it may be displayed in the future as different possible authentic installations." [108] The fate of 275 Church St. is undoubtedly tied to the draconian property laws of New York City, and given that Young also lives at that address, his own personal health. This acquisition is a concrete move to lift the work from the financial hostilities of urban real estate markets; Tribeca developers would no doubt be delighted to gut renovate another building passing out of rent control and "returning" to market rates. Even without owner-centered property laws, cities are highly volatile environments. What is 275 Church St. compared to the architectural grandeur of "Old Penn Station" (1910-1963)? And further, even the best planning cannot take into consideration the economic situation into which a city will be plunged over the course of just one generation, particularly when a pestilence settles in. In 1993, would anyone have guessed that in March of 2020 5% of the population of Tribeca would flee over the course of just a couple months? [133]

Dream House is peculiar because it *feels* site-specific for those of us who have visited 275 Church St. In Dia's reading of the work, however, it is not. It is perhaps a stroke of luck, or the result of midlife inertia, that it came to be situated at 275 Church St. for as long as it has. And with regard to it being an "ongoing" or "permanent" installation, it is also not that. It is true that the idea of the work has continued to exist over a long span of time, but the work itself is only open to the public four days a week. [60] Even within those four open days, sometimes the show gets canceled. I myself have made a visit during open hours only to find the door locked. But there are lessons in the *Dream House* existence that can be applied to the cultivation of other long-time-period art works. Foremost it is necessary to understand the potential volatility (financial / political) of a location, but also that prescribed downtime is critical for longevity. It allows for the maintenance necessary

Figure 2.11. "Old Penn Station," one of New York City's early 20th century architectural gems. "Destruction began on October 28th, 1963, as protesters watched silently in the rain." [29]

for continuous operation and eases the personnel burden, the demand for a continuous parade of volunteer docents. So despite all of the cues that point an observer to understand *Dream House* as "site-specific" and "ongoing," it is actually neither. It is less a long term performance than it is a very long series of 10 hour-performances. Some days the show goes on, some days it does not, and the time-looping nature of its stasis at this location is now entirely dependent on Mela Foundation's ability to keep the location financially stable. Dia's interest in staging it in other locations is surely a critical act of conservation, but also a conceptual work-around that reminds us that even though *Dream House* *feels* like an eternal work, it is actually more like *Cats* than like Cage.[26] [27]

2.3.3 The problem of long long and indefinite time: *The Clock of the Long Now* (time and responsibility)

When I work with John Luther Adams, I am working to realize his artistic vision. I bring my full capacity as an artist, scientist, thinker, and listener to the task so that the realization of his vision is as rich as it can possibly be. I do this because I believe in his vision of a sound world, and also in his vision of a world in which these sounds exist. If I were to perform a historic piece of notated music, there would be an understanding that I am working to fulfill the intentions of the composer who may or may not be present, who may indeed be long not-present, as in the case of Cordier, but regardless of the gap between the composer and me, the same understanding abides that I will bring my full capacity as an artist to the project of realization. Perhaps in this process I have reference to other realizations of the sound world in the form of recordings, but perhaps I am compelled to work solely from a set of predictive instructions left by the composer.

[26]For the record, *Dream House* at 275 Church St. has actually been running longer than *Cats* did, the first Broadway run of which lasted from 1982 until 2000, a mere 18 years. The 2016 revival only lasted a year.

Time-based performing arts are unique in this sense of interpersonal responsibility across periods of time greater than a lifetime. In what other area of human existence does such a relationship exist? If I prepare a recipe for peas and carrots handed down through several generations, am I actually responsible to the author of the recipe to recreate it precisely? If I am eating the peas and carrots alone, certainly not; I will prepare my peas and carrots exactly as suits me, even if in so doing I have the vague sense that I am dishonoring the memory of a beloved ancestor's culinary efforts, triumphs, failures, and "a-ha" moments. Maybe I imagine a sort of game unfolding over time, between my ancestor and myself, wherein some days I make the peas and carrots exactly as prescribed, and some days I make the peas and carrots by flambéing them in tequila rather than boiling them. However, If I am preparing the peas and carrots for friends, perhaps my responsibility to the recipe author is somewhat heightened by nature of the fact that I now have a responsibility to feed the people coming to my home, and particularly if I announce the dish to be my ancestral peas and carrots recipe. Of course, would my dinner guests know if I followed the recipe precisely? What if I substitute coconut oil for butter, shallots for onions, corn for peas, and parsnips for carrots, and then announce to the guests that I have prepared my ancestral peas and carrots, but with several contemporary updates to the recipe? In fact, no responsibility to the peas and carrots recipe author exists. My responsibility is to my guests, to my own reputation as a cook, and to the occasion: if legumes and root vegetables are called for, then my responsibility is simply to provide deliciously prepared legumes and root vegetables, and not, say, hamburgers.

What about in the sphere of governmental structures? American political discourse often returns to the idea of the "intentions" of "the Framers." Is attempting to interpret law the same as attempting to interpret Stockhausen's intentions in a performance of *Microphonie*? Exactly where lies our responsibility? Is our responsibility actually to the long dead individuals who were living on very recently colonized territory and who laid out the general legal structures that seemed appropriate to them at that time, but within which we still live (as a certain conservative wing of constitutional interpretation keeps insisting it to be), or is our responsibility to those of us who are alive now, working to continually renew the agreements we believe to be binding us together?

What about the static arts? If I am working to conserve the *Tapestry of the Apocalypse* (created between 1377-1382), I am working to protect several 650 year old pieces of wool from undue deterioration. My responsibility as a conservator is to the object, not to Duke Louis I of Anjou who commissioned its creation [51], nor to the (what must have been dozens of) anonymous 14th century weavers who actually created it. The Duke's intentions in commissioning it and his plans for displaying it are wholly irrelevant to my modern conservation efforts.[27] We feel a responsibility to the object as a thing of human creation with the potential to move and inspire other humans. Our responsibility is to the idea of inspiration, to this particular vehicle thereof, and perhaps to the

[27] At 6 meters high and over 100 meters long, and being made of organic materials (wool and silk), which will eventually disintegrate despite being kept in a dark room at a steady 19 degrees Celcius [50], this piece of cultural heritage is exceptionally unruly. It is speculated that he intended to hang the tapestries on poles outdoors. Recreating such a display now would ensure the *rapid* destruction of the tapestries.

Figure 2.12. The *Tapestry of the Apocalypse,* in Angers, France. (1377-1382). Photo used under Creative Commons license.

idea of "cultural heritage" so much as it can be contained in objects.

Time-based performing arts are different. There is a direct, intimate, relationship between author and interpreter regardless of the spans of time that exist between them.[28] That we continue to perform the music of long and very long dead composers proves that this relationship continues to be meaningful. Certainly, the experience of listening to a medieval canon is enjoyable for an audience member, and perhaps that enjoyment is sufficient reason for these pieces to continue to be performed. But in order for them to be performed, somebody alive now must choose to enter into this relationship of personal responsibility across time. I must enter into an agreement with Cordier that I

[28]Even the field of philosophy, which extends a conversation across time, does not contain the same immediate personal responsibility between authors. And in scientific study, the responsibility is to the act of inquiring, not necessarily to previous inquirers.

am working to realize Cordier's intentions in order for Cordier's work to exist in acoustic space. "How do we make the taking of long-term responsibility inevitable?" ([26] p.6)

> Since the soon-to-be outnumber the living; since the living have greater impact on the unborn than ever before thanks to the depletion of natural systems, atmospheric disruption, toxic residue, burgeoning technology, global markets, genetic engineering, and sheer population number; since our scientific and historic understandings now comfortably examine processes embracing eons; and now that our plan-ahead horizon has shrunk to five years or less—it would seem that a grave disconnect is in progress. ([26] p.11)

I have mentioned elsewhere that the Adams pieces are less "sculptures" or "installations" than they are ongoing performances with no predetermined end. Unlike the Halberstadt performance Cage's *Organ*^{2}, which, if all goes according to plan, will come to an end in the year 2640, the performances of *The Place* and *The Wind Garden* are set to continue for as long as individuals are committed to prolonging them. These works are installed but not "a sculpture"; if we stop performing them, they will vanish until somebody decides to begin a new performance.

The Clock of the Long Now was partly conceived to interrogate these notions of cross-generational responsibility. Still being built, it is around 200 feet tall, buried inside a mountain in West Texas, along Interstate 10, 120 miles southeast of El Paso, and about 74 mile northwest of famed desert art-outpost Marfa, Texas. In true Pharaoh-building-the-pyramids form, the property it is being built on is owned by Jeff Bezos, who is also a funder of the project. The Clock was designed with the intention of running for 10,000 years.; its pendulum has a 7-second period of swing. [91] The thinking around the 10,000 year duration is exactly the same as the thinking that determined the performative duration of Cage's *Organ²* in Halberstadt: it locates us now in the center of a timeline that has unfolded by half. In this case, 10,000 years marks the recession of the last ice age and the beginning of agrarian culture, i.e. the beginnings of modern civilization.

The thinking around the challenges of building a machine intended to last 10,000 years reflects similar threads of thought as the notion of building a digital time capsule:

> When you start thinking about building something that lasts that long, the real problem is not decay and corrosion, or even the power source. The real problem is people. If something becomes unimportant to people, it gets scrapped for parts; if it becomes important, it turns into a symbol and must eventually be destroyed. The only way to survive over the long run is to be made of materials large and worthless, like Stonehenge and the Pyramids, or to become lost... The biggest problem for the beating Clock will be the effects of its human visitors. Over the span of centuries, valuable stuff of any type tends to be stolen, kids climb everywhere, and hackers naturally try to see how things work or break. [59]

Similar tenets are put forth by Goebel:

> The time capsule should be inexpensive and based on widely available, low-cost commodity hardware and software, as well as using only widespread and well documented data formats. It should be storable in a box or on a shelf, surrounded by four stable walls and a roof, without being connected to electricity and without requiring special environmental conditioning to control temperature and humidity. ([65] p.37)

Simple materials. No electricity. No maintenance. Minimal or intentionally designed human contact. By contrast to these propositions, *The Place* and *The Wind Garden* seem almost destined for near-term failure. Much will be said about the specific nature of each piece, but Clock designer Danny Hillis' fully elaborated principles of design make for an interesting foil for the design of *The Wind Garden* and *The Place.* The following tables outline these differences:

Table 2.1. *Clock*, *Garden* and *Place* compared, table 1

Clock of Long Now	**The Wind Garden**	**The Place**
Longevity		
The Clock should display the correct time for the next 10,000 years	Should be responsive to changing environmental patterns for...as long as possible	Should be responsive to changing environmental patterns for...as long as possible
Longevity Principles		
Go slow	n/a	n/a
Minimize sliding friction	Reduce potential for natural swaying of branches to disrupt	n/a
Stay clean and dry	Parts are directly exposed to the weather	Parts are directly exposed to the weather
Expect bad weather and earthquakes	In the 5 years The Wind Garden has been functional, bad weather has already proven catastrophic for the piece (See section 3.4.10)	Sensors routinely drop offline, but I am not privy to the possible reasons for this
Expect non-malicious human interaction	Exposed hardware is lofted in trees and kept locked indoors, which reduces such potential	Several governmental organizations have already inadvertently interfered with the functioning of the piece (see 4.1.2 below)
Don't tempt thieves	Exposed hardware is fairly well masked and out of reach within its environment	Hardware obtained exclusively for the installation is secured inside the museum, data sensors are in extremely far flung scientific installations

Table 2.2. *Clock*, *Garden* and *Place* compared, table 2

Clock of Long Now	The Wind Garden	The Place
Maintainability		
It should be possible to maintain *The Clock* with little maintenance, using bronze-age technology	Currently, *The Wind Garden* is only maintainable by me, using uniquely designed software and contemporary consumer-grade computer equipment	Currently, *The Place* is only maintainable by me, using uniquely designed software and contemporary consumer-grade computer equipment, and several aspects of it are entirely out of my control
Maintainability principles		
Use familiar materials	Macintosh computers are currently ubiquitous	The scientific equipment needed to run the piece is highly domain-specific
Make it easy to build parts	...but not buildable by individuals. The accelerometers used to measure the wind are also not buildable by individuals	Almost nobody has seismic monitors
Include the manual	This document is in part an attempt at making "the manual" more permanently and widely accessible	Same

Table 2.3. *Clock*, *Garden* and *Place* compared, table 3

Clock of Long Now	**The Wind Garden**	**The Place**
Transparency		
It should be possible to determine the operational principles of *The Clock* with close inspection	An individual would need to train directly with me in order to make adjustments to *The Wind Garden*, or to thoroughly read and comprehend this document, or an extant highly technical and comprehensive manual I have previously written in order to build a version with currently available technologies	Since this document does not reach "manual-level" detail for *The Place*, an individual would need to train directly with me in order to make adjustments to it
Allow inspection	Its working features are invisible. None of its components are available for inspection	Same
Allow rehearsed motions	n/a	n/a
Expect restarts	Perform daily restarts	Same

Table 2.4. *Clock*, *Garden* and *Place* compared, table 4

Clock of Long Now	**The Wind Garden**	**The Place**
Evolvability		
It should be possible to improve *The Clock* over time	My current role is to do exactly that	Same
Evolvability Principles		
Separate functions	Not possible	Not possible
Provide simple interfaces	Simple is relative, but the "simple" interface I have designed could not be used by a lay person	Same
Scalability		
It should be possible to build working models of *The Clock* from table top to monumental size using the same design	n/a	n/a
Make all parts similar size	n/a	n/a

Even at this overview level of understanding of Adams' pieces, it becomes clear that we are engaged in an uphill battle with regard to longevity and the notion that these pieces should run "in perpetuity." In some regard, Brand and the initiators of the Halberstadt *Organ²* performance may have done themselves a favor by demarcating an "end" to their undertaking, even if that end is very, very far off; it provides a concrete goal. How do you design something intended to last "forever"?

Brand's, Adams', and The John Cage Organ Foundation's goals in creating these pieces are not dissimilar. In creating a mechanical object explicitly designed to run for 10,000 years, and allowing (demanding, in fact) that people physically interact with it, Brand is hoping to compel those who interact with it to think about their place within a broader arc of human history, and their responsibility to the people who will inevitably come after. We have inherited knowledge, so should others. In a world in which the capabilities of modern technology are continually advancing[29], "Haste switches from a vice to a virtue; behavior that once might have been called reckless and irresponsible becomes swift and decisive action." ([26] p.25) The degree of shortsightedness of our actions only shortens in direct relationship to the rate at which technological advancement accelerates. Andreas Henke, mayor of Halberstadt has said, "We are all so consumed by our daily working lives. This forces us to stand back and slow down. It is very special to be a part of an art project that will connect generations and last for generations." [78] And Adams remarked, "*The Place Where You Go To Listen* was conceived of as a self-contained sound world in which the inaudible becomes audible... And it's my hope that this work may inspire the listener to new perceptions of the larger world in which we live." ([3] p.139)

Brand and Adams feel a sense of *personal* responsibility to the future

[29] The ways in which rate of technological change is measured have themselves changed over the years, and are difficult to compare directly. For example, in 1965 Gordon Moore observed that the density of transistors in integrated circuits and thereby their computational capacity tended to double roughly every two years, a benchmark that later became popularly known as Moore's Law. But as manufacturing techniques have improved and the size of transistors has continued to shrink, we have approached the theoretical limitations of the underlying medium, namely the atomic structure of silicon. After Moore, it is now the GPU, capable of running massively parallel operations on thousands of cores simultaneously that has become the preferred platform for computationally expensive processing jobs like neural network training, deep learning, and of course, cryptocurrency mining.

and the earth, and are attempting to cultivate that feeling in observers of their work. My role in Adams' work is, as I have said, one of great *personal* responsibility to Adams' vision. By extension, it is my hope that those who engage with his work are able to glimpse the world as Adams understands it. Can a piece of generated music, or a single organ chord, or a giant clock inside of a mountain instill such a sense of *personal* responsibility within its observers to other actual individuals?[30]

The Clock makers hope to impress upon their guests the simultaneous vastness and shortness of 400 generations by way of enormous mechanisms. The John Cage Foundation hopes to do the same by way of continuity of presence and action, and commitment to their interpretation of the score. Adams seems to hope to capture a viewer's attention by way of synaesthetic ephemera: this gentle breeze I feel on my skin is made more real by the coordinated sounds that also float around me. This fleeting quality of daylight in which my eyes are enveloped also envelops my ears. The fluttering sub-bass in the floor is a result of an earthquake that is happening *right now*. The urgency of relationship between natural phenomenon and aural feedback is quite the opposite of the perceptual immobility of the large clock. Certainly the mechanism of The Clock moves, but it is an almost imperceptible motion. Like tectonic plates, we must trust that it moves because people who know tell us that it moves, and if we wind it, this is confirmed in our observation of the correct time (like earthquakes reminding us tectonic plates are indeed moving). It is not the

[30]Can their size, situation, or unique constitution even simply compel people to observe for longer than 27.2 seconds, which has been repeatedly shown to be the average length of time observers look at pieces of art on museum walls? [172]

sudden synchronicity between our various senses, which rarely discover such parallel motions, but the discontinuity between what we understand to be happening and what we perceive to be happening that compels us to think on a longer timeline.

Having commenced on September 5, 2001, and run for 22 years now, *Organ²* has thus far succeeded in surviving nearly the length of a generation. The last 22 years have been a time of peace, stability, and prosperity in Germany. Placing the organ inside a structure that has itself stood for nearly 1000 years (built in 1050) [78] seems intuitively like a good choice of venue to unfurl something scheduled to last 639 years. It is the kind of "closet space" Goebel refers to in his considerations of an effective digital time capsule.

What if *Organ²* breaks down, momentarily halting the performance? We have all been at concert performances involving live electronics electronics that failed. Planning for failure in such performances is as much a part of building a piece with live interactivity as working out the aesthetic goals. Imagine a temporary failure of *Organ²* that lasted for a month while a new compressor was installed or a broken key repaired, or a new set of sandbags sewn to replace ones that were stolen.[31] In the scheme of 639 years, a 1-month long period of down time would be equivalent to a .469 second long failure in a piece that was an hour long. Does it matter that we perceive those quantities of time on radically different scales within our own human experience, or can we force ourselves to understand how a month and half a second can be the same?

[31] Like the *Dream House*, *Organ²* has limited viewing hours in order to reduce the likelihood of vandalism. However, unlike the *Dream House*, *Organ²* continues to perform during its off hours.

Fundamental within these ideas continues to be the idea of intergenerational responsibility. Neugebauer, head of the John Cage Organ Foundation remarked, "In three-and-a-half years, I will turn 70, and I would like to stop. It would be great to hand it over to the next generation in good shape." [78] As the piece is based on 700 year old technology, it meets several of Hillis' principles for longevity: maintainability, transparency, and evolvability. It has also been widely publicized: the record of its existence is internationally distributed. The two biggest impediments toward long term success are probably the constant need for electricity,[32] and, as Neugebauer implies, finding continued interest from new conservators.

It is decidedly aspirational in the present day to imagine 25 generations worth of successful hand-offs of stewardship and fundraising. I would suggest that the linchpin for the successful completion of the work is in the designed theatricality built into the performance of the piece. A human-lifetime of chord changes have been published and are advertised by the Foundation (See Tables 2.5 through 2.8). Further, the organ has not been fully built. The organizers could have chosen to build the entire organ for the beginning of the piece; the decision to add pieces to the instrument as it performs shows a canny insight into human nature: our love of ceremony, our penchant for ritualistic activity, and our desire to build objects and monuments (see Figure 2.13). In this context, the building of the Burchardi organ is as much a part of this performance of the piece as the specific chords being played, as it creates a slow

[32] In the same manner that The Clock has had been built with two potential power sources, certainly a subsequent generation of *Organ²* minders could devise appropriate electrical solutions for their time.

motion momentum toward an embodied goal. We are not simply executing the score: we are slowly and deliberately creating the physical body of the organ. In 21st century Western society, large buildings are too easy: too easily built, too easily razed, too easily rebuilt. There is no equivalent for the multi-generational project of building a pyramid or a Gothic cathedral in terms of physical construction, but this doesn't alter the reality that societies like building things and have proven less committed to maintaining them.[33] Building a simple object extremely slowly, with gloved hands may be exactly what is necessary to capture the spirit of intergenerational imaginations.

The several poetic conceits that were conjoined to determine the performance parameters of *Organ²* are conceits of the initiators of the performance, not of Cage *himself*. Does that alter the level or nature of responsibility involved in the scenario? If the parameters of this performance were outlined in the score, if Cage himself designated the 639 year length, would that give this particular performance timeframe greater authority? "As slow as possible" is suggestive, but who is to say if 639 years is actually that? Perhaps the piece could go slower. But does the aura of authenticity extend in that manner?

Finding discussion of the apotheosis of John Cage somewhat tired, I would normally eschew deconstructing a figure like him and his near-messianic

[33] See, for example, the New York City subway system, or California PG&E. Marx would say: "...the problem of maintaining the quality of resources goes deeper into the structure of capitalism...both factory owners and farmers allow long-lived capital investments to fall into disrepair. This reluctance to tie capital up in durable capital stems from the danger of unexpected market conditions which can wipe out the value of an investment before it has paid for itself." ([142] p.701) We could then extrapolate a maxim that states, if historical evidence shows that long-term maintenance in a thing will never pay for itself, the thing will never be maintained.

Figure 2.13. Amidst a global pandemic, Organist Julian Lembke adds a pipe during the 639 year long Halberstadt performance of Cage's *Organ²/ASLSP (As Slow as Possible)*, Sept. 5, 2020. Photo used under Creative Commons license.

stature within the realm of contemporary music, performance art, and virtually any modern artistic practice that frames itself as "experimental." In the case of *Organ²*, it is difficult to ignore the semi-permanent sonic shrine to a composer in a church, the pilgrimaging aspect of visitors on chord-change days, the commencement of the piece on September 5th (Cage's birthday) and the assignment of chord-change days to the 5th of the month in which they occur. It may have felt urgent to pile symbolism upon symbolism in order to determine any kind of unified logic for how the piece should go,[34] but the cumulative effect is the slow and steady morphing of a person into a prophet. Does this project

[34]...in a church...in Germany, the cradle of Western concert music and land of entombed composer-heroes.

transform St. Burchardi Church into the Bayreuth of experimental music? If that is the case, such elevation of the place, the composer, and the sense of occasion surrounding the act of building the organ to semi-sacred status might also be the difference between finishing the performance of the piece and not finishing the performance of the piece. Certainly, that has been the case so far. The second most recent scheduled chord change, on September 5, 2020, went ahead despite being deep in the middle of a global pandemic. Regarding this decision, and his personal commitment to Cage's idea, Rainer Neugebauer commented, "Unlike the Olympics or the World Economic Forum in Davos, we couldn't postpone it. The chord change had to go ahead. It's in the score." [78]

Table 2.5. *Organ²* chord changes, table 1 [89]

Change	Begin/Pause	Notes	Length
Impuls 1:	P:		05.09.2001
Impuls 2:	K:	gis‘, h‘, gis“	05.02.2003
Impuls 3	K:	e, e‘	05.07.2004
Impuls 4	P	gis‘, h‘	05.07.2005
Impuls 5:	K:	a‘, c“, fis“	05.01.2006
Impuls 6:	P:	e, e‘	05.05.2006
Impuls 7:	K:	c‘, as‘	05.07.2008
Impuls 8:	P:	c“,	05.11.2006
Impuls 9:	K:	d‘, e“	05.02.2009
Impuls 10:	P:	e“	05.07.2010
Impuls 11:	P:	d‘, gis“	05.02.2011
Impuls 12:	K/P:	c‘(16‘), des‘(16‘), as‘	05.08.2011
Impuls 13:	P:	a‘, c“, fis“	05.07.2012
Impuls 14:	K:	dis‘, ais‘, e“	05.10.2013
Impuls 15:	K:	gis, e‘	05.09.2020
Impuls 16:	P:	gis	05.02.2022
Impuls 17:	K:	d‘	05.02.2024
Impuls 18:	K:	a‘	05.08.2026
Impuls 19:	P:	‘e	05.10.2027
Impuls 20:	K:	g	05.04.2028

Table 2.6. *Organ²* chord changes, table 2

Impuls 21:	P:	d‘	05.08.2028
Impuls 22:	P:	a‘	05.03.2030
Impuls 23:	P:	dis‘, e“	05.09.2030
Impuls 24:	P:	g	05.05.2033
Impuls 25:	K:	h	05.12.2033
Impuls 26:	K:	f, d‘	05.08.2034
Impuls 27:	P:	f, d‘	05.09.2034
Impuls 28:	P:	h	05.10.2034
Impuls 29:	K:	des“	05.06.2035
Impuls 30:	K/P:	A (16‘)des“	05.09.2037
Impuls 31:	K:	as‘, as“	05.03.2038
Impuls 32:	P:	as“	05.07.2038
Impuls 33:	P:	as‘	05.05.2039
Impuls 34:	K:	d‘, as‘	05.12.2039
Impuls 35:	P:	d‘, as‘	05.04.2040
Impuls 36:	K:	des, b	05.01.2041
Impuls 37:	P:	des, b	05.03.2042
Impuls 38:	P:	A (16‘)	05.11.2043
Impuls 39:	K:	a, d‘	05.07.2044
Impuls 40:	K/P:	e‘ais‘	05.03.2045

Table 2.7. *Organ²* chord changes, table 3

Impuls 41:	K:	h‘, c“, ais“	05.03.2046
Impuls 42:	P:	c‘(16‘), h‘, c“, ais“	05.10.2047
Impuls 43:	K:	c (16‘)	05.02.2049
Impuls 44:	K:	dis‘, a‘	05.04.2050
Impuls 45:	P:	a, d‘, e‘	05.02.2051
Impuls 46:	P:	dis‘, a‘	05.11.2051
Impuls 47:	K:	es, h	05.05.2053
Impuls 48:	P:	c (16‘)	05.11.2054
Impuls 49:	P:	es, h	05.07.2056
Impuls 50:	K:	b‘	05.08.2057
Impuls 51:	K:	A (16‘)	05.05.2058
Impuls 52:	P:	A (16‘)	05.11.2059
Impuls 53:	K:	ges‘, c“, des“	05.04.2060
Impuls 54:	P:	ges‘, c“, des“	05.06.2060
Impuls 55:	K/P:	e‘b‘	05.11.2060
Impuls 56:	K:	h‘, c“, es“, c‘	05.02.2061
Impuls 57:	P:	c“, es“, c‘“	05.04.2061
Impuls 58:	K/P:	d‘e‘	05.09.2061
Impuls 59:	K:	ais, dis‘, fis‘	05.08.2062
Impuls 60:	P:	ais, fis‘	05.02.2064

Table 2.8. *Organ*^{2} chord changes, table 4

Impuls 61:	K/P:	a, a‘d#‘	05.01.2067
Impuls 62:	P:	d‘	05.06.2067
Impuls 63:	P:	a, a‘	05.07.2068
Impuls 64:	P:	des‘(16‘)	05.03.2071

Chapter 3

Obsessive Detail: John Luther Adams' *The Wind Garden*

Artist Statement

The Wind Garden (La Jolla) is a musical composition in the form of a landscape. Composed with and within the signature landscape of the UCSD campus – the eucalyptus grove – the work is an invitation to listen more deeply to the music of this place.

All the sounds of *The Wind Garden* are produced by the wind and the light conditions on the site, in real time. There are no pre-recorded elements. And the work will never repeat itself exactly. Even for people who experience it on a regular basis, each encounter with *The Wind Garden* will be a unique moment of listening and discovery.

The sounds in the garden are vaguely reminiscent of bells, voices, and strings. But the movement of the trees, the leaves, and the air in the grove makes it difficult to say exactly (from) where they emanate.

In midday, the sounds are high and bright. At night, they are lower and darker. On overcast days, all the sounds are more subdued. And the sounds of summer are generally brighter than the sounds of winter. Throughout the day and throughout the year, at every moment the sounds in the grove seem to rise and fall with the wind.

Hidden in the trees are 32 small loudspeakers. Attached to the highest branches are 32 accelerometers that measure the movements of the trees in the wind. As the velocity and direction of the wind changes, so does the amplitude of the sounds, and the way they move within the grove.

The musical foundation of *The Wind Garden* is two "choirs" of virtual voices—a Day Choir tuned to the natural harmonic series, and a Night Choir tuned to the sub-harmonic series (an inversion of the harmonic series).

As night falls, the sounds of the Night Choir become deeper and darker. As daylight returns, the sounds of the Night Choir rise and fade away. In early morning and again around sunset, both the Day Choir and the Night Choir are equally present—producing especially rich harmonic colors. The rising and falling of these choirs traces the contours of the sun's movement above, below, and around the horizon over the course of the year.

John Luther Adams [147]

3.1 Prelude: The Endless Ladder

Many parts of this chapter are adapted from the nearly 300 pages of technical documentation I created for *The Wind Garden* following a comprehensive redesign of the installation I performed in 2016. This new design involved major changes to the architecture of the whole system, including the way that *The Wind Garden* obtains, processes, and articulates data. Similar to my redesign and expansion of *The Place Where You Go to Listen* in 2020, these improvements targeted layers of the system that were unstable or particularly vulnerable to technological aging. As discussed in more detail in section 4.1.2 with respect to *Place*, with *The Wind Garden* it was clearly necessary to get ahead of problematic technical dependencies as early as possible in order to avoid scenarios where it would become very difficult or impossible to port code directly.

The full Technical Manual for the current iteration of *Wind Garden* is an extremely granular document that was created less to assist with maintenance day-to-day than as an effort to help preserve *The Wind Garden* once John Luther Adams and I are no longer around to advocate for the specific considerations this work requires. From my introduction to the *The Wind Garden* Technical Manual v1.2:

> The purpose of this document is twofold. First, it exists to provide high-level descriptions of *The Wind Garden*'s main components, an overview of how they work, instructions for maintenance and repair, and guidelines for troubleshooting should problems arise. The information will be useful to any person tasked with routine maintenance and/or minor repairs, and has been conveniently placed in the first three chapters. The other function of

> this document is as organ of record to the specifics of this unique artwork: a historical preservation document. Included in chapters 4 through 9 is enough detail about the installation's internals for a clever, motivated person to recover from a catastrophic loss of some kind (whether that be a massive hardware loss, or loss of the grove itself), or to rebuild the entire installation itself, should that ever become necessary. [147]

I excerpt these (admittedly dry) sections of the manual below not just to help explain *The Wind Garden*, but more importantly to highlight the extent of time, care, and detail that goes into the creations of such documentation. It also stands to illustrate one other very uncomfortable but important fact: such documents becomes obsolete almost immediately after they are created. I can recall the fleeting moments between the time when the Technical Manual *actually* reflected how *The Wind Garden* works, and the point after which the manual could only offer impressions of what once was. The onus of this kind of preservation is, therefore, on people like me who are able and willing to maintain and update a sprawling and highly-detailed form of technical documentation, and then to continue to do that forever. This endless ladder of unstable documentation, maintenance, improvements, and preservation leading to further documentation is the process by which a digital interactive artwork is able to be carried forward through time in a perpetual state of *new-enough*. This process can and should be thought of as an aspect so deeply embedded in these works as to be inseparable from all the other ways they can be said to exist—indeed as fundamental as any experiential qualities the work may possess. In this sense a digital interactive artwork work can never truly become *complete*, in the same way the performance of a symphony cannot "complete" a musical composition. Its ontology lies elsewhere, diffused, in a state of perpetual becoming. It is appropriate, then, to speak of these works as *performances* that will continue to climb the ladder as long as the personal and institutional will for that exists.

The question of whether or not to produce written documentation is an interesting one, for the reasons explained above, but also because aside from raw technical cataloging there are unquestionably other, less concrete aspects of digital interactive artworks *must* be preserved in order for an interactive artwork to remain artistically intact. I identify at least two major branches of what I feel are critical forms of written documentation for such works:

- narrative or experiential description of qualitative engagement
- code

These two branches may seem very different, but I argue they take a very important and unifying stance against the forces of documentational entropy. Narrative devices, which I employ liberally through my Technical Manual for *The Wind Garden*, depart the domain of technical objecthood to address instead those subtler objects created between the the minds of those who experience the artwork directly and the artwork itself. See the opening quote of Section 2.1 for an example of this kind of documentation. A beautifully laid out description of a technical process or algorithm does little to inform a conservationist of the unique situational counterpoint that is present when seated in the Grove as the daylight wanes and gives way to dusk, nor can it communicate the ways in which *The Wind Garden*'s many non-musical components should be tuned such that they function like a single organic choir. It is crucial to communicate what Adams intended the experience to *feel* like during a walk from one end of the Grove to the other, or how it *feels* when the 6pm winds rush in off the Pacific ocean. For these kinds of subtle communications I rely on a non-technical form of storytelling, in which those qualities found in the simple pleasures of spoken or written language are brought to bear on what are in the end gentle instructions on how to conserve.

The paralingusistic features of computer code discussed in Section 2.2 are a valuable resource when creating documentation for digital artworks. Where narrative descriptions provide guidance on how to align with experiential directives, code is able to communicate subtleties about the technical layers of digital artworks that may be difficult or cumbersome to articulate with spoken language. Although there are numerous examples of this from all the artworks discussed in this paper, one useful example of this can be found in the codebase for *The Place Where You Go To Listen*, discussed later in Chapter 4. A review of the source code for this project will reveal a parsing routine for inbound geomagnetic (aurora) data that simultaneously displays how data streaming from remote stations can be intermittent and inconsistently shaped, how to gracefully handle these situations when they arise, and how to meaningfully compensate for the loss of one or more data streams. This kind of communication to future engineers and/or conservators lessens the overall burden of maintenance and preservation, and provides actionable insight into the idiosyncrasies of the entire system. In this way the ladder of preservation, as I would say, becomes less steep, the rungs less slippery. For this very reason, my technical manual for *The Wind Garden* includes a number of appendices that contain the full printed source code for every Java class, bash script, python tool, and javascript widget in use in the installation.[1] Notably absent from these appendices are, of course, all the Max patches. Again, see Section 2.2 for an examination of how these kinds of files violate many of the conventions of software development.

3.2 Overview of *The Wind Garden*

The Wind Garden is a multi-channel interactive sound installation installed as a permanent piece in the Stuart Collection on the UCSD campus. The work was commissioned by the Stuart Collection after the collection's founding director, Mary Beebe, attended the Seattle Symphony's premiere performance of Adams' Pulitzer Prize winning orchestral work *Become Ocean*. Initially, Adams conceived of the work as purely acoustic, a physical sounding sculpture to be situated on the campus. After spending more time scouting potential locations on the campus, he settled on the Grove, and determined that the work could not be purely analog. According to Adams, "There was something about these trees on the site, this lovely view of the Pacific, and the wind when it comes up every afternoon and passes through that appealed to me." [2] On the one hand, the decision to move from a sculptural object to a responsive electronic installation introduced significant logistical complications to the piece: How is electricity dispersed throughout the Grove? How should

[1] Of course all code is also stored in version-controlled repositories, in the cloud, but somebody somewhere sometime may be very grateful indeed to have these physical materials on hand when GitHub shuts down or gets hacked, or when the repository keys are lost.

high performance audio components be situated in the Grove and be suitably protected from the elements? On the other hand, the piece became more expansive, something that could take on a malleable sonic life, a characteristic which would be impossible for strictly acoustic sound-generating components.

Adams was interested to capture something of his own experience of day transitioning into night along the California coast, and to create a sound world that would suggest this. For Adams, this experience was not strictly about light and dark, but also about the manner in which the coastal wind patterns change throughout the day. At dusk in La Jolla, the wind comes off the ocean and up over the cliff to where the UCSD campus is situated. The specific phenomena of light and wind modulate depending on the time of year. The sounds of the piece, then, are articulated through realtime analysis of 1) local wind conditions, 2) time of day, and 3) calendar date. When Adams states that "the work will never repeat itself exactly," this is strictly true. While there are certain recurring aural characteristics day-to-day (day is always represented by a harmonic series, and night a subharmonic series), the three natural factors determining the creation of the soundscape ensure that it will never be exactly the same at any two points in time.

For as much as it can be said of anything generated by an artificial intelligence, *The Wind Garden* is a living thing, and as with all living things, deeply embedded within this artwork is the idea of change. Wind conditions and the calendar date are always changing, but so is the Grove itself, and all that surrounds it. Branches thicken over time and sway less in the breeze. Boughs crack, causing speakers to shift and tilt. The sensor in the uppermost reaches of the tallest trees will die and fall silent. And, as happened in the winter of 2016 (discussed below), storms come through that topple some of these trees, taking speakers and sensors with them to the ground. This is not bad luck; it is inevitable. The Stuart Collection has made a long-term commitment to being custodians of this piece and addressing these issues as they arise, a condition that was pivotal in Adams' decision to accept the commission in the first place. Embedded in the very fabric of the work then, is the ongoing problem of its maintenance. With *The Wind Garden*, it is never a question of if it will break. It will break. The abiding questions are when and how it will break.

My own work with *The Wind Garden* began in 2015 after the first designer, Jem Altieri, stepped away from the project. My knowledge of the genesis of the piece comes directly by way of my long working relationship with Adams, and my long association with this piece in particular. After Altieri's departure, I was approached by the Stuart Collection to complete the artwork, and address some of its persistent issues with an eye toward making it more stable (that is, break less often, and for shorter periods of time). In order to understand the complexity of problems faced in keeping the piece running stably, the next section will describe in greater detail what the piece is, how it is made, and how it functions.

3.3 *The Wind Garden* Design

3.3.1 Physical orientation

The Wind Garden is physically installed, north to south, in the Grove, the group of eucalyptus trees in the southwestern corner of the UCSD campus. Figure 3.1 shows the site survey of the area in which The Winds Garden is situated. Referencing the diagram, the structures to the east are the La Jolla Playhouse, whose box office opens to the Grove; to the west is North Torrey Pines Road, an artery that connects UCSD to the cluster of tech and biotech companies to the north; and just west of Torrey Pines Rd. are the cliffs of Torrey Pines Beach which tower over the Pacific Ocean. This choice of site is notable because it functions as a kind of hub that links a number of cultural nodes in the immediate region, which strongly contributes to what I will refer to later as *The Wind Garden*'s role as *monument*.[2] These nodes are 1) the UCSD campus as a whole, 2) the UCSD "arts district," which is comprised of The La Jolla Playhouse, Potiker Theater, as well a number of other sculptural works held by the Stuart Collection, 3) the greater North La Jolla residential area, 4) The greater La Jolla (non-academic) scientific community, and 5) the

[2]In unpacking the relationship between sculpture and monument, Rosalind Krauss writes about a particularly rich of "monumentality": "Bernini's statue of the Conversion of Constantine, placed at the foot of the Vatican stairway connecting the Basilica of St. Peter to the heart of the papacy is another such monument, a marker at a particular place for a specific meaning/event." ([96] p.33) Constantine was one of the leaders of a splintering old Roman empire. His conversion to Christianity just before the battle in which he consolidated power is understood as leading directly to the rise of the Holy Roman Empire, and, therewith, to the building of St. Peter's Basilica. [128] Onlookers are reminded, as they stand at this physical seat of power, of the singular event that lead to the entire world order in which they exist.

Figure 3.1. *The Wind Garden* site survey

geologic boundary between land and ocean.

The Grove consists of two path/speaker trajectories, described by thirty-two speakers and four subwoofers, arranged along two discrete axes. Adams has named these: the Apse, which is the short central path/area that runs east to west; and the Crossing, which is the longer path that runs the length of the Grove south to north. With the exceptions of the speakers and the sensor array itself, all of the technology and equipment that drives *The Wind Garden* resides inside the La Jolla Playhouse ticket booth in a limited access, secure storage rack. Here also is a mute panel for the piece; the installation can be muted at any time by Playhouse staff.

Figure 3.2 shows a map of the full Grove including the Apse, the Crossing, the locations of each speaker, the approximate focus point for each speaker, and the tones assigned to each speaker:[3] The "Apse" and the "Crossing" refer to the physically analogous locations of a Gothic cathedral. Adams' choice of sacred nomenclature is not accidental; he is striving to cultivate in the visitor to the installation a sense of listening reverence. For reference, Figure 3.3 shows the floorplan of the Chartres Cathedral, with the relevant areas labeled.

The speaker array is supported by a set of electrical conduits running throughout the Grove, as shown in Figure 3.4. The conduit is buried when possible, and sections that run above ground and up into the trees are painted natural colors so they are as unobtrusive as possible.

[3] Just prior to *The Wind Garden* opening in August 2017, a new labeling system was put in place to refer to Speakers (1-36), which were formerly labeled as Trees (22-1, 32A, etc). The new notation is clearer, but would cause some confusion if compared with older documentation.

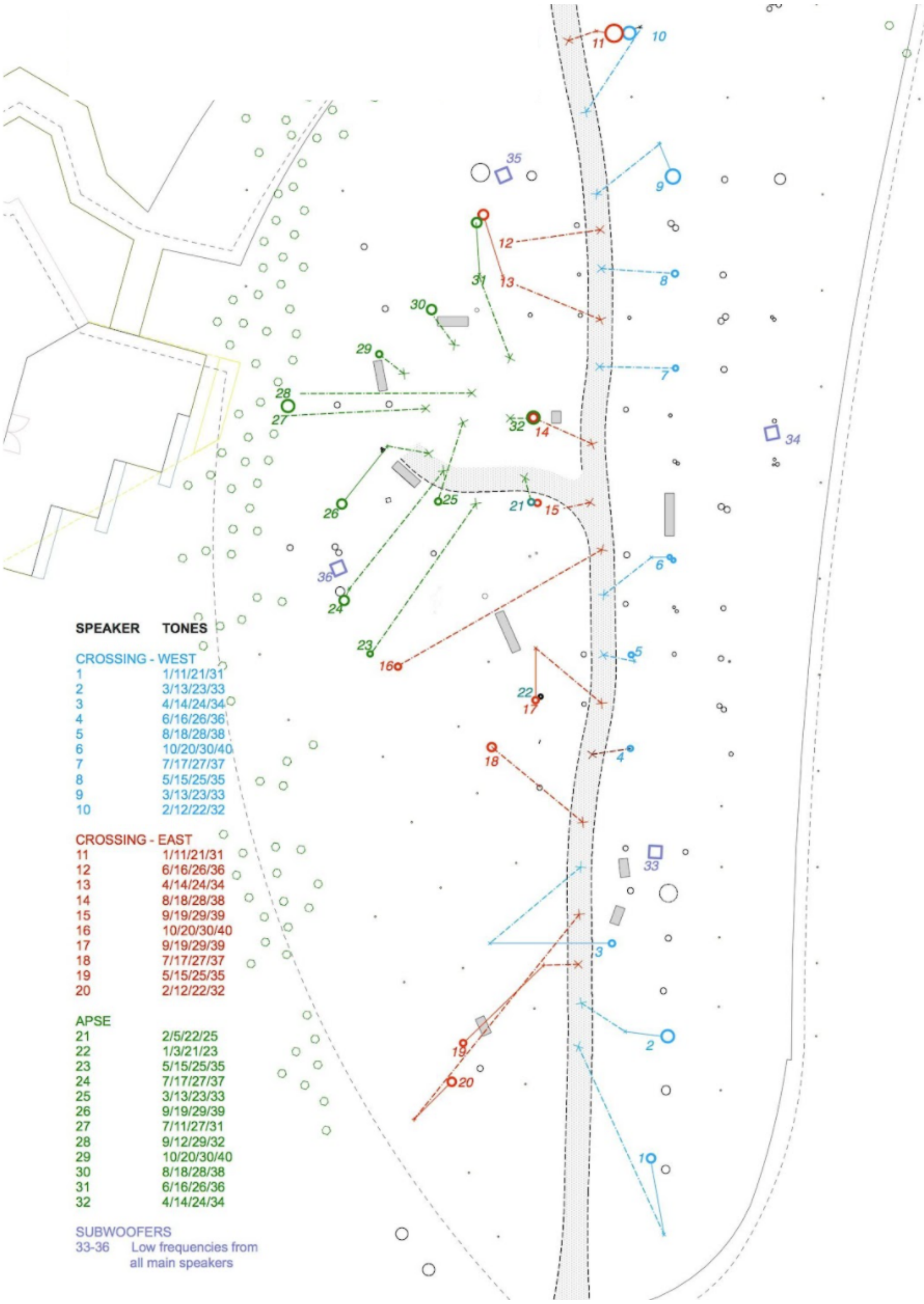

Figure 3.2. *The Wind Garden* speaker map, focus, and tone assignments as of August 2017

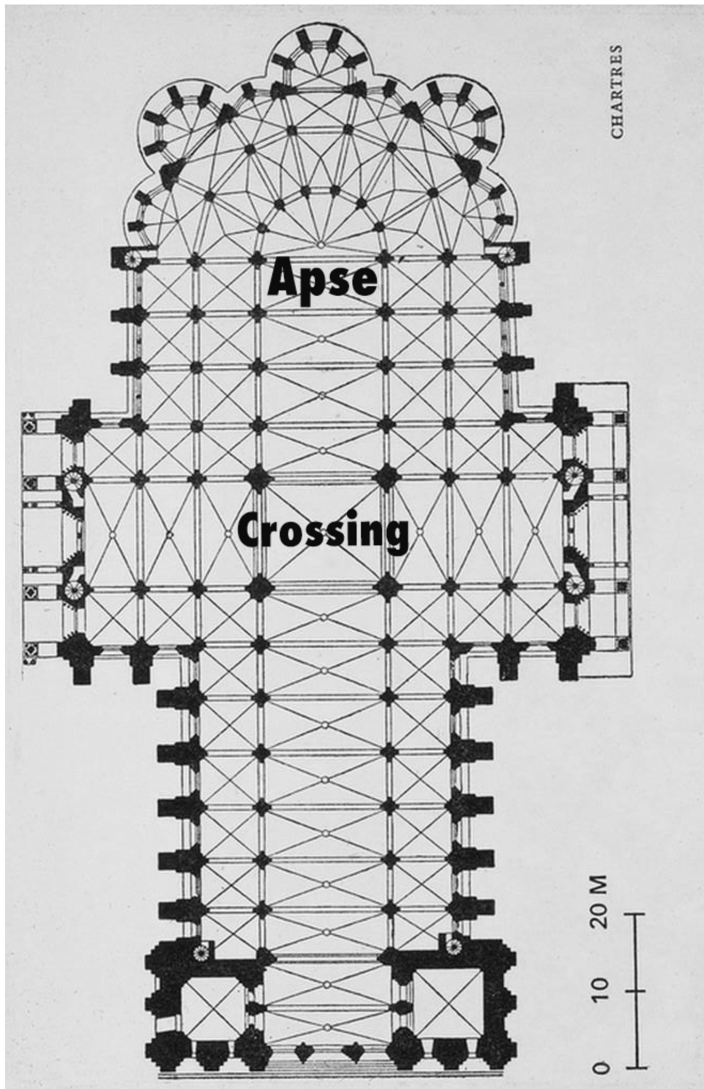

Figure 3.3. The floorplan of Chartres Cathedral showing the "Apse" and the "Crossing." Curiously, the footprint of *The Wind Garden* (418' x 114') is *very* close to the same as the footprint of Chartres Cathsdral (416' x 104'). Public domain image courtesy of ArtStor.

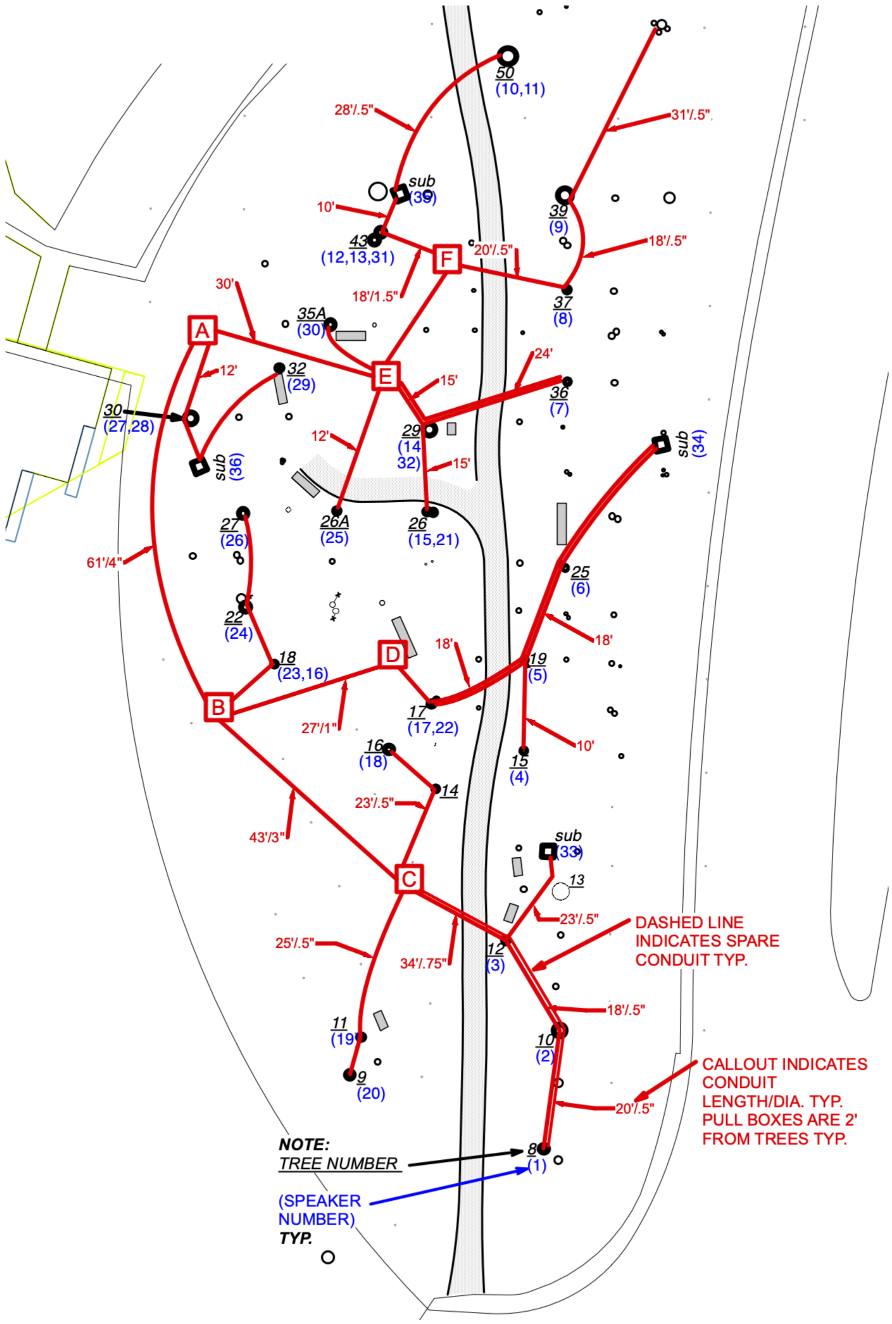

Figure 3.4. Map of the buried and tree-mounted cable conduit network

3.3.2 Aesthetic design

Each axis and each speaker diffuses a focused array of harmonically related pitches that are voiced according to the factors listed above (wind, time of day, date). As mentioned, there are two basic “choirs” in the piece, the Day Choir, and the Night Choir. The Day Choir is a harmonic series over a fundamental of B♭2, the Night Choir is a Subharmonic series emanating from B♭1. Together, there are 40 possible unique pitches in the sound spectrum of the piece in a constant state of blending. Before undertaking the physical installation, Adams produced a handwritten score for how pitches would be assigned per-tree. Figure 3.5 shows Adams’ original score.

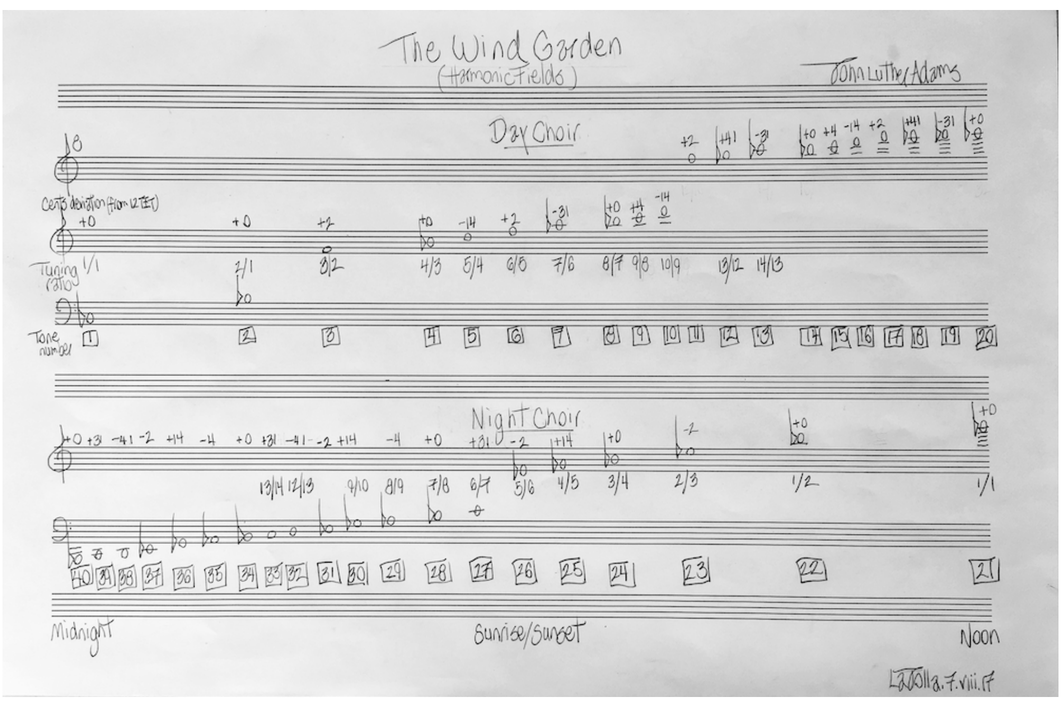

Figure 3.5. Original pitch score for John Luther Adams’ “*The Wind Garden*,” used courtesy of the composer

The Wind Garden represents the state of the immediate environment 24 hours a day, 365 days a year. In theory, the installation should always be running and producing sound. Wind conditions dictate the overall amplitude of the installation, but there are various other factors that influence how loud the piece appears to be at any given moment. Environmental factors such as traffic conditions, nearby construction, and time of day all influence perceived loudness. The minor key sonorities produced at night are pitched significantly lower than the daytime sonorities and therefore make much more use of the subwoofers (which are amplified considerably lower than the tree-mounted speakers). At night during low wind conditions, *The Wind Garden* may be very quiet indeed.

Calendar date is also an important factor in the way the installation sounds from day to day. Due to the way in which *The Wind Garden* dynamically synthesizes tones, critical windows like solar noon during the summer solstice will sound markedly different than solar noon at the equinox. Similarly, midnight during the winter solstice is when the piece generates the most low frequency content, so the four subwoofers are likely to be considerably more active during that time. Adams considered the solstices to be "tent post" times of year from which the rest of the year slopes away. The two fundamental frequencies do not change, but at the summer solstice the focus is in a higher part of the spectrum with little subwoofer activity, a shimmery, watery, very wind driven sound. The winter solstice is more like a dark blanket of steady lowness.

The technology that drives *The Wind Garden* is capable of "intelligently" adapting itself to a wide range of wind conditions, including what I refer to as the boundary states of near total stillness and storming winds. As wind intensity increases and accelerometer data starts to spike, the system automatically adjusts all sensors' post-processing to dynamically scale back amplitude and tone articulation in order to maintain reasonable volume levels and balance. While it is true that this is an automatic process, the system works because *The Wind Garden* has been tuned by hand, tree by tree, specifically for the La Jolla installation site as it was in the Summer of 2017. Note that by using the word "tuning," I here depart from its typical musical definition; the fundamental frequencies from which Adams' harmonic/subharmonic fields are derived are fixed. Tuning in the context of *The Wind Garden* instead refers to a suite of different observations, tasks, and adjustments which together can be considered central to all preservation efforts. Here, tuning equals data shaping. Tuning this work means:

- Listening for specific trees, speakers, or sections of the Grove which may have become disproportionately too loud or too quiet
- Assessing how physical changes in the Grove may have affected the incoming data streams, and nudging those streams back into optimal ranges
- Listening for overall audio density, coverage, and balance
- Confirming the focus of the 32 mounted speakers throughout the Grove
- Making fine adjustments to channel gains

It was clear early on that the system managing *The Wind Garden* needed to be dynamic enough so that the piece would be beautiful at various sound levels but never too quiet or too loud, a challenge faced routinely by performing musicians, but which takes on a wildly different scope when a work is spread across 418 feet south to north and 114 ft east to west. How loud is too loud at any moment at any location within the Grove? How far do the branches chosen for speaker placement swing? How strong will the wind *ever* be? The specific values and ranges of the interpolation system, and the custom loudness transition curve were carefully established, tuned, and tested by Adams and me, and can be understood as a fundamental component of the artwork. These parameters, are, of course, related to the physical configuration of the speakers, which are themselves a balance of physical placement, audio fidelity, and simple practicality (sometimes the "ideal' location for a speaker was impossible to reach).[4] Subsequent tuning of the system also necessitates looking at data on a per channel level. Sensor data cannot be compressed in the same way across all of the sensors because different branches move more or less freely and some sensors are on thinner or thicker branches. The data generated by this physical reality is wildly different from sensor to sensor. Decisions must be made uniquely about where the floor and ceiling are for each branch/sensor/speaker, how each responds to volatility, and if any should be allowed to react more freely.

At the same time, however, while treating each sensor individually, it is

[4]These considerations extended to a very minute level: during the installation process it became clear that the speakers needed to be mounted with special nylon bushings in order to prevent harmonic resonances in the metal shielding that weatherizes the speakers.

critical to understand the Grove holistically. The Grove, being a single place (a *site*), must attenuate as one object, even if the parts of that object do so on individually dictated terms. The entire Grove must be able to react to a storm event, not just select individual speakers. In order for the Grove to respond to ripples of wind, the individually tuned speakers must be capable of responding en masse, to ripple. Different elevations of wind produce different qualities of sound: gusty wind and steady wind sound different. The trees and the wind are in dialogue; the sounds being produced by the system is making that dialog more apparent to any observer.

While it is true that, by design, *The Wind Garden* should always be sounding, and the sounds modulate slowly, *The Wind Garden* is not a drone piece. There may at times be drone-like qualities to it, but the system was tuned to allow for considerable space between the tones emanating from different trees. In our working, Adams described the soundscape as "pointillistic." Naturally, due to the number and close proximity of speakers to the Apse, the sound in this area tends to be more aurally dense. Conversely, along the Crossing and especially near the northern and southern edges of the Grove, the sound tends to be very airy and dispersed. In its ideal tuning, *The Wind Garden* displays these characteristics:

- The correct density should allow for surprising, emergent moments of spatial melody. These will be most common closer to the north and south ends of the Crossing
- The piece should *breathe*. Too much volume destroys what should be a delicate and reaching experience. Too much scaling corrupts the natural

respiration of the Grove

- At times (but not at all times), it should be possible for an inattentive passer-by to move through the Grove and not realize he/she/they are inside a sound installation

- Listening with intention should be rewarded

- Walking with intention should be rewarded

- No sound the installation produces should at any point be piercing or shrill

- Speaker focus should provide smooth, even coverage beneath the primary axes, and gently fading coverage off-trail. Holes in the soundscape and soft spots in the focus should be corrected.

- Midnights near the winter solstice are the time of year when *The Wind Garden* dwells in its deepest frequencies, and the time during which the subwoofers will be most active; they should rumble, not boom

3.3.3 Hardware design

The sensor network that controls the sonic activity of *The Wind Garden* was developed by Douglas Alden and consists of thirty-two 3-axis accelerometer nodes (LORD Microstrain G-LINK-LXRS-2G-M) mounted in trees throughout the Grove, connected wirelessly to a base station (LORD Microstrain WSDA-Base-104-LXRS). The wireless network operates on channel 24 of 2.4 GHz IEEE 802.15.4. The base station provides a continuous, system-wide synchronization signal, or "beaconing," that maintains a precision timing reference across all nodes. Timestamp synchronization of all sensors in the network is maintained within +/- 32 microseconds. The base station also allows for the configuration of the wireless nodes including discovery, initialization, radio frequency setup, sample rates, and managing the nodes power consumption via sleep, wake, and sample modes. To preserve battery life, the accelerometers run at 8Hz. Each accelerometer corresponds to a specific channel of audio, which is assigned to a specific tree/speaker in the Grove, and each channel/tree produces between 2 to 4 tones. This is determined by way of a user-configurable mapping matrix, which can be seen in Box 2 of figure 3.9. The realtime data streams from the accelerometers come in packages of three floating point values, one each for axis X, Y, and Z. These values are what control the moment-to-moment articulation of each cluster of tones.

Each accelerometer, its electronics, and a lithium D-cell battery are attached to an aluminum mounting plate inside an enclosure made from commonly available ABS drain, waste, and vent pipe and fittings. Figure 3.6 shows one of the fully assembled and mounted G-LINK-LXRS-2G-M accelerometers with weather housing.

Each unit's housing is mounted to a branch with size 10-24 machine screws (thin branches) or 1/4"-20 bolts (thick branches). Figure 3.7 shows a diagram of how a sensor housing is mounted to a branch. Most (but not all) of the hardware that runs *The Wind Garden* is represented in Figure 3.8.

The Mac Pro shown above is at the center of the entire system. This machine is a late 2013 Mac Pro 2.7 GHz 12-Core Intel Xeon E5 with 64GB of

Figure 3.6. Tree mounted G-LINK_LXRS-2G-M 3-axis accelerometer

RAM. It is responsible for:

- All of Wind Garden's audio processing, including synthesis, spatialization, and filtering
- Output of 32+4 discrete channels of audio @ 48kHz
- Communicating with the SQL database[5]
- Data interpolation

[5]At the time I began writing the unpublished operators manual for *The Wind Garden*, the system was still oriented around a SQL database. In the interim years, a time period of steady maintenance, rebuild, and the writing of *this* document, the SQL database has been replaced an automated data pipeline. Much of the descriptive technical text in this document was originally set down in the operators manual. For the most part, I have left references to the SQL database in this document as it is a reminder of how quickly these constructs go stale, and also as something of a historic reference point. If in the future, this piece goes offline and is subsequently attempted to be rebuilt, let this footnote be a warning to those who would navigate these waters: *Hic sunt dracones*.

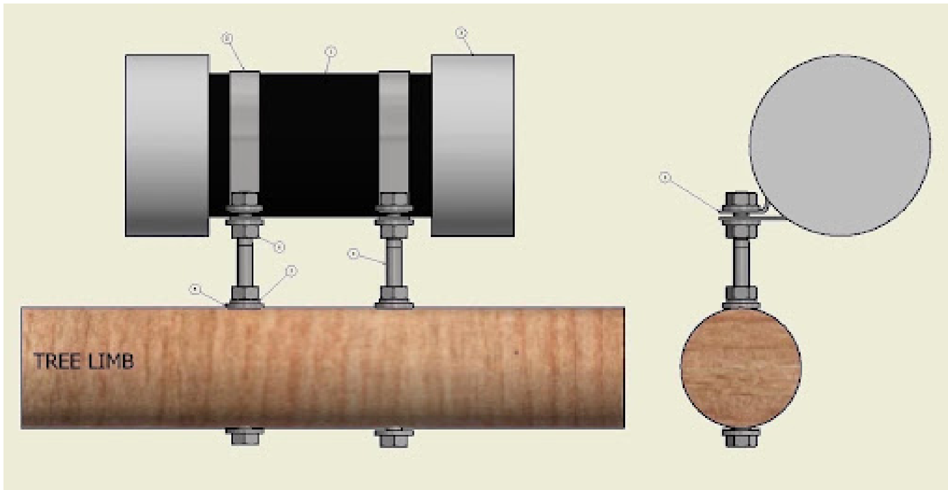

Figure 3.7. Sensor mount

- Tone/Tree assignments
- Muting
- All of Wind Garden's internal system logic and time/datekeeping
- Failover and fault tolerance systems
- Backend for the monitoring and email notification systems

The MADIFace XT is the bridge between the Mac Pro and the RME DACs that feed the Myer Sound monitoring server, which in turn ultimately feeds the amplifiers and speakers. The rack contains a Raloy Rack Console unit, which allows operators direct console access to the Mac Pro and the SQL database server.

There are several additional components to the installation that are not represented in either the rack or block diagrams above. These are:

- Dell PowerEdge R330 (Cage rack)
- Lord Microstrain WSDA®-Base-104-LXRS® Basestation)(Cage rack)

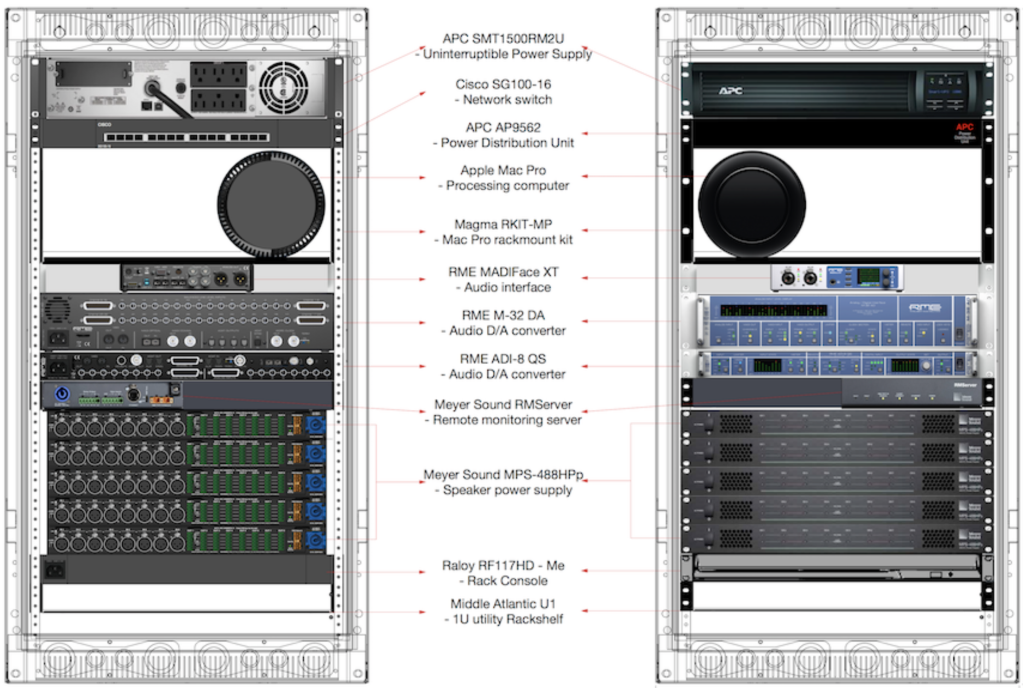

Figure 3.8. Hardware system inside the La Jolla Playhouse Cage that runs *The Wind Garden*

- 32 x Microstrain 3-axis wireless accelerometer array (Grove)
- Sensor antenna (mounted on Tree 30 in the La Jolla Playhouse grove
- Backup USB HDD (Cage rack)

The Dell R330 is a Linux server running Ubuntu 20.04 LTS distribution with the 4.4.0-78-generic kernel at the time of this writing. Its hardware configuration is as follows:

- Intel Xeon E3-1240 v5 3.5GHz, 8M Cache, 4C/8T, turbo (80W)
- 16 GB RAM, 2133MT/s, ECC

- 2 x 500 GB Hot-plug Hard Drive 7.2K RPM, NLSAS, 6 Gbps RAID 1 for SAS/ SATA
- PERC H330 Raid Controller
- Dual Hot Plug Power Supplies 350W
- On-Board LOM 1 GBE Dual Port

This machine performs 3 critical functions: 1) it acquires and parses realtime streaming input from the sensor array; 2) stores all data streams to an SQL database; and 3) forwards this data to *The Wind Garden* software running on the Mac Pro upon request. The Lord Microstrain basestation communicates with the sensor array and is connected directly to the Dell R330 via a USB cable. The sensor antenna is mounted to the exterior wall of the Playhouse and has a wired connection to the basestation.

3.3.4 Software design and sound synthesis

The Mac Pro runs OSX 10.11.6 (El Capitan),[6] with the 1.6 Java Runtime Environment (JRE) installed. An Nginx 1.10.3 daemon serves http. Various bash and Python scripts support *The Wind Garden* monitoring system.

The main *Wind Garden* software is a custom application based on an early beta version designed by Jem Altieri, and at the time of writing this I continue to maintain the program. Currently it runs in the Max/MSP 7.3.1

[6]This was the OS at the time of writing. See "Catastrophic Failure" section below for more information about this.

environment, with a number of additional Java layers and components. The main application is responsible for:

- All audio processing, including synthesis, spatialization, and filtering
- Calculating sun angles
- Output of 32+4 discrete channels of audio @ 48kHz
- Communicating with the SQL database
- Second stage data acquisition and data post-processing
- Low/high wind system interpolation
- Global gain staging
- Tone/tree assignments
- Logging
- Muting
- All of *Wind Garden*'s internal system logic and time/date-keeping
- Failover and fault tolerance systems
- Backend for the monitoring and notification systems

The Max/MSP audio scheduler is configured with these values:

- Sampling rate : 48000
- IO vector : 2048
- Signal vector : 2048

A number of other important initial parameters are collected from the main *Wind Garden* user interface panel. These are:

- Day fundamental frequency (default 116Hz)

- Night fundamental frequency (default 1856 Hz)
- Voice bandwidth (default 2)
- Sun bandwidth (default 2400)

Considerable care was taken to ensure the main application is 100% vanilla Max, with no third party objects or components. The exceptions to this are the Java layers which run inside MXJ containers; these are: MasterClock.class, SunAngles.class, DistFromRunningAvg3D.class, and RMS.class.

MasterClock.class is responsible for synchronizing *The Wind Garden* application to a GMT reference with respect to the local time zone. There are two independent copies of this clock running in the installation at all times: the first is the one controlled on the main panel that tracks date and time in order to calculate the momentary angle of the sun. The controls for this instance of MasterClock.class are exposed in the upper left corner of the main user panel, and allow for arbitrary date and time scrubbing. The second instance is controlled by *The Wind Garden* Time Machine interface. When the Time Machine is activated, realtime data acquisition is stopped by unlinking from the main MasterClock and attaching to the second instance controlled by the Time Machine. Using two clocks in this way allows for a user to recall and play back historical data independent of the time of day, which can be very useful for testing and tuning purposes. The two MasterClock.class instances output UTC for Pacific Standard Time to the SunAngles MXJ, prepended with these latitude and longitude coordinates:

32.715000-117.162498, or 32°42’54.0"N 117°09’45.0"W (San Diego, CA)

SunAngles.class is responsible for tracking the localized solar hour, and generating dynamic values used by the bandpass filters in the synthesis stage.

The basic generator in *The Wind Garden* is the MSP object [noise∼], which is used to generate a signal with a uniform power spectral density. The output immediately undergoes a fast Fourier transform (FFT size 16384 and overlap 8). Both the real and imaginary number components of this analysis are multiplied by a fixed-band impulse generator that uses the output of SunAngles MXJ to generate a synchronized frequency band that sweeps with the calendar date and the hour of the day.

The resulting signals are routed into a bank of bandpass filters sorted by bin index, [receivingBandpass.filter∼] which use the day fundamental frequency and night fundamental frequency to dynamically tune the bandpass filters to a harmonic series for day $(1f, 2f, 3f, 4f, 5f...)$ and a subharmonic series $(\frac{1}{1}f, \frac{1}{2}f, \frac{1}{3}f, \frac{1}{4}f, \frac{1}{5}f...)$ for night. An inverse FFT is applied and the resynthesized signal is put back into the time domain. All channels are sent through the routing/assignment matrix, and finally the amplitudes of each tree/speaker signals are modulated by the incoming (post-processed) data from the accelerometers.

The day/night mixture at any given point is of course determined primarily by the time of day, but it is also shaped by a custom amplitude curve that is designed to weigh night-time sonorities somewhat more heavily than day-time sonorities. Thus there will almost always be some small degree of "night" in the audio mix, even during the day.

3.3.5 Data acquisition

The sensor network setup and data acquisition (Python) scripts were developed by Jason Ponce, Douglas Alden, and Jem Altieri, and make use of a custom build of the MicroStrain Communication Libraries (MSCL). Data acquisition in *The Wind Garden* happens in three stages. The first stage occurs at the tree-mounted accelerometers, which poll for motion deltas along the X, Y and Z axes at a frequency of 8Hz. Each sensor transmits a floating point value for each axis to the Lord Microstrain Basestation.

The second stage occurs between the Lord Microstrain Basestation and the Dell PowerEdge R330 Linux server. The realtime data streaming from the 32 sensors in the grove is collected and parsed by a Python application called accelerometers-to-mysql.py, based on generalized acquisition software from Lord. After parsing, this data is written to a local SQL database along with an index and a UTC timestamp. This script must be always running for *The Wind Garden* to function.

The third stage of data acquisition occurs between the main Wind Garden application and another custom Python script called time-data-feeder.py, which in effect sits between the Max/MSP Wind Garden application and the database. This application is where the actual SQL query is generated, made on behalf of *The Wind Garden* application. This is essentially a pull request in the form of a UTC time-synchronized SQL query wrapped in a Java external, running within the Max/MSP environment. The data for the desired time frame is requested from the database (typically "now," unless historical data is desired), and the data itself is streamed back to the main application via a

UDP port unique to each sensor. This script must always be running for *The Wind Garden* to function.[7]

A final script called monitor-latency.py may optionally be run on the Linux host. This script outputs a calculated latency between the data requested by *The Wind Garden* and the values the database returns to the patch. This script is non-critical, and may be run by an operator in a terminal to help diagnose sensor dropout issues.

The sensor data is all contained in a mySQL database called foursoundgardens_data. Table names in the foursoundgardens_data database correspond to the tree numbers with which an accelerometer is associated.

[7] As mentioned above, the SQL database no longer exists. This description of its position within the data flow is a prime example of why it had to be eliminated.

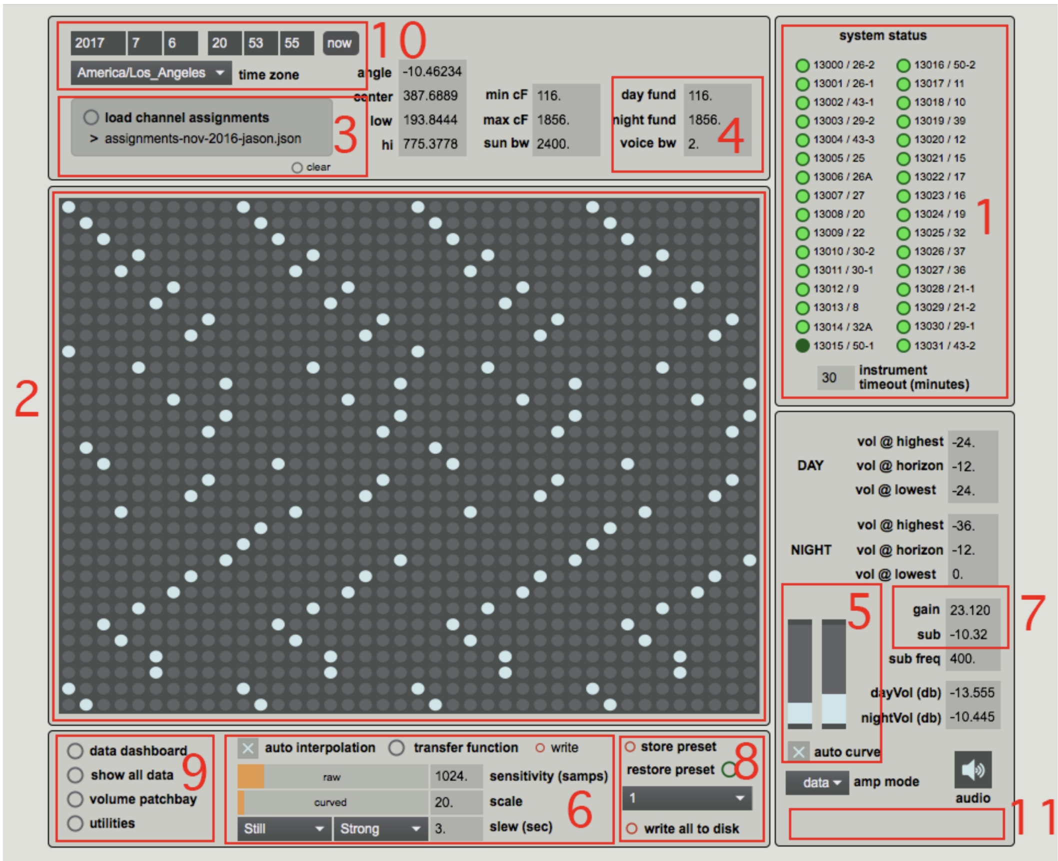

Figure 3.9. Main panel of *The Wind Garden* user interface

3.3.6 User interfaces

Figure 3.9 shows the main panel of *The Wind Garden* user interface. Following is an overview of the functionality this panel provides.

Box 1 shows the connection status of each accelerometer in the sensor network. A bright green circle (on) indicates that sensor is actively transmitting data and *The Wind Garden* application is receiving it. A dark green circle (off, as shown here with Tree 50-1) indicates the sensor is offline or has otherwise exceeded its data transmission timeout. In this example, the timeout duration has been set to 30 minutes. These status lights should be reflected exactly by *The Wind Garden* monitoring web app.

Box 2 is the tone matrix where specific pitches are assigned to specific trees throughout the grove. The X axis represents the tone numbers, corresponding to harmonics or subharmonics of the day/night fundamentals; the Y axis is the speaker. Thus, the speaker designated by row 1 (no relation to Tree/Speaker number in the Grove) voices tones 2, 12, 22, & 32.

Box 3 shows the name of the JSON that contains the active tone assignments, and provides an interface to load alternate files.

Box 4 establishes the fundamental frequencies system-wide for both day and night (currently B♭). All other tones and intervals are calculated from these fundamental frequencies using a harmonic series (for day) and a subharmonic series (for night).

Box 5 is the relative mix of day to night harmonics within the audio field. As the day progresses, a custom curve automatically controls the relative weighting. *The Wind Garden* favors night time sonorities, and depending on the calendar date there will almost always be some "night" in the mixture.

Box 6 contains the UI for one of the more critical *Wind Garden* components: the automatic weather scaling and preset interpolation system. The topmost orange horizontal bars show the raw (post-processed) wind data entering the system (represented as an average of the 32 sensors), and the lower orange bar shows the same data after it has passed through the transfer function of the boundary preset interpolation system. These values are also displayed in *The Wind Garden* Status web app. Box 6 also has a button that will open the transfer function for editing.

Box 7 is where global gain (in decibels) can be set for the 32 mains (the tree-mounted speakers) and the 4 subwoofers. Normally the interpolation system has control of these two values, and they will shift and slide around during normal operation. Disabling the auto interpolation via the checkbox in Box 6 gives gain control back to the user. Note that auto interpolation should *always* be disabled when making changes to boundary presets. Not doing so means realtime data will still be actively affecting all parameters exposed to the interpolation system (including per-sensor post-processing). When a preset is saved to disk, the state of all system parameters are recorded.

Box 8 lets the user recall and save boundary presets (Stillness and Strong Winds).

Box 9 contains buttons for accessing various information panels and utilities. The button for "Show all data" displays the full contents of the JSON that contains the system's interpolation data. The volume patchbay opens a utility that allows for hardware-independent fine tuning of the gains for each of Wind Garden's audio channels. Figure 3.10 shows the volume patchbay. Values are in dB and are positive or negative from (patch) unity. The Utilities button opens up a second user panel with many helpful tools.

Box 10 contains *The Wind Garden*'s master clock and calendar. Under normal operation the clock displays the real time and calendar date, but these number boxes can be changed at any time to hear any other time of day or night on any other date. The NOW button returns the system to the realtime clock.

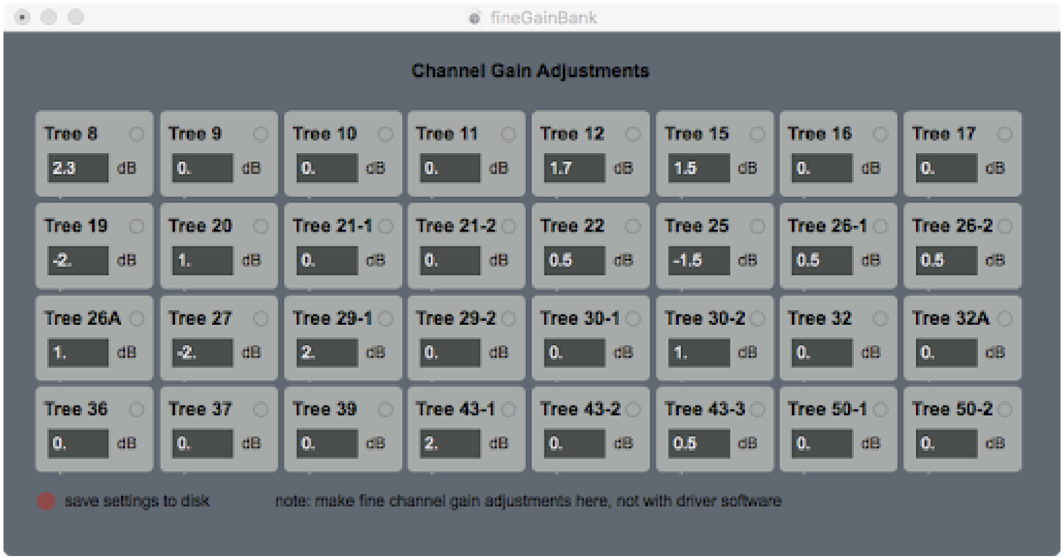

Figure 3.10. Web app volume patchbay

The area inside **Box 11** is where the system will indicate when the system is actively muted, and the duration remaining on the mute countdown timer. This area remains empty if no mute period is active, as shown above. Like the sensor statuses, the mute status is also shown on *The Wind Garden* Monitoring web app. If an active mute needs to be canceled and the numeric keypad is not functioning as expected, it is possible to cancel the mute manually via the user interface.

Within **Box 4** is an area for accessing various functions, utilities, and information panels. Figure 3.11 shows the panel that is brought up after clicking the Data Dashboard button:

This panel shows graphs of the realtime wind/accelerometer activity that is streaming to *The Wind Garden* application sensor by sensor, and provides roughly 30 seconds of historical data before the graphs recycle. This panel is especially useful for quickly identifying a misbehaving sensor, a loud

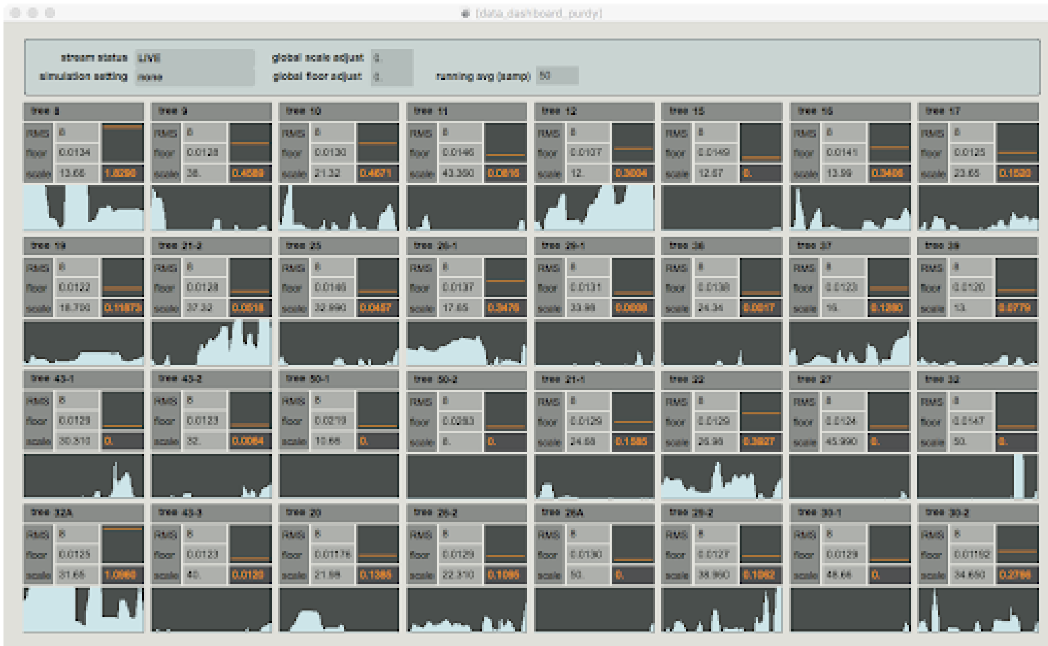

Figure 3.11. Sensor activity

tree, an errant tone, or a "stuck note" within the Grove. The graphs in the Data Dashboard show the incoming data after a user-defined post-processing stage, and are therefore not strictly representative of the wind throughout the Grove as a person on the ground might experience it. They are instead representative of a "Grove" that has been hand-tuned, tree by tree, in order to sound as good as possible within the larger context of *The Wind Garden*.

Monitoring Web Application: An online web tool has been created that allows for a rapid, non-technical overview of *The Wind Garden*'s status and overall health via any web browser. Figure 3.12 shows the frontend for this tool. It can be accessed via this URL:

http://132.239.175.92:8080

The monitoring web app is a custom javascript application served by a local nginx http server, which is hosted on the same Mac Pro as the main Wind Garden application. The app is a client-side application and has very low-bandwidth requirements, so the impact on system resources is negligible. Figure 3.12 shows the current status of each accelerometer, the realtime wind conditions in the Grove expressed as an average of the outputs of all 32 sensors, and the current mute status of the installation. The sensors are displayed in a grid and are labeled by tree number. Each sensor will show as being in one of three possible states:

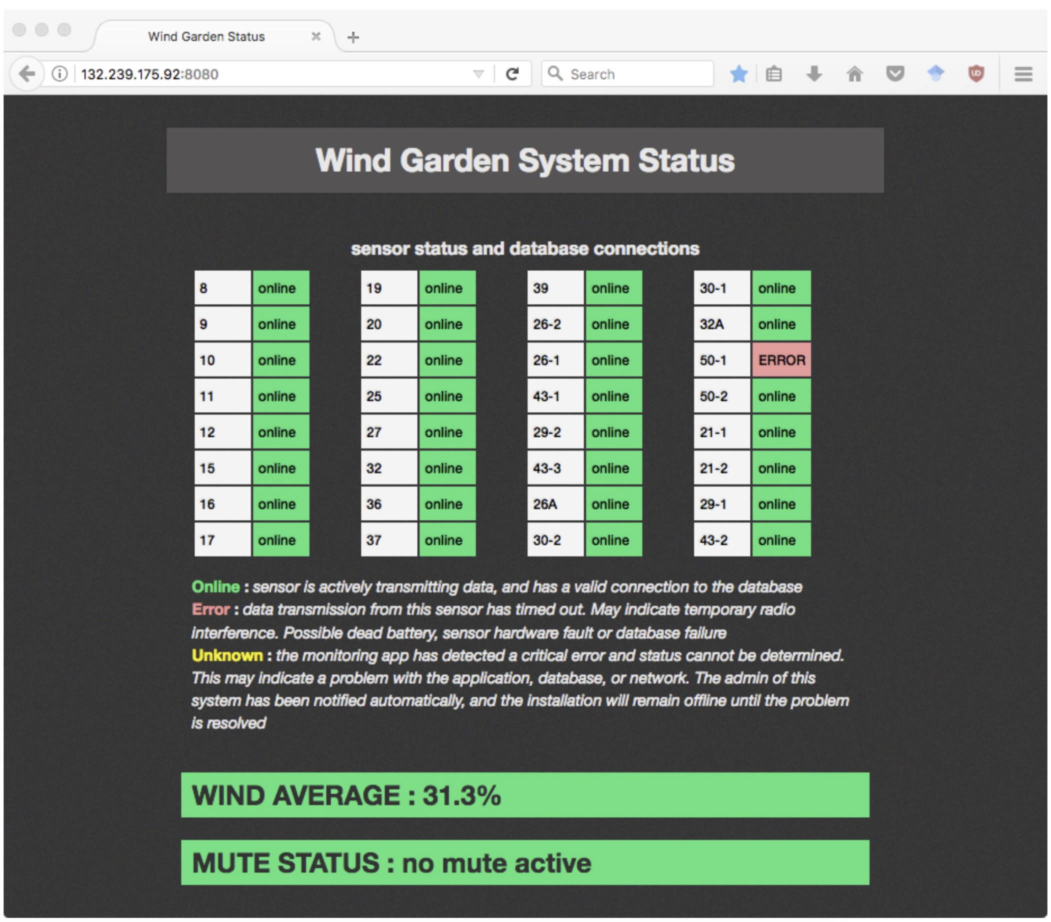

Figure 3.12. Frontend for *The Wind Garden* monitoring web application

- Active (green): the sensor is online, has a valid connection to the database, and is reporting to The Wind Garden application

- ERROR (red): This is a general per-sensor error condition that can represent a sensor hardware fault, a dead battery, or that data transmission has timed out (for any reason)

- Unknown (yellow): The monitoring application has lost connection to *The Wind Garden* and sensor status cannot be determined

The Wind Garden system is also capable of sending out email notifications to one or more people in the event of an error, specifically the ERROR and Unknown conditions. At the time of this writing, all errors including temporary sensor dropouts trigger email alerts. The email notification system is a pair of Unix bash and Python scripts that interact with the system monitoring web app.

3.3.7 Data processing, post-processing and interpolation

This section describes the step-by-step path the sensor sample streams take once they enter the main Wind Garden application, up to the point they enter the audio synthesis stage.

Initial processing

To somewhat oversimplify, *The Wind Garden* application receives 32 channels of raw sensor data from the accelerometers in the Grove. This data arrives at the application as a package of three floating point values, one float for each axis of the accelerometer. These values arrive per-sensor, streamed via unique UDP ports, and are routed internally via these port numbers. Once inside The Wind Garden application these three floats are processed like so:

- the triplet is converted to a single 3D vector
- that vector's distance from a running average is calculated
- the RMS value of the resulting figure is calculated

This process produces a final floating point value that represents the displacement, or average "movement" of a single sensor across a given sampling window.

The above three steps are handled by two java classes that run in MXJs within the application's data acquisition abstractions. These classes are: DistFromRunningAvg3D.class and RMS.class.

Post-processing

Once the accelerometer data has entered the Wind Garden application and a generalized displacement value for each sensor has been calculated, those values then enter a user-configurable post-processing stage. This stage is exposed to the UI via *The Wind Garden*'s data dashboard, which allows for per-tree tuning of the data streams prior to entering the synthesis engine. Each tree has a corresponding post-processing panel like the one shown in Figure 3.13. Each panel presents a number of UI elements, including three which can be configured by the user. These user-definable elements are RMS, floor, and scale.

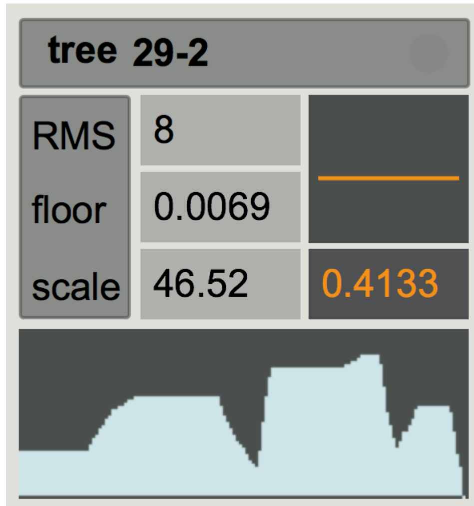

Figure 3.13. Post-processing UI panel

- RMS is an additional root/mean/square stage that may be applied for additional data smoothing

- The floor value can be used to raise or lower the noise floor of the incoming signal, effectively making the sensor less or more sensitive to small movements in the branches

- Scale is a scaling value by which the overall post-processed data may be multiplied. Raising this value will have the effect of emphasizing momentary difference in the incoming signal during both high and low wind conditions, and generally produce a wider, more dynamic amplitude curve

Under normal operation, RMS, floor, and scale values are dynamically controlled by the auto-interpolation system.

The remaining UI elements are provided for informational resources for the user: the blue graph shows roughly 30 seconds of post-processed data as the synthesis engine receives it downstream; the orange decimal shows instantaneous values of the post-processed data; and the orange bar depicts a running average of the last 75 data points.

If a specific tone in the Grove seems to be particularly prominent, or if average wind conditions over time become such that one or more trees tend toward over/understimulation, the post-processing panel is where these problems can be corrected.

3.3.8 Boundary presets and data interpolation

While the post-processing panel is a powerful tuning tool, in most cases the user-definable values in this panel will be dynamically controlled by *The Wind Garden*'s auto interpolation system. It was clear early on that the installation needed to be capable of responding well to a wide range of weather conditions, and not just an arbitrary state that we deemed "average" for La Jolla. Conversely, it was not practical to anticipate and hand-tune for more than a few discrete weather states.

The technique used to solve this problem was to define two "boundary presets," or extreme weather presets, then hand tune the full system separately for those two extremes, then dynamically perform a custom, nonlinear interpolation between them. When activated, the interpolation system performs a realtime calculation of the total wind energy in the Grove (in this case defined as a running average of all sensor outputs) and responds to increasing or decreasing winds by modulating the post-processing of every tree (RMS, floor, and scale), and the gains of all "main" speakers and subwoofers. Figure 3.14 shows the UI for the auto-interpolation system shown on the main patch interface.

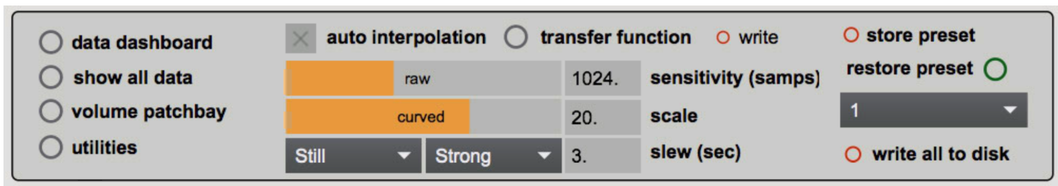

Figure 3.14. The auto-interpolation system user interface

The orange slider labeled "raw" shows the calculated average of the actual energy entering the system before any modulation occurs. This is the value that is tracked to drive the interpolation. As the raw value increases, a lookup table containing a transfer function is referenced. The output of this function controls the orange slider labeled "curved," which controls the degree of interpolation for the entire system, from the "Stillness" preset (full left) to "Strong Winds" preset (full right). Figure 3.15 shows the rather exotic transfer function used to interpolate between presets.

Although the interpolation system controls nearly 100 discrete parameters in *The Wind Garden*, including data post-processing for each tree, the transition table can perhaps be understood most easily in terms of gain levels. As the "curved" bar fills from left ("Stillness") to right ("High Winds") the transfer table is read proportionally from left to right. The lower left corner represents the 100% "Stillness" preset, where the speakers are at their highest gain levels. The upper right corner is the 100% "Strong Winds" preset, where

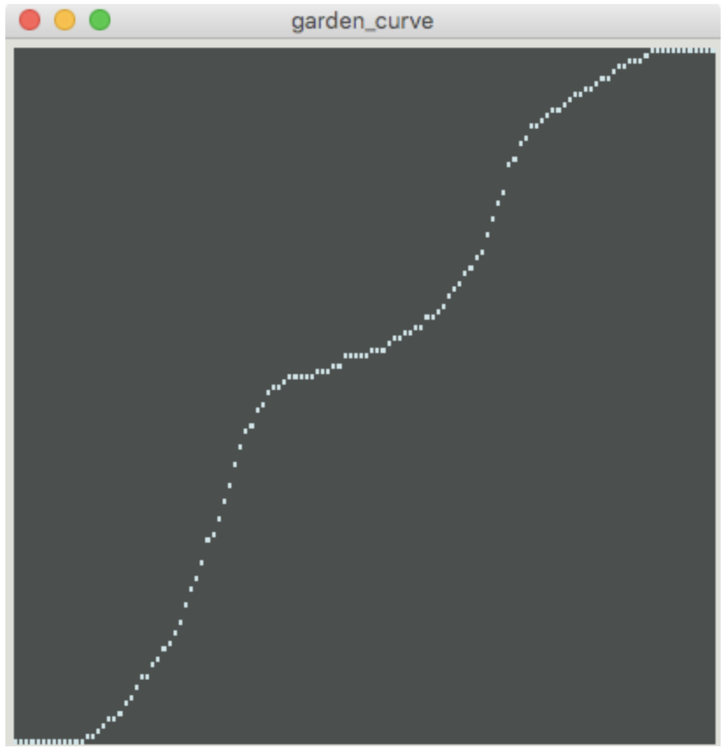

Figure 3.15. Transfer function used for interpolating between boundary presets

the volume of all speakers is attenuated dramatically to prevent the system from becoming too loud. During stillness to low wind conditions, the installation remains 100% in the "Stillness" preset. As winds increase to moderate, there is a quick increase in the transition and thereby a rapid attenuation of amplitude. Between 40%-60% "raw" the function plateaus somewhat, and the "curved" slider will hover halfway between "Stillness" and "Strong Winds" until it jumps again rapidly to accommodate uncharacteristically high winds.

This curve has been meticulously crafted for this specific eucalyptus grove, tuned against near absolute stillness on one end, and against the archived data from the storm that occurred in late December 2016 on the other. This transfer function is largely responsible for the perceived smoothness of operation of *The Wind Garden* across a variety of weather conditions. This curve could not be substituted with a linear interpolation of data as the piece would get too loud too fast, or would not get quiet enough fast enough during major weather events. Developing this curve was a painstaking process of observing weather acceleration and deceleration patterns over time, and then fitting the technology to both support and articulate those patterns.

In practice, there should be very few circumstances that would call for modifying the transition curve in any way. It has been exposed to the user interface specifically to allow for changes that may need to be made far into the future, after the Grove has undergone significant physical change. Tuning over the next 5 or 10 years will most likely be accomplished by making small changes to the post-processing of individual trees, and the volume settings in one of the boundary presets.

3.3.9 System utilities

Box 4 controls a basic wind simulator that can be used for testing and tuning purposes. This tool uses a brownian motion algorithm that may or may not represent how actual wind behaves in the Grove. Exactly zero minutes were spent on the futile pursuit of attempting to realistically model how actual wind might behave among the leaves and branches of the Grove, so this tool is something of a crude hammer. Still, it has proved useful on a several occasions. Preset buttons are provided to quickly dial in different kinds of winds.

Box 5 controls the Time Machine. This tool can recall and "play back"

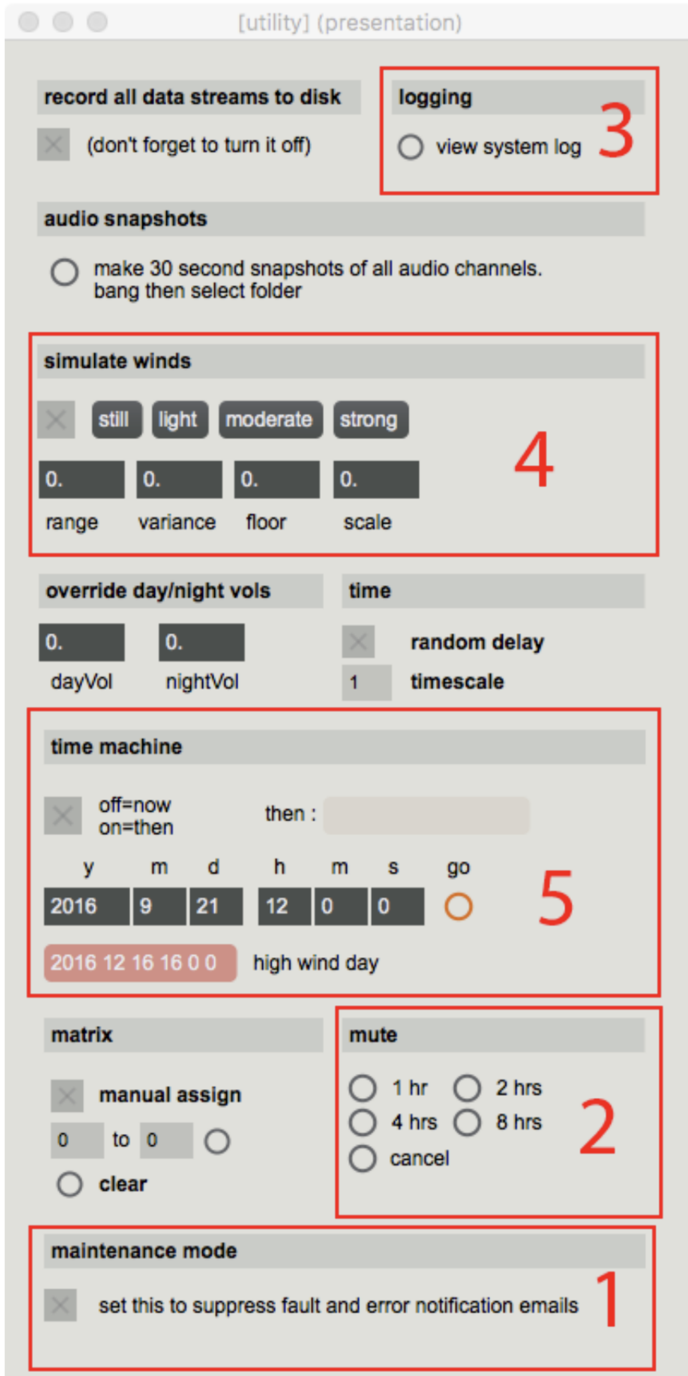

Figure 3.16. The utilities panel interface, which houses numerous useful tools

historical wind data that has been previously committed to the database. Using the Time Machine stops the acquisition of realtime, or “now” data, and redirects all SQL requests to pull starting from the Y/M/D - H/M/S variables specified in the Time Machine UI.

Box 3 in the Utility Panel diagram, which shows how to access *The Wind Garden* system logs, deserves a special mention here because of its value in helping identify the origins of problems with the system, and exactly when these problems occurred. *The Wind Garden* application has a unified logging mechanism, and all major system events in *The Wind Garden* are logged here. These include date and timestamped messages about these events:

- Sensor online
- Sensor offline
- Sensor failures
- Failover events
- System errors
- System shutdown
- System startup
- Mute/mute cancel events.
- Maintenance mode on/off
- Audio capture on/off

The system logs are a useful troubleshooting tool, and any investigation into a technical problem would probably start here.

3.4 Specific Issues in Conservation of *The Wind Garden*

3.4.1 Overview of *The Wind Garden* maintenance

I have provided such in-depth descriptions of how *The Wind Garden* was made not only because I played such an integral role in its creation and development, but in order to help convey the complexities involved in keeping this artwork in existence. As I have said above, there is no question of if it will break. It will break. It is best therefore to plan to be surprised by *The Wind Garden*, and as custodians to this living thing prepare to adapt to its needs.

The previous section of this document provides a high-level description of *The Wind Garden*'s main components and an overview of how they work, but viewed another way, this could also be understood as a blueprint for troubleshooting the work when problems arise. There is enough detail in the full Technical Manual about the installation's internals that a clever, motivated person could use this document to recover the work from a catastrophic loss of some kind (whether that be a massive hardware loss, or loss of the Grove itself), or to rebuild the entire installation, were that ever to become necessary.

A brief review of the descriptive subsections above also illuminates the range of threats to the longevity of *The Wind Garden* that occur across the several strata of its existence:

Physical Orientation:

Changes to the Grove that are both expected (tree growth, storms) and unexpected (massive storms). If we extend Adams' sacred metaphor of a cathedral, we can think of the Grove as a cathedral whose walls are always moving. In ten years, the cathedral will have a very different shape than when we began. Changes in the physical orientation might also come as a result of changes of priorities of the Stuart Collection, or a change of administrative oversight within the UC system, the umbrella authority above the Stuart Collection.

Aesthetic Design:

As mentioned above, the tuning of *The Wind Garden* is fundamental to the work. Maintaining the tuning requires maintenance at regular intervals, and will into the foreseeable future.

Hardware Design:

This could include speaker damage, sensor failure, reaching hard disc capacity, or any of the other problems that regularly plague any computational hardware.

Software Design:

More will be said below about the transition from the original conception of the software design to the software that actively runs the piece now, but currently the most persistent problem with the work is that every problem that arises is unique. This speaks directly to the problem of implementing an idiosyncratic software design for a one-of-a-kind work. There is no corporate help-desk to be summoned. I am the help desk.

The Wind Garden cannot be thought of as analogous to a static physical art object. It is more like a live performance that never ends, and only takes a brief pause once nightly to reboot. The computer that runs logic, synthesis, and spatialization automatically does this at 3:30am, and/or whenever the monitoring system detects a critical error and attempt to self-correct. The installation is silent during this time, but with the current system hardware the total downtime is < 2 minutes (or ca. .1% of its performance life.[8]

The piece requires regular maintenance, and part of my current, ongoing work with the Stuart Collection is to keep *The Wind Garden* running in such a way that the maintenance it requires does not become an undue burden for any parties involved. One can easily imagine a scenario wherein the maintenance required becomes too expensive or too time consuming, or the nature of it too cumbersome for the Stuart Collection to wish to support the piece any longer.

3.4.2 Technical platform constraints and limitations

At this time, Cycling 74 is still supporting Java VMs inside patches via the [mxj] external. This is good. Not because Java is good (it's not), but because *The Wind Garden* has a critical dependence on Java due to the way the

[8] As mentioned in Chapter 2, downtime is critical. Even in a scenario wherein we are attempting to "run forever," we need moments of pause. Such a structure was always built in to the management of *Dream House*. The John Cage Foundation is attempting to manage their performance without it, but, of course, by limiting visitor hours, it is conceivable that they could sneak in some re-boot time here and there across the centuries, should that prove necessary.

installation tracks and converts sidereal time. However, as the years go by Java support has becomes less and less visible in Cycling's documentation, and there is a growing sense in the Max community that support for Java will eventually be dropped altogether. Nobody outside the company knows if and when this will occur, although as more stable, popular and well-supported programming languages like node.js become increasingly integrated into Max it seems that time may be close at hand. When that day comes a deep technical assessment will need to be performed to determine whether it is still be possible to run the *The Wind Garden* in Max/MSP. Even if it *is* determined to be feasible, at the very least it will be a very time-consuming and expensive undertaking to decouple from Java. And should it be determined that it is *not* possible to use Max anymore then I (or whoever is maintaining the installation at that time) will be confronted with a total line-by-line rewrite (not a port!) of the entire work. This will take an extraordinary amount of time and expertise, and if neither John or I am around to perform and guide this work it is unclear if whatever emerges at the other end can still be called *The Wind Garden*.

3.4.3 Problems in development that informed our stance toward maintenance

As a musical system (a parameterized encoded score) that is both monitoring a living system (the Grove) and articulating a deeply linked representational system (the sonification of environmental factors plus time), *The Wind Garden* is at all levels of its design particularly sensitive to any given technical approach. It was clear early on that if the piece was to succeed, all design decisions would need to serve two primary goals equally. These are: 1) the ultimate aesthetic result in the form of articulated sound; and 2) the viability and preservation of the work itself. All technical work therefore proceeded with these goals in mind, and to date all evolutions of the technology stack have been targeted to ensure the longest possible time horizon for *The Wind Garden* at least as much as to address any momentary technical issue. Sometimes this process has been straightforward, and at other times it has been very difficult indeed to foresee how a technical choice will affect both what is there now and what will be there in perhaps five or ten years.

The evolution of *The Wind Garden*'s sensor network is a key example of this dynamic in action. In order to illustrate this I will provide a brief history and overview of the system in its earliest state, before I was brought on to the project and well before it opened to the public. As mentioned previously in the section on Hardware Design, the 32 LORD Microstrain G-LINK-LXRS-2G-M accelerometers used in *The Wind Garden* were proposed by the Scripps Institute of Oceanography, and were recommended primarily based on their reliable performance when placed on buoys for the purpose of studying the macro patterns of ocean currents. These are wireless, battery powered devices that arrive from the manufacturer designed and optimized to operate at a standard target sample rate of 150Hz. In the oceanographic research performed at Scripps it is uncommon for more than two or three of these devices to be deployed within a given geographical area, and sampled data collected is transmitted wirelessly to a nearby basestation for storage and retrieval later. With *The Wind Garden*, however, all data is transmitted to a basestation (staged inside the La Jolla Playhouse), and then immediately written out to a SQL database. The main *Wind Garden* software continually queries the database as data is streamed in, and this data is handed off to the synthesis engine. While it was always important to preserve the cause/effect relationship of wind-to-sound, this configuration introduced a system latency of around 7 to 8 seconds, which at the time we found to be acceptable. However, this store-and-query method created additional maintenance concerns due to the not-insignificant overhead of warehousing all the inbound writes. Even once the warehousing was resolved, we were still plagued by ongoing connectivity issues, often in the form of mysterious sensor dropouts and other "ghosts in the machine" for which there were often no obvious solutions other than time consuming sensor network resets.[9] For the first few years an estimated 90% of problems with *The Wind Garden* were related to sensor health reports and database connectivity issues. This time was also marked with a number of periods where the system was degraded to the point at which we decided to temporarily disable the entire installation.

This was the early design in place when I first arrived on the project. While perhaps sufficient as a proof of concept, there were numerous issues with system stability and reliability that impacted daily functioning in a finished product that were unusually difficult to diagnose. As a result, the piece was largely unmaintainable. It was not uncommon to have 10%-15% of the sensors not reporting data at any one time, even shortly after a full cycle of battery

[9] The sensor health monitoring system parses inbound sensor data and looks for values that change from moment to moment to determine if a particular sensor is "alive" or not. If unique values are not reported across a certain time window, the non-reporting sensor gets marked as potentially or fully dead, is removed from the network, and its associated tree "borrows" data from a nearby sister tree, which gets logged and reported.

replacements.[10] At the time, Adams and I agreed that past a certain threshold (20% sensors offline) we would temporarily shut down the entire *Wind Garden* until the situation could be improved. Indeed, this happened often enough that I wrote scripts to automate checking for this exact condition, and to shut the system down if that threshold was ever exceeded.

Yet the question of why a sensor might not be reporting data remained difficult to answer, and took years and considerable redesign before it was resolved. Effective diagnosis of sensor failure/dropout was complicated by several key factors:

- Physical location of the sensors (often in upper boughs) means that dead batteries can only be confirmed once every six months
- An overcrowded radio environment that was operating well out of the manufacturer's guidelines (32 sensors present vs two or three)
- Transmit data density: each sensor reported 3 (X, Y, Z) x 150 samples per second x 32 sensors, for 24 hours a day—far out of spec from the manufacturer
- Potential additional radio interference from theater radio transmitters

[10] Due to the placement of the sensors high in the trees, sensor service and battery replacement in *The Wind Garden* is a time consuming and expensive process. As I no longer reside in the San Diego area, the process requires a lift rental with a qualified operator and close coordination between the operator and myself as I work with that person remotely to bring the network down, remove and re-add sensors from the connection pool, validate, bring the network back up, and test. The whole process takes a minimum of two days. Battery replacements and sensor service therefore happen on a schedule, twice a year, with essentially no opportunity to double back if errors are made on-site. One must simply wait for the next service window in that case.

used during productions at the La Jolla Playhouse

- False-positives were possible and difficult to detect (false-positive here meaning a sensor that is reporting dead to the system but still transmitting data)

- Unknown secondary effects from a sensor sample rate that was many times greater than what was needed for our application

- Middleware to accommodate the data warehousing

- Simulating synchronous realtime data ingress and egress between the database server and the synthesis/logic system server

- Variable system latency and time synchronization issues introduced from middleware and the software shims that enabled "realtime"

A sensor "not reporting" data could be the result of any of these factors, or more than one!

3.4.4 Downsampling, redesign, and redeployment

At the time of install, the G-LINK-LXRS-2G-M accelerometers arrived from the manufacturer configured to sample at a rate as high as 4096Hz, with a lower bound of 150Hz, which we used.[11] Meanwhile, 150Hz still vastly exceeded both what *The Wind Garden* needed to function properly, and introduced significant stability concerns with respect to how to handle a continuous ingest at this scale using commodity hardware. Data at this scale is capable of filling up

[11] Subsequent firmware releases from Lord dropped the sample rate floor to 32Hz.

a hard drive and crashing the system unless it is regularly rotated, compressed or exfiltrated. A very early solution was put in place that automated this process monthly by compressing and shipping all historical data to Amazon S3. In this way historical data was preserved, and could be staged as needed.[12] We also partnered with Lord on the issue of the sensor sample rate, and succeeded in convincing them to create for us a custom firmware that lowered the sample floor to 8Hz. Once deployed, we observed an immediate improvement in system stability when the full sensor network had been downgraded. This was a great unexpected win for the project, and the installation is still (at the time of writing) running this custom firmware that allows an 8Hz sample rate. However, we did also observe some unexpected secondary effects from this implementation. For example, certain scripts and software tools from the manufacturer that are used for testing and maintaining the sensor network would not function properly with the new firmware applied. We also noticed that the battery life of the sensors was mysteriously degraded. I raised these issues with Lord, but they unsurprisingly declined to apply additional engineering resources to our admittedly very niche edge case.

The dynamic here is revealing; many creative projects will never enjoy the same corporate-sized budgeting that is seen in industry, even, it should be said, with projects as well-funded as *The Wind Garden*. So when considering interactives and the arts there will always exist this tension in the form of hidden trade-offs with respect to cost, suitability, stability, and support. Similarly, the

[12] Aside from my own use of historical data from outsized weather events for tuning purposes, historical Wind Garden data has never been used anywhere by anybody. *The Wind Garden* no longer preserves such data.

often unexplored territory traversed by novel interactive experiences frequently demands a special kind of "creative engineering" (when being polite), or "cowboy engineering" (when being glib) that embraces deep technical borrowing, creative recontextualization, and plenty of free and open investigation. It is for these reasons that large scale interactive art projects are especially vulnerable to poor early design decisions.

Around this same time, I began work on a number of targeted tools to help minimize downtime and unforeseen maintenance. One example tool from that period was a robust automatic failover system that would allow the installation to keep running even at >20% sensor failure (per Adams' wishes). This failover system works by assigning every sensor, or "tree," a nearby sister tree from which data can be replicated in the event that a sensor goes offline. For example, if Tree 50 were to fall offline for any reason the data stream from adjacent Tree 51 is duplicated and sent to the sound processing engine for Tree 50. A 15000ms delay is introduced into the copied data stream to prevent rhythmic unisons from occurring in the Grove. When Tree 50 starts reporting data again, the siphoned stream is detached and the original tree is connected back to its original data channel. All changes in state are logged and represented in the main user interface.

Another tool from that period was development of a comprehensive monitoring suite that allows third parties to be automatically notified by text message or email when minor problems arise, and would send detailed reports to me when major errors occurred that required my specific attention. Bundled with this suite of tools is a web application for easy realtime monitoring by non-technical people at the Stuart Collection, native Linux and Mac system services that monitor and report on connectivity to the basestation, the database, and each other, and a tool capable of resetting and restarting the entire installation automatically if any of the various critical layers were to crash.

During the early years after opening, much of my work was spent developing such mitigating strategies to simply keep the installation online and sounding as much as possible, but it had become obvious to me that a comprehensive solution to several problems required a full system redesign. In early 2018 I submitted a proposal to the Stuart Collection and began work rebuilding the backend. Today, *The Wind Garden* hosts no SQL database and the query layers are removed entirely (though a decoupled time-series database runs alongside the installation to aid in data visualizations and troubleshooting). Sensor data is now ingested directly via a custom data pipeline that feeds the synthesis engine. Sensor network stability has been improved to the point where the old failover system is unnecessary, and all changes together have reduced overall system latency by almost 75%. These improvements are measurable in terms of overall visitor experience, as the Grove is now more articulate and much more responsive to changes in wind conditions. But perhaps most importantly, these improvements have dramatically decreased complexity while retaining the same aesthetic quality, and increased the likelihood that this work can and will be preserved now and into the future. Figures 3.17 and 3.18 shows a before and after comparison of the two versions of the piece.

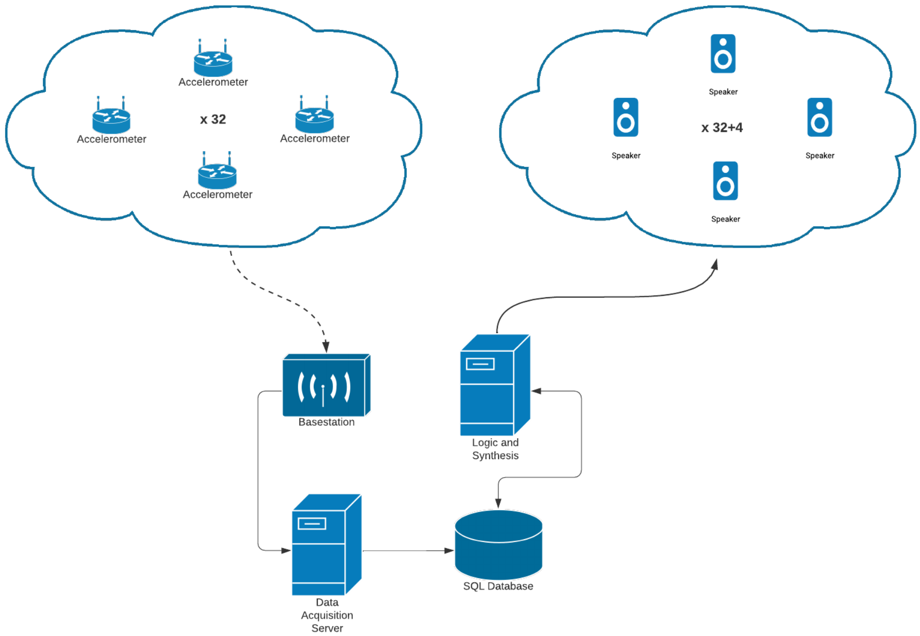

Figure 3.17. *The Wind Garden* system before redesign

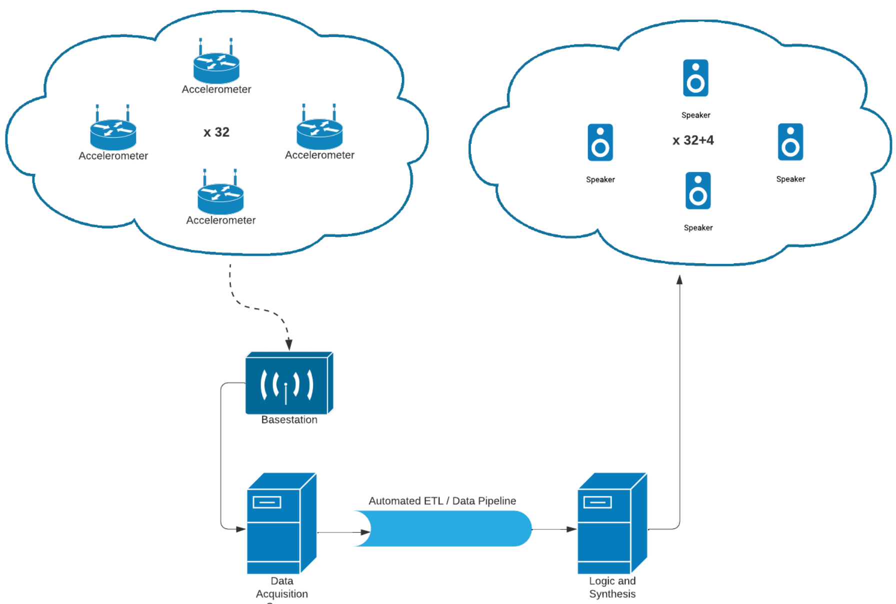

Figure 3.18. *The Wind Garden* system after redesign

3.4.5 Regular physical maintenance

In order to keep the *The Wind Garden* functioning, a visual inspection of all speakers and sensors in the Grove needs to be performed from the ground at regular intervals. Potential problems include:

- Damage to speakers or sensors
- Damage to speaker wire and cable conduit
- Tree growth that is presently or may soon be interfering with speakers or sensors
- Trees that have come into contact with other trees (larger branches in particular)
- Broken branches
- Damage to benches, speaker enclosures, tree tags, or walking paths

Because the piece is so enmeshed with a living environment (the Grove), a professional arborist must review the overall condition of the Grove and provide a detailed report once a year. When the accelerometers were placed on each branch considerable thought was given to future growth of that branch, and to the growth of other nearby limbs. As the trees grow, selective pruning will be required to ensure adjacent branches do not block the wind or interfere with other accelerometers. Additionally, accelerometers will have to be moved when branches thicken and movement is dampened to the point that there is no longer adequate signal being measured. Therefore, also once a year, a lift should be used to inspect all tree-mounted hardware, and to replace sensors and/or sensor batteries, as needed. See figure 3.4 for a comprehensive mapping of cable and conduit runs.

Accelerometers during this process should be moved as little as possible, as site selection and placement of the accelerometers is critical. Accelerometers are mounted on branches at specific locations in the Grove as close as possible to their associated speaker, generally speaking. We have determined that ideal branches are generally 1 to 3 inches in diameter, have good exposure to the wind, and respond well to the breezes that flow throughout the Grove. If accelerometers need to be moved, we have included a drilling tool in the accelerometer kit to properly align holes and provide proper spacing for the mounting brackets. Particularly important when tightening the clamps of the accelerometer mountings is to orient the housing so the notch on one corner of the lid is pointed toward the receiving antenna on Tree 30 in order to maintain remote communication. As mentioned, each sensor has been installed as close to their associated speaker as possible. But in some cases installing in the same tree was impractical. At some point in the future there will be additional tags produced to mark the trees that have a sensor in them, and this information will be incorporated into our site/speaker maps.

The extensive network of cable conduit throughout the Grove presents specific maintenance challenges, as this network carries lines for both power and audio to every tree in *The Wind Garden* and is critical to the function of the installation. Our conduit network was designed specifically to convey and protect these lines while being as unobtrusive as possible. This means that conduit is buried whenever possible, and lengths that run up the trunks of trees are made with custom weatherproofed materials that can be painted a natural color and which can be easily molded to the contours of the trees. Buried conduit is relatively secure, but the exposed runs which are mounted to the trees are particularly vulnerable to the elements, and also to the natural growth of the Grove over time. A number of complex repairs have already occurred after tree growth or the natural movements of trees in the wind have been great enough to dislodge or rupture conduit and cause power failures or audio problems. Even when these disruptions have not been serious enough to require a total shutdown of the installation, in a network this size where half the lines are underground and the other half are mounted high in living trees it is often challenging and expensive to determine exactly where a cable rupture has occurred, even before a repair is undertaken. Even routine maintenance of *The Wind Garden* requires heavy equipment rentals, and the contracting of multiple professional services, including UCSD Facilities Management, on-site technical specialists such as electricians, arborists, etc., and myself. Previously, technical maintenance involving the sensor network was performed by a Research and Development section at the nearby Scripps Institution of Oceanography, but I have since taken over that role. This means that in all but a few trivial scenarios my time must be budgeted into *all* maintenance efforts. Sometimes I am able to perform this work remotely in collaboration with other engineers on-site; at other times both routine and non-routine service requires my physical presence at the site. It should be noted that this type of maintenance service is entirely separate than *tuning* of the installation, which occurs on a different schedule and which also requires my physical presence.

Twice a year, tests must be performed to ensure the audio from the Grove remains clean and free from rattles, buzzing, and other distortion. One reliable way to test the full audio chain is to run reasonably loud sine tone sweeps through the Grove channel by channel, with a careful listener checking for problems. In order to facilitate this, a simple testing Max patch has been added to the main Mac Pro that makes these tests a straightforward process. The results of this test must be logged for long-term reference.

Part of audio testing also includes sound focus. Sound focus is as an entirely separate process from site tuning, and should be performed one at a time with focus always occurring first. Achieving good speaker focus for *The Wind Garden* can be likened to performing lighting focus for a stage wash, where coverage and consistency is the goal. Our experience has shown that when focusing speakers sending white noise, pink noise, or other broadband signals through each channel is most effective. Focusing by using the tones produced by *The Wind Garden* itself is likely to produce inconsistent results.

Exact speaker focus points (on the ground) are notated in Figure 3.2, the Speaker Focus Map. These locations are presented by Adams as ideal focus points, with the aim of providing even sound pressure levels along the two critical axes, and also throughout the Grove as a whole. Conditions in the Grove may make exact focus as it is notated impractical or impossible. However, when replacing or repairing speakers, or when making changes to the trees themselves (trimming, pruning, etc) it is critical that this notation be matched as closely as possible.

This notation was originally devised as a guide for future technicians, but it should be understood that it is ultimately what is *heard* in the Grove—the actual sounds of the installation *in situ*—that should inform final speaker placement. If a notated position of a speaker sounds wrong, if natural foliage overly dampens or diminishes the sound, or if there are "holes" or "soft spots" in the soundscape, then subjective adjustments by a trained sound designer should be made to produce a sound field that is as even as possible. Very fine per-channel adjustments to gains that are independent of hardware/driver/software mixer settings can be made through the volume patchbay, accessible from the main user interface panel.

Plans have been put in place for dealing with the various problems discovered in regular maintenance. For example, if during a visual inspection or during a sound test a speaker is determined to be damaged, or that there is damage to the speaker wire and/or power conduit on the trees, the technician at hand should:

- Use the tree/speaker tags and site map documents if necessary to identify the audio channel that corresponds the failed speaker or damaged conduit
- Physically disconnect that channel from the Meyer Sound Speaker Power Supply in the Cage. (This is an important step that will prevent a short circuit in the Grove that can damage hardware in the Cage)
- Notify the Stuart Collection to schedule a replacement or repair

3.4.6 Regular hardware maintenance

Note that the following section makes extensive reference to a SQL database layer of the stack that no longer exists. Take it for what it is.

The Wind Garden SQL server retains a growing database of all sensor activity, and there are a number of different subsystems on both the Mac Pro and the Linux server that produce logs. Some of these logs are not subject to automated rotation procedures. While these logs are not particularly verbose and are unlikely to cause many problems, they still require a periodic checking of disk capacity.

The Python scripts that run data acquisition and data storage are capable of producing huge logs when configured to do so. If a specific log has ballooned disproportionately it may be that one of the scripts has a log level set to DEBUG. Under normal operation (that is, when there is no troubleshooting being performed) there is no need to use a DEBUG log level, and this should be changed to WARN. The three data acquisition logs are:

- accelerometers-to-mysql.log
- monitor_latency.log
- time-data-feeder.log

Logrotate is used to make sure they do not unnecessarily fill up the disk. The logrotate commands are contained in /etc/logrotate.conf.

Adequate drive capacity is especially critical for the Dell PowerEdge. This machine hosts the SQL database, and a disk full situation will break

ALL processes downstream. If this happens the piece will go silent until the problem is resolved and disk space is cleared. *The Wind Garden* collects data at a respectable pace: 3 floating point values 8 times a second x 32 sensors. Although it has been discussed, at this time there is not sufficient interest in warehousing archival wind data.[13] This means that the SQL database (foursoundgardens_data) must be manually purged or re-homed periodically to keep the disk partition usable. However, purging the database also purges any historical reference points that may be constructively recalled and used for tuning purposes when using *The Wind Garden* Time Machine.

Daily incremental backups of the Mac Pro are made to the wired Backup USB HDD. In the event of a catastrophic system crash, the full Wind Garden system can be recreated from the folders and software in these backups. These backups are incremental and not drive images. In the event of a catastrophic disk crash, special care will need to be taken to ensure the correct versions of the OS, the Java Runtime Environment, and other applicable software packages are installed and configured properly.

In the unlikely event that *The Wind Garden* Mac Pro and its backups are irretrievably lost, it is possible to restore the installation using an offsite disk image. The image is a clone of the Mac Pro's internal SSD and is stored on UCSD's Google Drive cloud service, using a Stuart Collection account.

[13] Adams initially thought that the data gathered by the accelerometers may be useful beyond the scope of this project, but in five years of database storage, nobody was ever interested in reviewing this data. Also, *The Wind Garden* is physically located only a few miles from the Scripps Institute of Oceanography. It is not inconceivable that there may be a 2.0 version of the piece for which historical data may be used. See the several thought-experiment versions of the piece outlined in Ch.4

Presently this cloud share is mounted on the Mac Pro at boot, and the drive image itself should be easy to locate at that mount point. This is a last-resort failsafe, and as such the disk clone process is performed manually and at very irregular intervals. While the core components (correct Max and JRE versions, java classes, critical abstractions) could be recovered easily, the latest version of the patch may or may not be represented in the clone. By the time this process is needed, it may be the case that that hardware has changed enough that a clone cannot be restored to a modern system. In that case it may be necessary to use the image to extract individual components for upgrading and/or porting. At this time only the Mac Pro is imaged. The Linux machine, the SQL database and sensor network would need to be set up manually.

3.4.7 Regular software maintenance

Under normal circumstances, regular software upgrades to an OS are desirable for the long term health of the OS. However, there is a good chance that updating either the OS or the Java Runtime Environment will break parts of the installation, especially since there are a number of scripts running behinds the scenes, and Apple's OS updates have a tendency to make significant changes to the way their systems are organized internally.

Upgrading Max/MSP to point releases should cause no problems, and even larger upgrades are usually not problematic when done within one or two major release cycles, especially while using vanilla Max patches. But this is not always the case, so in order to do so successfully, there should be a lot of discussion first and a lot of expertise on hand before an upgrade is attempted.

This is especially true if the current version is years newer than the version employed at the time this document was created (Max/MSP 7.3.1).

Upgrades to the Dell PowerEdge machine (running Ubuntu Linux with the 4.4.0-78-generic kernel) are prudent for security reasons but, again, care must be taken when undertaking them. The software loadout on this machine is very minimal and very standard: MySQL 5.7.18 and Python 2.7. This version of Python will of course become deprecated soon in favor of Python 3. When that day comes the data acquisition scripts will likely have to be ported in order to keep the system maintainable.

In summation, the interlocking components are of such idiosyncrasy and complexity that no upgrades to any part of *The Wind Garden*'s technology stack should be made by a third party. Another way of saying this is that the long term health of *The Wind Garden* is contingent on my own long term health, or my apprenticing another technician into the project.

Finally, the web-based monitoring application sometimes loses connection to the *The Wind Garden*, meaning sensor status cannot be determined by the web app. There have been numerous possible reasons this status might be triggered, including a database failure, a problem or crash with the Wind Garden application, or a network error. When the monitoring web app reports an "Unknown" status, it provides some best-guess text in the wind condition and mute status boxes that may aid in troubleshooting. Remote monitoring is difficult because alerts need to be meaningful, and one of the main goals throughout the development of this work has been to eliminate false positives. Ten alert emails per day cease to be meaningful; an appropriate alert actually needs to show real problems. Although the system status may be unknown, it is possible that the installation may still be functioning normally (but this has not typically proven to be the case). There are two typical problems that trigger an "Unknown" error. These are:

- The Wind Garden application has locked up or crashed. The error text in this case will read: "application has crashed or is unresponsive."

- There is a problem relating to the database machine or the connection between the database and the Wind Garden application. The error text in this case will read: "data streams not found." Note that while this error may be due to an actual problem with the SQL database, a crashed or misused Python script running on the Linux server will also trigger this message

3.4.8 Site tuning

Site tuning starts by selecting one end of the boundary presets: either Stillness or Strong Winds. If actual weather conditions are not cooperating, a Wind Simulator has been added to the Utilities. The boundary presets describe the state of the entire system, including speaker and subwoofer gains. Prior to beginning the tuning process it is critical to disable the auto-interpolation function (by unchecking the box on the main Wind Garden interface) and manually load the desired boundary preset. This will ensure changes are made from a known state. If the above two steps are not performed *before* tuning is started and changes are then written to disk, there is a risk of accidentally overwriting important values elsewhere in the preset.

Once a boundary preset is selected, the data dashboard can be used to access each tree/speaker's post-processing stage to discover reasonable values for the given wind condition. Using the blue realtime plot as a reference, the RMS, floor, and scale values can be adjusted until the trees respond with reasonable output curves. Figure3.11 above shows what a graph might look like under "low" to "moderate" wind conditions.

After baselines have been established for the two extremes, the rest of the tuning process is an art that emerges from the tuner's understanding of the entire artwork. To achieve this understanding, all tuning efforts should make liberal use of the date/time interface on the main panel to dial in many different times of day, and many different days of the year. Noon and midnight on the summer and winter solstices are critical windows (tent post times), and these times should always be referenced. Further, the wind simulator and/or the Time Machine can be used to test settings against different wind conditions, which can be combined with different times of day and days of the year.

3.4.9 Recurring problems

Radio Interference:

At this time *The Wind Garden* sensor network is not the only radio network in the vicinity of its location. Part of the frequency band used by these devices overlaps with UCSD's 802.11 networks, and the La Jolla Playhouse has also been known to employ devices that use the same protocols and share the same portion of the radio spectrum. Unfortunately for all involved, the specifics of this protocol provide no method for device authentication, which means that if the same radio channels are used it is possible for one party or the other to inadvertently add and remove devices to their network, and possibly even stop data acquisition. This means that it is critical that there always be open communication and coordination between the Stuart Collection and the staff in the three Playhouse theaters with respect to how radio-capable devices are being used and configured. Every additional layer of administrative oversight only complicates the long-term health of the piece.[14]

Sensor Failure:

Because *The Wind Garden* accelerometers are wireless and thus run on batteries, and because each sensor has a radio that competes for space within an already crowded radio spectrum occupied by UCSD's own wireless network, sensor errors, dropouts and failures are a fact of life. Some sensors that are either physically far away from the basestation antenna, or which do not enjoy direct line-of-site are more likely to experience temporary dropouts. For example, the sensor for tree 50-1, which is at the extreme southern end of the Grove, often reports errors. However, because the installation was conceived as a unified harmonic whole, an early design decision was made not to let any instrument (tree/channel/speaker) go silent for very long, even in the event of a total sensor failure. To address this problem we originally implemented a robust automatic failover system (described earlier in this chapter) that is capable of making "smart" choices about when and how to failover, and then bringing the instrument back online later without the need for user intervention.

[14] See the discussion in Chapter 4 regarding administrative layers relative to *The Place Where You Go To Listen* for a more in-depth exploration of this point.

Within this system, when a sensor exceeded its transmission timeout and went offline (for any reason), the system held that sensor in a queue, and a timer was started to allow for the device to return to normal active status on its own. Once the failover timer expired after 1 hour, the system queries a file that maps each tree in the Grove to an optimal failsafe sister tree. The dead data stream was then disconnected, and the failsafe tree's data stream was duplicated and co-routed to the failed instrument. A 15-second delay was added to the new stream to avoid rhythmic unisons with the sister tree. Original mappings were restored automatically if and when the original failed sensor was repaired and brought back online. The tree-to-failsafe-tree mappings are stored in a JSON file called failover.json, and could be changed at any time to account for Adams' artistic choices, and/or the inevitable changes the Grove would undergo over time.

However, recent uncertainties about the long-term stability of the sensor network has made the auto-failover system seem off point. As of August 2017, the auto failover system remains in place, but has been disabled. Instead, a script was put in place that monitors the number of sensors showing an ERROR condition, and reboots the machine when a certain threshold is exceeded (currently 5 sensors). This process has tended to bring the full network back online without requiring failover. If the sensor network problems can be resolved in the future, the failover system could easily be reenabled.

In the case of a total sensor network failure or if there is damage to any of the Lord Microstrain components, immediate and drastic action would need to be taken to recover the system.

Loudness:

The Wind Garden is situated in an active public space, immediately adjacent to another performing arts center (La Jolla Playhouse). Although extensive measures have been taken to ensure that the loudness of the entire piece is optimized across a variety of weather conditions (see the "exotic" transition curve above), it nevertheless happens that the piece becomes too loud. Loudness complaints arise not just from the La Jolla Playhouse, but from the broader UCSD community. In order for these issues to be addressed in a long-term way, it is critical for complaints to be accompanied by notes about the specific time of day of the incident, the wind conditions at that time, and any other details that might help us understand the issue when we are unable to hear it for ourselves.[15]

3.4.10 The fragility, beauty, and ever-changing nature of this artwork, and the importance of understanding it as such in order to ensure its long-term preservation

Catastrophic incident 1: storm

Because the eucalyptus grove that hosts *The Wind Garden* is a living, growing, chaotic system, and because it is not possible to hand tune the installation for every possible weather scenario, it was important that *The Wind Garden* be able to respond and adapt gracefully to a full spectrum of foreseen and (in particular) unforeseen weather conditions.

[15]By now it should be clear that *The Wind Garden* is being managed remotely.

This reality was brought into sharp relief during the Winter of 2016 when the San Diego area was hit with a series of unusually powerful storms. The winds during those storms were much, much higher than any of us had anticipated. The winds were so strong, in fact, that a particularly important tree was toppled one night: a huge, seemingly indestructible, old-growth eucalyptus that dominated the northwest section of the Grove, lovingly named Tree 20/21 (using the old nomenclature). Figure 3.19 shows that this tree was home to no fewer than three speakers, two for the Apse and one for the Crossing.

Losing Tree 20/21 left the work with a lot of holes. First, we were left with a very noticeable aural hole in the installation; when standing in the Apse after the storms you could physically feel the sound pressure vacuum pulling at you like an open airlock. It was...uncomfortable, at least it was so for trained ears. We were also left with a significant musical/conceptual hole, as the tones in this particular tree link the Apse and the Crossing harmonically. Finally, we were left with an enormous visual hole, as this large tree and its broad canopy described nearly the entire northern boundary of the Apse.

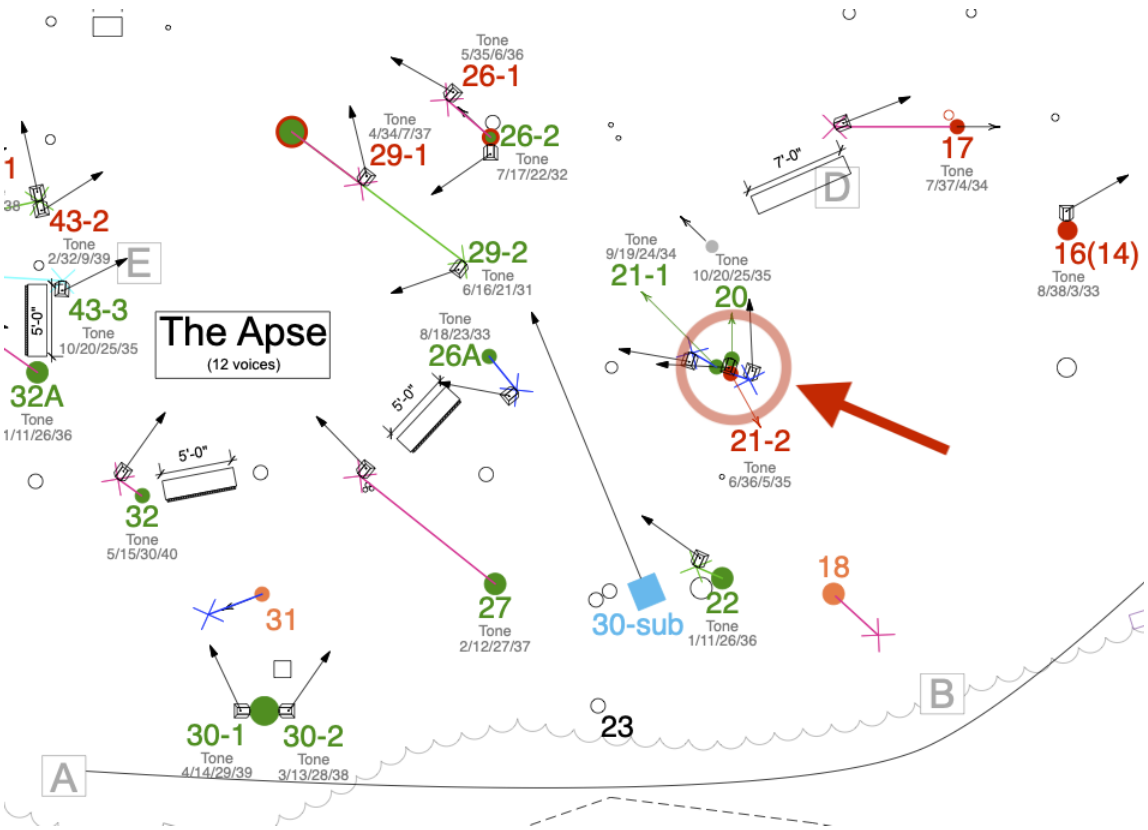

Figure 3.19. Fallen tree

The out-sized winds of this storm meant that our carefully tuned data streams were pushed way past specification. For its part, the installation responded exactly as it was programmed to do: it took those out-sized data streams and hammered the synthesis engine with them, and for a short while *The Wind Garden* howled like it was ushering in the end of the world. There were a number of noise complaints from the surrounding communities, and a quick decision was made to shut the installation down until I was able to physically return to San Diego to get things under control.

We have since repaired *The Wind Garden*, and although the visual hole will remain for many years, Adams and I did very good work in selecting sensible new homes for the fallen speakers, and in retuning and re-balancing the full installation prior to its opening in August 2017. We both agree *The Wind Garden* has never sounded better.

Catastrophic incident 2: crash

Around October of 2021, I started to receive messages from San Diego that *The Wind Garden* was behaving erratically. Both Mathieu Gregoire and Mary Bebe from the Stuart Collection contacted me to tell me that the sounds produced by the installation sometimes seemed out of sync with the time of day, and that occasionally there would be what sounded like "stuck notes" that would ring unchanged for hours. During the same period I received similar messages from other people at UCSD and in the surrounding community who felt a particular affinity for the piece and with whom I had become acquainted during *The Wind Garden*'s years of development. "Strange," I thought. As described above, my monitoring system is configured to restart the installation in the event of specific failure conditions, and while I had been receiving a higher number of restart notices than usual, I had attributed those to problems arising from delayed routine maintenance that year. It was clear there was a more significant problem.

When I logged in to *The Wind Garden* from my home in Philadelphia, I was immediately alarmed. The system logs were full of stack traces and cryptic OS-level error messages. I was seeing regular "beachball" and "pinwheel" events every few minutes that usually indicate blocked threads or worse, there were many seemingly random Java errors from the Wind Garden application itself, and, perhaps strangest of all, I was unable to access most (but not all!) sites on the Internet using the machine's web browser. The system and installation would start up successfully, but after that everything seemed broken.

Thus started one of the more memorable and bewildering troubleshooting experiences of my career. The problems were so deep, extensive, and seemingly random that had I been there in person, I probably would have opted for a "clean slate" approach, wiped the drive and restored from backup, which happens to be one of the few maintenance procedures I can only perform in person, on-site. Knowing what I know now, should I have chosen to take that path, the plane ticket, the rental car, the hotel, and all the time it would have taken to wipe, restore, and rebuild would have not solved the problem.

Rebuild

> ***IN ANY CASE, WITH ANY MACHINE, NO UPGRADES TO ANY PART OF THE WIND GARDEN'S TECHNOLOGY STACK SHOULD EVER BE MADE BY A THIRD PARTY***
>
> If an upgrade seems necessary for some reason please contact the UCSD Stuart Collection to coordinate with the designers/programmers. Meanwhile, here is a general rubric for software upgrades in case I fall into a crevasse:
>
> **Upgrading the Mac Pro (running OS X 10.11.6, JRE 1.6)**
>
> In short: **don't do it**
>
> It is likely that updating either the OS or the JRE will break parts of the installation, especially since there are a number of scripts running behind the scenes, and Apple's OS updates have

> a tendency to make significant changes to the way the system is organized internally.
>
> Upgrading Max/MSP to point releases should be no problem, and even larger upgrades are usually not problematic when done within one or two major release cycles, especially with using vanilla Max patches. But this is not always the case, and there should be a lot of discussion first and a lot of expertise on hand before an upgrade is attempted. This is especially true if the current version is years newer than the version at the time this document was created.[16]
>
> Jason Ponce, *The Wind Garden Technical Manual*

In the technical manual and preservation document I produced for *The Wind Garden* I include a section (cited above), written in bold text for maximum emphasis, that implores future engineers not ever to upgrade the operating system on the Mac that runs the installation. I say this because there are too many dependencies in *The Wind Garden* that I know from experience are extremely brittle with respect to the environment in which they run. This includes python and javascript libraries that are no longer being maintained and which will eventually not be accessible, a handful of 32-bit externals for Max/MSP that have been abandoned by their creators and which will not run on a 64-bit OS, and also the fact that while Cycling74 is currently still providing support for Java JVMs within Max, this support lessens year by year, and this too will eventually become discontinued. The final JVM detail is the most troubling with respect to the long term prospects of *The Wind Garden*, since while libraries and externals can conceivably be recreated from scratch by me

[16]Excerpted from *The Wind Garden Technical Manual* v1.2 (by Jason Ponce, Revised 2019, unpublished)

or another motivated engineer, *The Wind Garden* relies on Java components at the deepest levels, and without Java *The Wind Garden* cannot function.[17] As one of the very few people who understand how this installation works (or perhaps better, *should* work and sound), this fact is, of course, a source of considerable anxiety for me, and the exact reason I practically beg future maintainers not to upgrade. That said, I understand all too well that this is not a tenable scenario, nor a viable strategy for long term conservation—it is, clearly, another tidy microcosm of Cerf's "executable content" problem. But in the end *The Wind Garden* does not belong to me, and I must try.[18]

I took a few days to research and understand *The Wind Garden* situation. Slowly, the truth came into focus. The root cause of all these problems came not from a careless upgrade, or from an unpaid bill, or from an Amazon.com style ultra-expensive typo. Nor did it come from a design flaw in the codebase of the installation, or its specific deployment and implementation. The cause of *The Wind Garden* outage in 2021 was that a root security certificate from a popular Certificate Authority (CA) had expired, and was not being resigned by Apple. When root certificates from a CA expire and remain unsigned, any client that uses certificates will no longer trust that CA. In our case the certificate

[17] The deepest level in *The Wind Garden* would be time, which is of course essential to the entire work. Max/MSP has a curious relationship with time, and while it has a stable audio rate scheduler for the processing of digital signals, the OS threads that handle macro time in Max run at a lower priority, and are not suitable for work that requires high degrees of synchronization to, say, the external world. While it is possible to configure Max/MSP to promote the high priority scheduler to run inside the audio thread, this is not ideal for situations like realtime interaction, which can be computationally expensive. At this time the Java runtime hooks are the only method by which code running in a *patch* can extend the core Max application, and thereby get access to the operating system itself.

[18] Adams, after all, is not Paik. See 4.2.

in question was IdentTrust DST Root CA X3, a cert bundled deep within the Mac operating system which many components of the system made use of, including those that provide authentication services in networked environments like the Internet.

A full discussion of the multitude of ways this expired certificate impacted *The Wind Garden* is beyond the scope of this document, but the implications of the experience are very relevant. Due to the way that IdentTrust DST Root CA X3 was integrated into the OS a full backup and restore would not have solved the problem, and to date Apple has not provided any official path to either restore the cert or to resolve the issue using an alternative method.[19] In effect, even though the OS in question was the original version that was factory installed on this (very expensive) Mac, that version of Mac OS is now very suddenly, and without warning, entirely obsolete. The only remaining option is to upgrade, which in our case is far more than just an "upgrade" but a complex technical undertaking with an unknown number of side effects (see bold text in the quote above). I submitted a proposal to the Stuart Collection, a project was mounted, and at the time of this writing, *The Wind Garden* remains offline while I complete work on the redesign.

These incidences are guiding parables for all the people involved in the maintenance of this work going forward: *The Wind Garden* is not done changing, nor will it ever be. Sooner or later it is going to rise up and demand

[19]Manually updating root certs on a computer to other CAs is possible, though it is a highly technical process and well out of bounds for most users. It is also unclear what effect modifying root certs on a Mac will have on any preexisting warranty or support agreement with the manufacturer (Apple, in this case).

our attention again, and those of us who step in to do the work will need to understand not just what to do but how to do it. Even just the act of tuning *The Wind Garden* is to engage with the installation as a co-creator. It is therefore critically important that future stewards endeavor to understand the artwork deeply and holistically before changing any values anywhere in the system. And it is likewise very important for me to do all I can to communicate the nuance of Adams' musical ear to anyone who will tend the *Garden* after we are gone.

3.5 Physical Reality / Conceptual Liminality

I have suggested that this document is itself a step toward the conservation of the works in question. Publishing this thesis, even in as limited a fashion as offered by the University of California and escholarship.org, helps disseminate these ideas, moves them into other domains, makes them available to more readers. The goal of this chapter is not necessarily to enable the reader to perform maintenance on *The Wind Garden* (yet more documentation of specific bodies of code would be necessary for that), but to outline, in very real terms, the internal complexity involved in creating and maintaining such an elegantly streamlined project, and to suggest something of its vulnerability. I do believe that there is enough documentation herein that if an intrepid artist were so inclined in some distant future, they could with the aid of this document rebuild *The Wind Garden* from scratch using entirely new materials and languages. In that respect, the detailed description of how it functions, without all of the language-specific code that makes it work, is perhaps just as valuable.[20]

Aesthetically, *The Wind Garden* occupies a liminal territory between sculpture and site-specific art, while also being a music performance. It has a large number of fixed "sculptural" physical objects (accelerometers, directed speakers, conduit, specialized housings and attachments etc.), without which the piece does not exist. In Krauss' classical sense, it is sculptural and monumental; it marks a place as significant, even if the physical objects that make the piece are not themselves the "markers," the markers instead being the sound objects toward which the observer is directed. It is site-specific in that it necessarily exists in the location in which it was created, which is *physically* external to the structure of a "white-box" institution. And of course, it is, above all, music.

It is at this point that I move aggressively away from Ingebord, Goodman, and Adorno regarding the relationship of the score to the piece. The code is not the piece. The hardware is not the piece. The Grove is not the piece. The wind, which has a direct role in determining the actual sounds of the piece, is not the piece. Adams' score is definitely also not the piece (the score alone would not even suffice as a starting point toward reconstructing the piece). Perhaps because Adorno was writing in a primarily pre-digital era, in which the codification of the idea relied upon a set of physically recorded instructions, this piece and others like it defy previous notions of categorization. If we are to talk about the piece in any kind of abstracted sense, then we can only

[20]Vincent, *et al.* argue that keeping a copy of the original source code is vital to being able to rebuild a work from the ground up. [188] Were this document a museum-conservation-level documentation of that single piece, most or all of the code that drives *The Wind Garden* would be included. More on that below.

understand the piece as the nexus of its constituent elements. Yet as with many artworks whose significance extends beyond its original conception, it is useful to examine *The Wind Garden*'s "constituent elements" from two separate perspectives: the theoretical design elements of which it is comprised, and the elements of the piece as they function in-place, as a whole work of art, from the vantage of momentary experience. Figure 3.20 illustrates the first perspective.

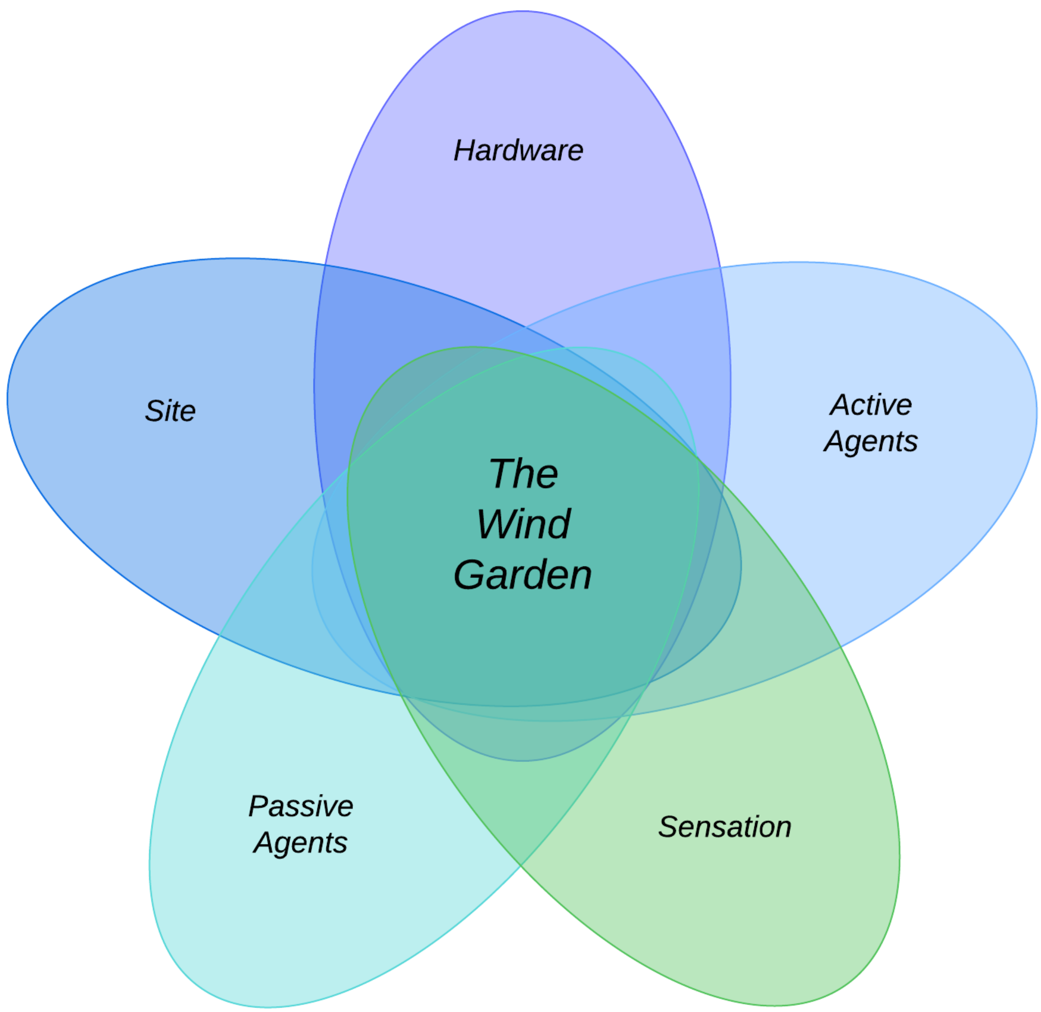

Figure 3.20. Design elements in *The Wind Garden*

Where:

- **Hardware**: Speakers, microphones, computers, sensors
- **Site**: specific physical location
- **Passive Agents**: weather, environment, time
- **Active Agents**: composer, engineer, visitors, audience
- **Sensation**: vision, sight, smell, touch, taste, memory

And Figure 3.21 below illustrates the elements of *The Wind Garden* from the point of view of someone visiting or even accidentally discovering the work in-place.

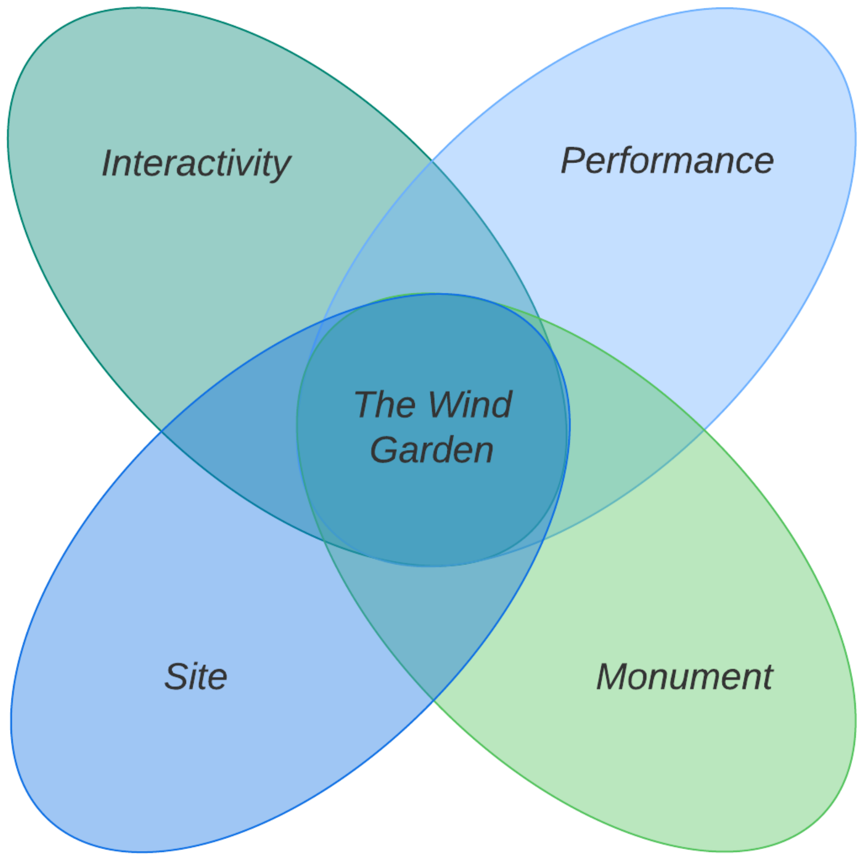

Figure 3.21. Experiential & conceptual elements in *The Wind Garden*

How necessarily tied to the Grove is *The Wind Garden*? Could *The Wind Garden* travel to another museum or be installed elsewhere like *Dream House*? Surely this would protect the physical components from degradation and would, for example, radically simplify changing batteries in accelerometers. One could imagine a scenario wherein another museum or gallery (or overzealous impresario) mounted the tuned speaker array with the same physical properties of the original (speaker model, mounting heights, focus angles, relative proximities) and link it to the same program that is running *The* (actual) *Wind*

Garden. This would create a sound field that is essentially identical to that of *The Wind Garden.* One could even imagine, in this football field-sized gallery installing tree-like objects in the exact locations as the eucalyptus trees in the Grove, so as to create similar patterns of acoustic shadowing as happens in the Grove. The technical realization in such a move would be more complicated than they would be in the *Dream House* relocation, but in terms of authenticity (or aura) of the work, it would exist on the same plane of curation. In these scenarios, the curator assumes the mantle of "Validator of Aura." If being removed from the vagaries of the New York real estate market increases the likelihood of survival for *Dream House*, then surely being removed, at the very least, from the vagaries of extreme weather events would similarly increase the likelihood of survival for *The Wind Garden.*[21] I am not advocating for such a move, but exactly such a move has been considered for *The Place Where You Go to Listen.*

[21] Or consider the situation of the Lascaux cave. The imperiled 17,000 year old original Lascaux cave is truly at the apex of the French idea of cultural *patrimoine*. In an attempt to preserve the original and protect it from various mold attacks while also "making accessible" this unique piece of cultural heritage, the Ministry of French Culture has gone to extraordinary lengths to "recreate" the original in the forms of Lascaux 2 (a recreation of the most highly decorated chambers), Lascaux 3 (a touring exhibit of several of the most interesting specific paintings) and Lascaux 4, a full scale replica of the original buried in the hill near the original, which will replace Lascaux 2 as the primary visitor attraction, constructed and painted from highly detailed 3D laser scans of the original and painted with stone-age techniques. [47] (Contemplate, for a moment, the confusion of archeologists 17,000 years from now, discovering twin caves above and below each other, decorated identically, but 17,000 years apart.) The series of replicas exist to satiate our social need to achieve some kind of personal communion with the painters of prehistoric times (and perhaps for the French Ministry of Culture to capitalize on that need), while keeping the actual object from being "hugged to death." This of course also calls into the questions of conservation versus access: what kind of cultural heritage is it if it actually cannot be experienced by anyone?

Chapter 4

The Place Where You Go to Listen & Something Pacific

4.1 *The Place Where You Go to Listen*

> They say that she heard things. At Naalagiagvik, "The Place Where You Go To Listen," she would sit alone in stillness. The wind across the tundra and the little waves lapping on the shore told her secrets. Birds passing overhead spoke to her in strange tongues.
>
> John Luther Adams, *The Place Where You Go To Listen*

I have a vivid memory of flying out of Alaska early one morning on my way to Oberlin, where I taught for a couple of fall semesters. It was a glorious early-fall day. Winter was coming in. I love winter, and I didn't want to go. As we crested the central peaks of the Alaska Range, I looked down at Mt. Hayes, and all at once I was overcome by the intense love that I have for this place—an almost erotic feeling about those mountains. Over the next fifteen minutes, I found myself furiously sketching, and when I came up for air I realized, There it is. I knew that I wanted to hear the unheard, that I wanted to somehow transpose the music that is just beyond the reach of our ears into audible vibrations. I knew that it had to be its own space. And I knew that it had to be real—that I couldn't fake this, that nothing

could be recorded. It had to have the ring of truth.
John Luther Adams, *The Place Where You Go To Listen*

The Place Where You Go to Listen (2004) is a sound and light installation at the Museum of the North in Fairbanks, AK. Adams describes it as "an ecosystem of sound and light." ([3] p.110)

> The architectural setting of *The Place* is a room situated just above the main entry of the Museum of the North...A small antechamber houses a display that introduces visitors to the work. The main chamber is approximately ten feet by twenty feet. The ceiling slopes gently from fifteen feet at the northwest corner of the room to thirteen feet at the southeast. Loudspeakers are hidden in the walls and ceiling all around the space. . . the room is empty of objects. ([3] p.22)

Adams wrote an expository book about *The Place* in 2009,[1] which contains an exhaustive presentation of the sound and light elements in the piece. Like *The Wind Garden*, the elements of *The Place* are organized around our significant cycles of time: noon and midnight, the solstices and equinoxes; like *The Wind Garden* these tent post moments in time are signaled by absolute values of sound and specific mixtures of colored light to and from which the elements at other times move. The piece also shifts with phases of the moon, fluctuations in activity within the magnetic field of the Earth (auroras), and seismic activity across the state of Alaska. "When a seismic event or an electromagnetic storm is under way, the room is filled with dynamic sounds. But more often than not, there's little drama and no fireworks." ([3] p.141) This data does not just

[1] *The Place Where You Go To Listen,* In Search of An Ecology of Music. Wesleyan University Press, 2009. This explanatory information will not be duplicated here.

guide the creation of sound, but the distribution of sound in the room is also mapped according to the location of the monitors transmitting the data. ([3] p.137) More on this below.

The Wind Garden and *The Place* are structurally similar: both harvest data in order to generate a realtime aesthetic response to the environment, and both are intended to run twenty-four hours a day for as long as the museums that hold them are committed to keeping them running. Two key differences between them is that *The Wind Garden* does not engage with light as a material, and while *The Wind Garden* is dynamically situated in an outdoor environment, creating a truly synaesthetic experience, *The Place* is a wholly mediated environment. Observers at *The Place* do not (hopefully) feel the seismic data that feeds it.

> The first day I was there, "The Place" was subdued, though it cast a hypnotic spell. Checking the Alaskan data stations on my laptop, I saw that geomagnetic activity was negligible. Some minor seismic activity in the region had set off the bass frequencies, but it was a rather opaque ripple of beats, suggestive of a dance party in an underground crypt. Clouds covered the sky, so the Day Choir was muted. After a few minutes, there was a noticeable change: the solar harmonies acquired extra radiance, with upper intervals oscillating in an almost melodic fashion. Certain that the sun had come out, I left "The Place," and looked out the windows of the lobby. The Alaska Range was glistening on the far side of the Tanana Valley.[2] [160]

---

[2]It is a thin veil that separates the sublime from the farce. Johann Maezel, of metronome patenting fame, toured Europe and the United States with a "Chess Playing Turk," a human-size "automaton" sitting at a chess board that could apparently beat anyone in a game of chess. The "automaton" turned out to be several smallish chess masters (at Maelzel's time, it was one William Schlumberger) operating mechanical levers within an elaborately constructed box below the chess board specifically designed and built to mislead onlookers. ([175] p.158) When Alex Ross came to *The Place* armed with tools sufficient to potentially

The Place is site specific, and yet it is not. "When I began *The Place*, I imagined that it could be realized anywhere on earth, tuned to any geographic location." ([3] p.142) Adams worked to have it located in Fairbanks because of his "abiding love for Alaska," and since its opening, we have worked to keep it installed in the museum and undergoing regular upgrades. His love of the location aside,[3] the fact that it is a fully mediated environment that does not cultivate the direct synaesthetic connections between environment and composed sound for the observer as occurs in *The Wind Garden* means that the room that contains *The Place* could in fact be anywhere, as Adams suggests. It is also not as monumental as *The Wind Garden*; the 10x20 room could be rebuilt in almost any museum with a large enough area in which to install it. Because it is inspired by and drawing on elements from the Alaskan landscape, it is surely appropriate that it remains in Alaska, but a different version of the piece could be built in another location drawing on the specific elements of that environment. I don't believe Adams would agree to *The Place* being moved from Alaska unless, as in the case of *Dream House*, it was met with an impossibly large existential threat. What would the meaning be of

"debunk" Adams' claims to musical-environmental interactivity, he was placing himself in the venerable journalistic lineage of Edgar Allan Poe who wrote the 1836 essay, "Maelzel's Chess Player," which similarly attempted to debunk Maelzel's implicit claims of the rise of a new post-human robot technocracy. Poe's conclusion that the apparently sublime machine was actually a farce was based on the observation that "The Automaton does not invariably win the game. Were the machine a pure machine this would not be the case—it would always win." ([146] p.323) Were an earthquake to register at one of the linked seismic monitor stations without it appearing in the sound of *The Place*, it would be tantamount to The Turk losing a match; evidence of farce in the place where we had been seeking the sublime.

[3] See Herzogenrath [77]

drawing attention to seismic and electromagnetic activity of Alaska while not in Alaska?[4] Despite this potential for modularity, the two types of catastrophic events cited in *The Wind Garden* (one imposed by the physical environment, and one imposed by technological failure) are just as relevant here.

4.1.1 Same problems, different decade

The Place offers an ideal object of comparison for *The Wind Garden* not only because I have been intimately involved in the design/redesign and maintenance of both works, but since both pieces are interactive, "environmental" compositions and make use of similar technology stacks. When assessing the current conservation efforts backing these works, the most profound difference between the two pieces is the fifteen years of general technical development that occurred between the creation and building of each. When issues arise (issues always arise) in *The Place*, they take considerably longer to resolve because of its age.

If our task here was to "solve," or at least improve, the problem of digital conservation from the perspective of a specific work's maintainability over time, the serendipitous setup of *The Place* and *The Wind Garden*, being so tightly adjacent in scope, purpose, and implementation, would afford us a rare opportunity to deepen our understanding of the issue via a simple

[4] This could become a discussion about the nature of art and meaning, and the function of activist art in society. Surely, however, were this piece to be built in southern Florida, it would be more meaningful to draw data from the Everglades, the local unique and highly-threatened environment, instead of from Alaska. However, the technical challenges involved in such an undertaking could be a mitigating factor that calls for continuing to draw data from sources that have already been coordinated.

examination of practical difference. Why is *The Wind Garden* so much easier to maintain? What were *The Place*'s early core design decisions, and how were those decisions made? If a different approach was taken for *Place* how would that have impacted maintenance of the work today? Given a new work today with a similar scope, would the same design decisions be made? If not, why not? Some of these questions can perhaps be answered, and some of these answers would now be meaningless. Others are lost to time. Ultimately, the specific answers may not be the point—technologically driven projects will always suffer from not being made 15 years later. The fact that design decisions, be they good or bad, will ripple outward for decades is built-in and guaranteed. Still, asking gives insight. And insight creates better engineering.

Since I took technical ownership of *The Place* years after its inception, I was not involved in the early design decisions for that project.[5] Although I have since redesigned most of the installation (See Figure 4.1, Figure 4.2, and Figure 4.3 for photos of the final result), there still remain inside it a number of dependencies that make any attempt at full modernization difficult, and it is mostly these dependencies that make maintenance of *The Place* difficult. The most problematic dependencies in *The Place* are:

- Reliance on third-party code
- Reliance on third-party data

[5] I would like to state here that nothing I have to say about the initial designs behind *The Place Where You Go to Listen* should be taken as criticism of the original engineer, Jem Altieri, or anyone else who has worked on the project. I have great respect for Jem's work, and I understand all too well how when working with rapidly changing technologies often a little bit of time allows one to make short work of problems that were once very hard.

- Reliance on relationships with third-party institutions

These dependencies are tightly intertwined, but I will discuss them individually.

Figure 4.1. *Place* post-overhaul: summer solstice noon

4.1.2 Dependencies

Code dependencies

Due to the scientific nature of the datastreams we sonify in *The Place*, specifically data from the UAF Geophysical Institute for auroras and the UAF Alaska Earthquake Information Center for seismic activity, we are in front of scientific software that we do not control. In the case of the five datastreams coming from the Geophysical Institute, that software exists at the Institute itself, and handles the connections to and transport of data from the actual data collecting instruments to the piece itself. This software layer is invisible to us; we only see the output streams and have no control over how it is shaped before it arrives. In the case of seismic data, due to licensing relationships

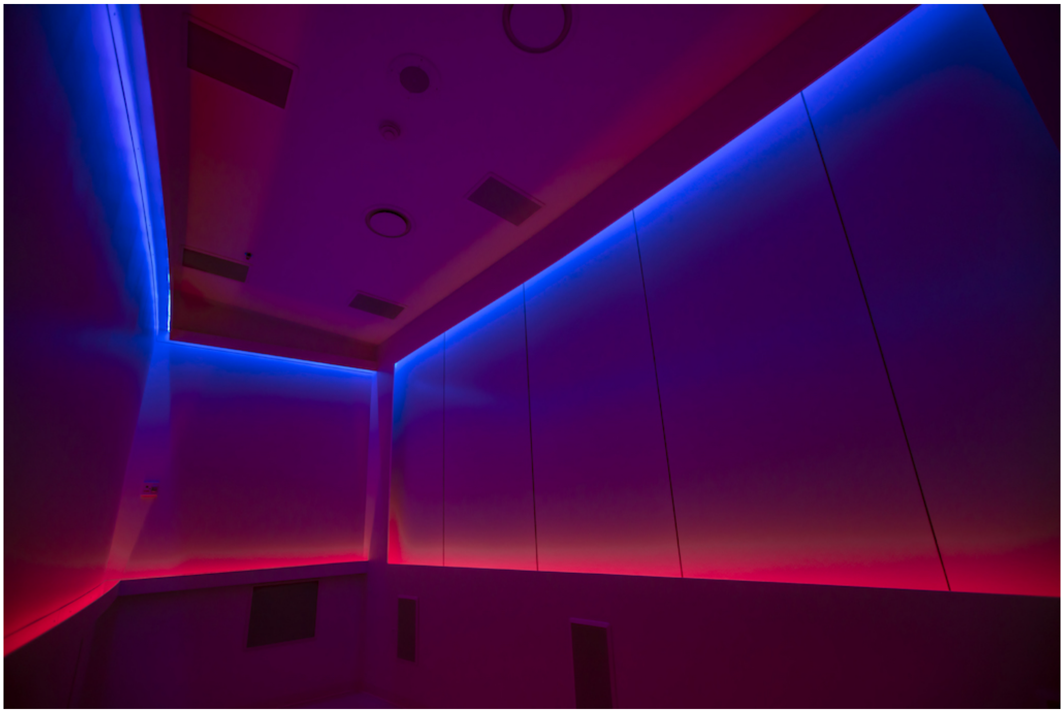

Figure 4.2. *Place* Post-overhaul: summer solstice midnight

between UAF and Boulder Realtime Technologies (BRTT), who produces the seismic monitoring software we use to extract data from the specific sites in which we are interested, we are required to install and run a large, complex client-side application on the same machines that process logic, audio, and light. Aside from creating additional CPU load to the system (mostly for functionality that we do not use), from a maintenance standpoint dependency on this commercial application is far from ideal, as the files used to validate licensing can and do expire, and we cannot control if and when that software is upgraded and old versions become deprecated. This single component has created a number of outages in *The Place*, and in some cases the installation has operated at partial capacity for periods of time without museum staff

Figure 4.3. *Place* Post-overhaul: equinox noon

realizing it. By contrast, in *The Wind Garden*, we own the data collecting hardware and there is no mediating software; the data travels directly from the accelerometers to the software that I designed and maintain.

Other dependencies are more routine but nevertheless problematic. The original design for *The Place* made liberal use of third-party externals, and when I began work on a second redesign and lighting expansion in 2019, I was stalled quickly when I discovered that one particular package of externals that *The Place* relied on heavily had not merely been abandoned by the original developer, but had been abandoned before a 64 bit version was ever released. This left me in the difficult situation of trying to reproduce the functionality of objects that do not run on modern hardware and for which no documentation exists. Emphasizing the point of Vincent *et al.* regarding the importance of preserving original code when considering the potential future of a work, when I was invited to update the work, there was no comprehensive technical documentation to which to turn. My primary options for understanding how the piece functioned were Adams' writings, conversations with Jem Aliteri, and via deciphering existing code. Some of this was comprehensible; some was not.

Data dependencies

As mentioned, *The Place* relies on external scientific data to generate sound for the "Earth Drums" (seismic activity) and "Sky Bells" (aurora borealis) voices. For both Drums and Bells five geographical data acquisition sites (each) throughout the state of Alaska were chosen to represent activity in that part of the state. This resulting audio in the gallery is spatialized in the soundscape in such a way that the cardinal directionality of the different geographic sites is preserved by the spatialized audio. For example, if a seismic site in the southern Kenai region of the state experiences an earthquake, the rendered sound of that quake will be heard emanating from a speaker in the southern wall of the gallery. The dependency here, therefore, is not any mediating software, but rather in the capacity of each of the ten research sites to continue obtaining data, and their willingness and ability to continue transmitting that data to us. When a specific magnetometer goes offline for any reason, neither I nor anybody else at UAF has any control over when, or indeed *if* it gets repaired. Given that these sites were selected by Adams specifically for their geographical locations, when a station goes offline it may not be possible to obtain data from another station in that region simply because no such station

Figure 4.4. The seismic stations transmitting data for *The Place*'s Earth Drums ([3] p.133)

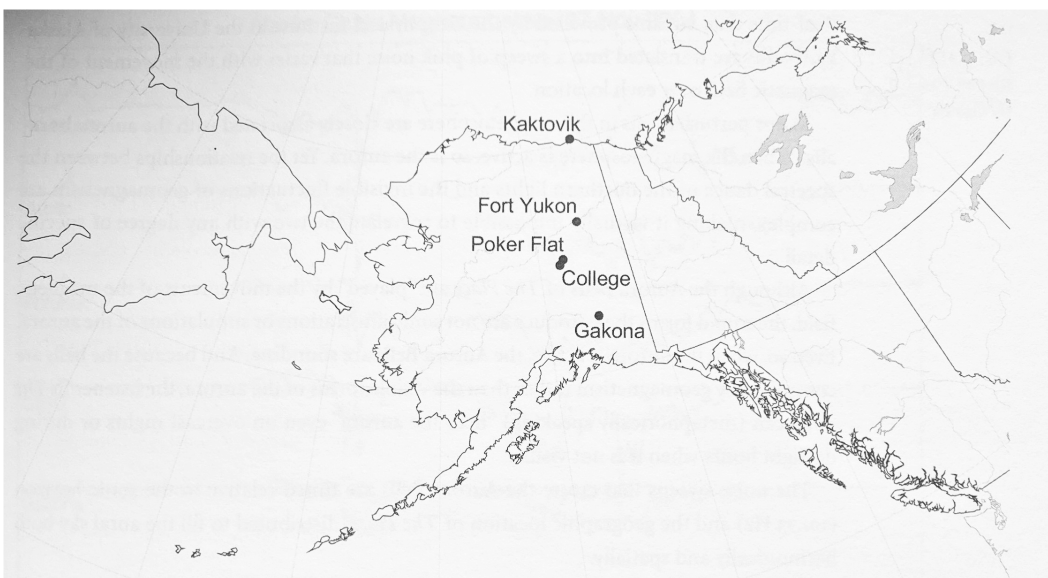

Figure 4.5. The magnetometer stations transmitting data for *The Place*'s Sky Bells ([3] p.127)

exists. Even if a nearby site or station does exist, it may not have the same relationship to UAF, and our access to that data simply may not be possible.

Personal dependencies

> Opportunities for scientists to facilitate art are rare, and we are honored to be part of something as important and essentially Alaskan as *The Place Where You Go to Listen*. For those of us who have helped to build and maintain the seismic stations, it is a special thrill to sit in that small room and hear the readings of instruments we installed interpreted as music.
>
> UAF Alaska Eathrquake Center

It should be obvious at this point that given the existing dependencies for both code and data, it is critical that strong working relationships with the corresponding institutions required to maintain the piece be preserved. There is a wide variety of agreements that exist between me, Adams, the Geophysical Institute, the Alaska Earthquake Information Center, the Museum of the North, the University of Alaska more broadly, and the National Science Foundation, which monitors the magnetometer stations (and which, relative to our interests, exists as a proxy for the US Geological Survey, which actually owns the stations). Some of these agreements are fully articulated and documented, and some are of mutual understanding, interest, and good will. Many of the resources these entities commit are entirely in-kind, as a result of some vague departmental notion of the potential for the interaction between science and art-making, or because of a more direct personal interest in supporting this work. Should any of those interests wane at any point, or should, for example, the relationship between the Geophysical Institute and the Museum of the North change for any reason, the Sky Bells voice would cease and the installation would have to be shut down until another source of geomagnetic data could be acquired.

Both the Geophysical Institute and the Museum of the North are under the aegis of the University of Alaska, Fairbanks, which is itself a component within the wider University of Alaska system. Like any large university system, the entities within it operate with varying degrees of research and fiscal autonomy, which is exercised by the people who both direct and administrate those entities.[6] In this respect, every single administrator who must agree to collaborate in this complex set of partnerships that allow for the "performing" of the piece *is an essential performer of The Place.* As the person in charge of maintaining these relationships, I cannot say at this time, if one of these relationships were to be severed, whether we would be able to source data from another organization, or even if any such organization exists and would be willing to commit resources to our project. Put simply, a single person at an organization that has no binding relationship with the Museum of the North is capable of shutting down *The Place Where You Go to Listen* indefinitely. Viewed in this way, it is necessary for many, many people to maintain some degree of *personal* responsibility, whether to the idea of the piece, to Adams, or to me in order for it to continue. Compare this scenario to *The Wind Garden*, which is supported technically and financially solely by the long term commitment of the Stuart Collection, an institution with an explicit mandate to support such works.

[6] I would conjecture that the quantity of readers of this paper with direct personal experience navigating the complex and often competing interests between administrative entities within a single university campus is 100%.

4.1.3 Another thought experiment regarding documentation, code, and preservation

Adams wrote the book about *The Place* in 2009, 5 years after the piece was completed. It offers a thorough, high level view of the piece as it existed before I was invited to upgrade and maintain it. It is beautiful documentation of the aesthetic goals and critical conceptual alignments of the piece (i.e. how celestial angles, and seismic monitoring sites map to chord structures, and *why* they do this). The photography of the room in the book gives a clear understanding of the first incarnation of the environment, and with a little supplemental documentation, it would be very easy to conceive of the upgrades that have been made since. For example, see Figure 4.6 for an overview of my plan for the recent expansion of the lighting system.

A century from now, if *The Place* has vanished and a curator wished to remount the piece having only the 2009 book as a reference, it could perhaps be possible, but would demand undertaking the arduous process of figuring out how, with contemporary tools, to compile and map these disparate data sources to sound and light (assuming data sources continued to be available to be mapped). *The Place* took three years to build; without the code that is running the piece, such a re-construction might take similarly long. If, on the other hand our hypothetical future curator had only the Max patches to refer to, and *if* they were able to open the Max patch, then it would be considerably easier to get to the end result of the piece. But as an example of a perhaps not-obvious problem lurking within this notion, consider the color simulator conundrum that we needed to work out during upgrade.

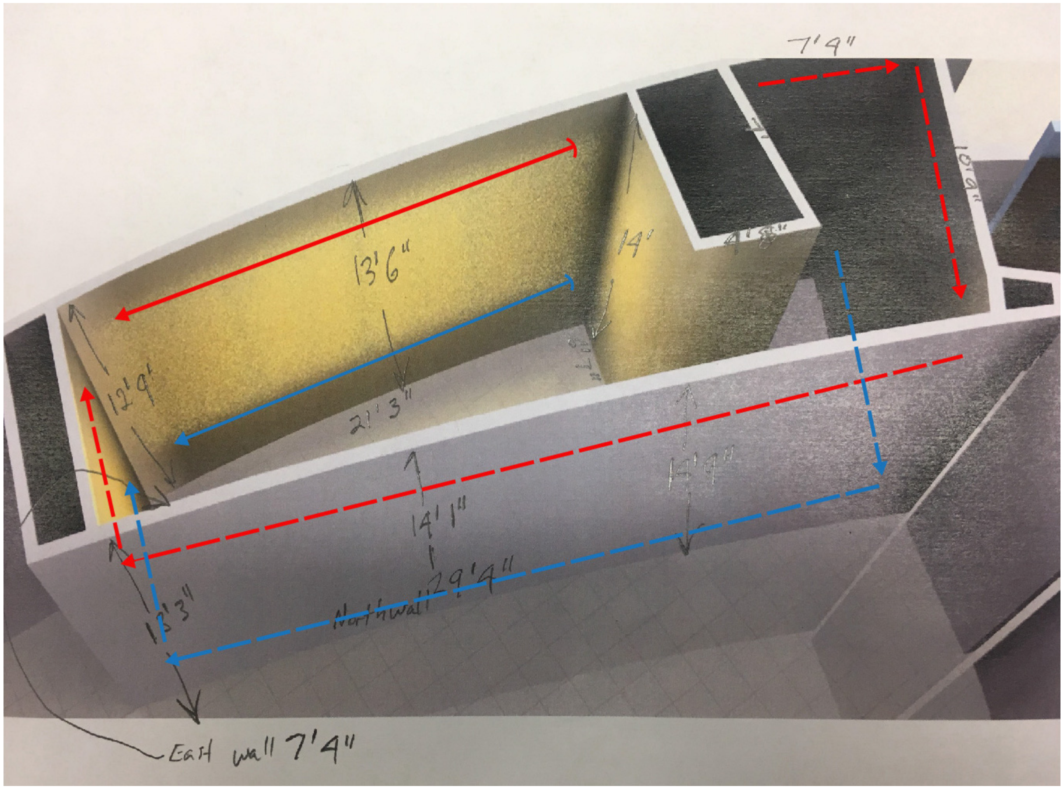

Figure 4.6. My early proposal for the *Place* lighting expansion (Jason Ponce)

Early in the expansion project Adams asked me to create a "light simulator" so that he could compose the lighting elements that would be introduced following an upgrade to LED lighting from the old CMY fiber optic system. The CMY system had advantages in that it provided a continuous color spectrum, but the LED's, despite being limited to 256 illumination values per channel, offer several other advantages, including cost, efficiency, and ability to be easily scaled around the room. Adams provided me the tentpost RGB values that he determined by observing color on his computer monitor in his home studio generated by the simulator I built for him. Below are two tables comparing the values he provided me based on his work with my simulator along with the the values I determined were necessary to use in the room after tuning the room by eye. These are two grouped RGB triplets per line, three values for Day (noon) color, three values for Night (midnight).

Table 4.1. JLA's original values derived using my custom "light simulator"

TP	R(day)	G(day)	B(day)	R(night)	G(night)	B(night)
1	255	0	255	255	0	255
2	255	0	0	125	0	255
3	255	80	0	0	0	255
4	255	145	0	50	85	255
5	255	200	0	25	170	255
6	255	255	0	0	255	255

Table 4.2. Final values used after tuning "by eye" inside the gallery

TP	R(day)	G(day)	B(day)	R(night)	G(night)	B(night)
1	200	0	85	200	0	85
2	255	0	0	6	0	21
3	255	17	0	0	0	255
4	255	54	0	42	5	255
5	255	98	0	28	148	255
6	255	136	0	0	255	255

The differences between these two tables are startling (and as I recall very unsettling to John at the time), and illustrate the difficulty and lack of portability in such design tools. In this case, taking John's ideal values (derived by using a computer display) and realizing those values inside a gallery not as a one-to-one representation of RGB numbers but as the *perceived* or *experienced* phenomenon of color in-place was far from straightforward. "Tuning the room by eye", then, meant running the simulator on my own laptop while physically inside the room of *The Place*, and attempting to match the color and brightness of my computer display to match the color and brightness of the LEDs in the room.

This example illustrates how a future remount of the physical installation using *only* the Max patch as a guide without other forms of documentation, would almost certainly end up looking or sounding different, or being differently physically structured even while maintaining the specific relationships between elements of the external environment and projected light and sound. If, during

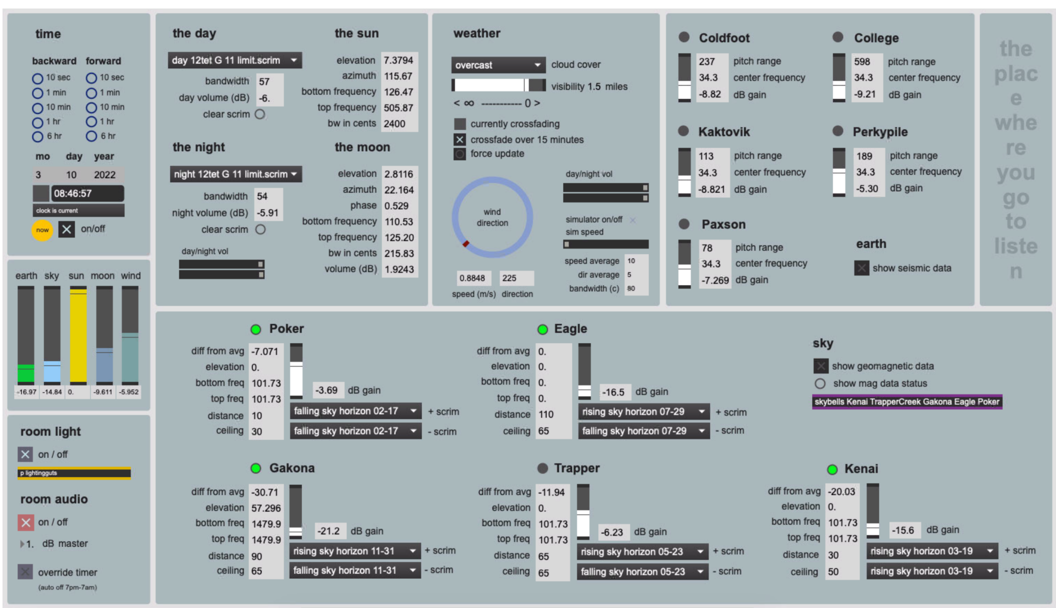

Figure 4.7. *Place* main user interface

this hypothetical future remount, the Max patch could not be opened due to software or platform obsolescence or for any other reason, and if we had only the file/textual representation of the patches to refer to, we would be in the worst possible scenario. Consider Figure 4.7, the main panel I built to quickly assess the functioning of the piece, and through which I mix the various media of the soundscape. If one was able to reconstitute a Max patch from the textual representation, it might with great effort be possible to derive the connections of the embedded objects, but it would not be possible to confirm the actual functionality of all the linkages, or the nature of externals needed to run the installation. In the case of *The Place Where You Go to Listen*, all of this functionality is simply and coherently represented and controlled via the main panel shown in Figure 4.7 above, yet this image would be of no use to a potential future conservator.

The more expansive an individual piece of digital art, the more comprehensive the documentation must be, particularly if the aim of the documentation is to be able to reconstitute the work with fidelity from scratch at a future time. At some point, the necessary documentation to potentially revive an older piece itself becomes as unruly as the piece, and starts to beg meta-questions about its own possibilities for preservation.

There must be another way.

4.2 A Way Forward: (Re)(en)coding an Evolving Art Object in Nam June Paik's *Something Pacific*

"It must have been great fun to be Paik."
Jim Lewis, "The Man Who Invented Video Art"

> Paik's *Something Pacific* for the Stuart Collection was his first permanent outdoor installation. This work relates specifically to its site, which includes the lobby of the university's Media Center as well as the lawns surrounding the building. Outdoors, the work features several ruined televisions embedded in the landscape; some are paired with Buddhas, and one, a tiny Sony Watchman, is topped by a miniature reproduction of Rodin's Thinker.
>
> In striking contrast to this video graveyard, the lobby of the Media Center houses Paik's lively interactive bank of TV monitors. Viewers are able to manipulate sequences of Paik's own tapes and broadcast TV. In accordance with Nam June Paik's wishes, this live video installation has been periodically renovated and updated with new technologies by current UCSD engineering students.
>
> Like much of Paik's art, *Something Pacific*'s outdoor and indoor sections use the video medium to contrast two very different experiences of time—one involving extended contemplation and the other instantaneous reaction. More importantly, the scattered ruins of televisions offer a cautionary tale for those entering the Media Center. Paik places televisions in the landscape in order to dramatize his belief that television has defined the American landscape since World War II. The outdoor TVs are all "dead" sets, skeletal remains that Paik has returned to nature, perhaps to be discovered in future archaeological digs. [38]

Technological progress often feels linear in retrospect: first there was the telegraph, then the telephone, then global wireless networks. In attempting to understand historic actions, we often want to apply a similar linearity to our understanding of things like artistic practices, but these are almost never linear. *Something Pacific* was created in 1986, and in its conception thwarts many of the problems that arose from Paik's *Untitled* (1993) (discussed above in Section 1.2.1), which was conceived almost a decade later. In technological terms, the seven years between the pieces is vast: three full cycles of Moore's

Law growth (back when that model still applied). Perhaps Paik himself did not fully grasp his own insightful thwarting of a problem inherent within his work, or perhaps after *Something Pacific* Paik decided to lean into Orlarey's "irreconcilable tension," a problem he had already previously sidestepped, rather than continuing to offer a convenient conceptual way out. Or perhaps, given *Something Pacific*'s positioning on a college campus, he understood it as a kind of artistic etude.

The initial incarnation of Nam June Paik's *Something Pacific* (1986) consisted of four principal categories of *objects*: a group of outdoor objects (statues and rotting televisions), a group of indoor objects, (a wall of television monitors accompanied by a synthesizer to manipulate them) a "cultural object," (originally, a feed from MTV in the early 1980s, and then a tape of an MTV broadcast, that plays on the monitors), and a subversive self-referential object (decaying versions of Paik's 1974 *TV Buddha*). The Stuart Collection description of the work above summarizes well the large-scale relationships of the various objects within the work. Between these four object categories is an interrelated layering of understanding and planes of time: obsolete technology, maintained technology, pop-culture reference, self reference.

TV Buddha is arguably Paik's most famous work; it consists of a commercially-purchased Buddha statue sitting in front of a television that is displaying an image of the Buddha captured by a closed circuit video camera. It has had several different incarnations over Paik's career. [49] The conceptual juxtapositions of *Something Pacific* are not bounded within one coherent physical object, so perhaps coming to a full understanding of the layers within

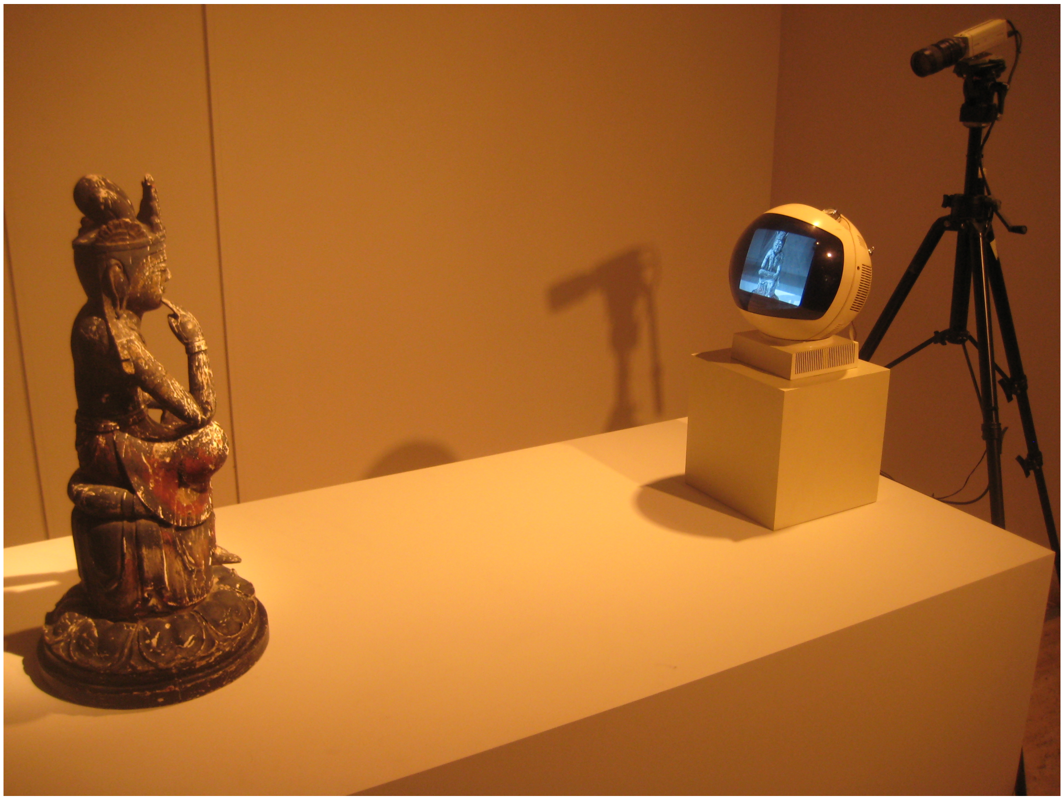

Figure 4.8. One of Paik's many *TV Buddha* sculptures. Image used under Creative Commons license.

Something Pacific requires something of a deeper understanding of *TV Buddha*. *TV Buddha* is a sculptural, time-based art, but it is not performatively time-based. *TV Buddha* is static in its execution of its performance, not unlike Young's *Dream House* or Cage's *Organ*^{2} on any day other than chord-change days. This is distinct from *The Wind Garden* or *The Place*, which are constantly changing and generating newness, and which I would qualify as both time-based and performative.[7] *TV Buddha* displays several recurring themes in

[7]As Adams pointed out, a pre-made recording would not fit the purpose. A long-looping recording would also be time-based, but not performative in the same way that I am proposing *TV Buddha* is time-based but not performative.

Paik's work: the recursiveness of closed-circuit televisions,[8] and the direct juxtaposition of binary ideas:

- meditation / consumption and media fixation
- ancient / modern
- stillness / motion
- narcissism / escape from self
- personal freedom / media tethering
- sculpture / performance
- singular authenticity / repeatability and reconstruction

How do we understand *TV Buddha* now? Does the fact that we (broadly speaking) are all watching ourselves living within a perpetual video loop change how we look at the comparative quaintness of the Buddha statue, the CRT monitor, and the analog video camera? Would a modern viewer, ensconced in a social media milieu of their own making see anything of themselves or their daily experience in the work, or connect this work as the ancestral forbear of the "influencer," able to project perfect calm while existing in a state of permanent, anxiety-inducing performance?[9]

[8]See also Paik's *Kaldor Candle* (1996)

[9]Unlike the rest of us trying to project calm while getting internet-famous, the Buddha is *actually* enlightened.

The most aesthetically striking object within the constellation of *Something Pacific* objects is the outdoor object, the collection of several *TV Buddha*-style sculptures, a self-referential collection of bronze and stone Buddha statues watching decomposing televisions. Because of their different material makeup, the watched televisions rust; the statues do not. The statutes appear to exist in a plane of non-time, ancient figures exempt from obsolescence, exempt from cultural irrelevance, suggesting to the viewer a path, perhaps, to their own forever-frozen immortality: just sit and watch as everything decays around you.

All pieces of art are conceptually frozen in the time of their making. Throughout this paper I have discussed issues of preservation and technological obsolescence. By including the self-referential object (*TV-Buddah*) in this work, Paik is giving a nod to the eventual decay of his entire oeuvre. It is not just the TV that decays, but the power of the image. In another generation, if viewers do not have the first hand experience of knowing Paik's earlier work, will the recursive self-reference mean anything to anyone except a few initiated art history aficionados? Someday (perhaps already today), *TV Buddha* will not appear provocative or challenging. It will appear naive and quaint, an artistic existential hand-wringing over the relatively finite period when TV held sway over our attention spans, not unlike the handwringing over questions of "liveness" mentioned above. Fortunately, it is not our job, in the case of *TV Buddha*, to solve the problem of ideological obsolescence via cultural quaint-ification. We can simply consider anew, every so often, what the artwork still means to us, if it still speaks to us, and understand it as an object of its historical moment.

The indoor objects of *Something Pacific*, the wall of TVs[10], expands upon the idea of the looped television of *TV Buddha* while dislocating it in space and inviting the viewer to reflect on their own image. If the observer understands the reference and makes the connection between the scattering of Buddhas in the lawn and the TV wall, perhaps they will then understand, while passing in front of the TV wall, that they themselves have taken the place of the *TV Buddha*.

Paik had an intuitive grasp of the "irreconcilable tension" and unruliness of technologically cutting edge art-making. Keeping the wall functioning was a concern from the beginning of the piece. "After twenty five years, the original Fairlight synthesizer quit. When we asked Nam June what to do when parts became obsolete, he said the students should carry it forward. So we engaged several engineering classes to reinvent digital versions of the interactive electronics." ([15] p.87) He also had a musician's sense of time scales: "I think I understand time better than the video artists who came from painting-sculpture. . . music is the manipulation of time. . . As painters understand abstract space, I understand abstract time." ([129] p.313) And of course, to understand cycles of time in a technological sense, is to understand cycles of obsolescence in technology. In stipulating that the indoor object be periodically updated, Paik is giving a clear path forward for the conservation of the work as a whole. The Stuart Collection need not concern themselves with maintaining twenty four 36-year-old televisions or an early generation

[10]Formerly TVs, and now an array of LCD panels with a live video camera embedded in the middle.

synthesizer. The updates that are called for are in spirit but not in form. There are potentially infinite updates that could be performed on the piece while conserving "the piece," its aura, and its authenticity.

Paik also understood this work also as something of a pedagogical exercise in concept as well as practicality. "I want these students to be able to influence these images as much as the images will influence them." And with regard to replacing degraded components: "...it should be made better. Every young kid expects more now from media. So they should go with the progress of industry." ([15] p.91) He was seeking to engage students in the process of art-making, and in the process of reimagining the very issues presented in the work.

And of course, because it is not just the physical objects of the TV screens themselves that demand updating, the perhaps more urgent question is regarding the final object of the piece: the cultural iconography of MTV as ubiquitous broadcast entertainment dominating the popular culture landscape of the moment. Like physical televisions left outdoors to rot, pop culture references also rot and become obsolete; they undergo a their own quaint-ification at the same speed by which their corresponding technological platforms accelerate into oblivion. I do not believe, however, that Paik's point is simply "everything decays." With any success, the juxtaposition of outdoor / indoor / self-referential / pop-cultural objects should compel us to think about the future of the technologies we now observe in the place of the TV wall, and the specific cultural object it projects, both of which should feel ubiquitous and all consuming *now*. More than that though, it should compel us to think about what drives these cycles of obsolescence (...capitalism / techno-feudalism...) and our our own complicity as we lock ourselves into these cycles. Maybe this set of juxtapositions is a little like the image displayed in Figure 4.9. There

Figure 4.9. Calvary Cemetery, Queens, New York, with the Manhattan Skyline in the background. Public Domain image from Wikimedia.

are several such iconic views of the Manhattan skyline from cemeteries in the the outer boroughs. Of course, the similarity of the two landscapes, and the implicit nod that the inhabitants of one will soon enough be the inhabitants of the other is what is immediately striking about these images: a skyline of the dead, and a skyline of the not-yet-dead. What the image does not immediately convey is the perpetual renewal necessary to keep the juxtaposition intact. The Manhattan skyline is no more a fixed object than is any of the interactive works discussed in this paper. Without massive buy-in from the inhabitants of the city, without a forever-booming speculative real estate market, the skyline itself would decay. With reference to *Something Pacific*, then, in the foreground is a metaphorical cluster of *TV Buddhas*, in the background, the largest TV wall in the United States of America.

Paik compared *Something Pacific* to the performance and subsequent interpretations of a symphony. ([15] p.91) I might compare it also to directing a play or an opera. I say this not only because of the potential for multi-media inherent in stage works compared to straight instrumental music, but also because the possible breadth of interpretation (and therefore the experience that is conveyed to an observer) is so much more broad. By comparison, instrumental music is constrained by the same ideas of devotion to the score and responsibility to an individual that I have discussed elsewhere in this paper. There is an understanding within stage works, at least in contemporary culture, that performative interpretation is critical, is desirable, and the breadth of possibility within that is nearly as boundless as the realm of technical possibilities offered in any particular venue. How wonderful to imagine a future where critics argue over the validity of a particular (momentary and finite) interpretive performance of *Something Pacific*.

•

Paik sets us free. The layering of conceptual objects in *Something Pacific* creates a unified totality of an art object that is able to weather both perpetual innovation and physical decay without any of the extreme lengths of documentation and preservation described in this paper. Embedded within this work, then, is a kind of formula for thinking about a time-proof artwork. On one level of speaking, *The Wind Garden*, *The Place Where You Go to Listen*, and *Something Pacific* are all finished works. For me, however, they are all very much works in progress. My name does not appear on these pieces by John Luther Adams, but in that they require my regular creative engagement, they are both ongoing works in progress. For me, the Adams pieces are "more complete"[11] compared to the Paik, a huge commissioned project that I am only now just beginning to undertake. That one artist's creative practice can be embedded or enveloped within another's is also fascinating. Given works that require several areas of expertise in order to create, such a collaborative model of creation makes sense in our time. As mentioned above, this has certainly been the working model at IRCAM and other multi-media art-making institutions. As such, I cannot point to the artistic results of my work on *Something Pacific* as a tangible incarnation of the ideas in this section, as I have not yet begun my collaboration with Nam June Paik (b.1932 - d.2006).

[11] Or, at any rate, they were complete before Apple refused to sign off on their completeness...

Chapter 5

Conclusion: ***Ars Oblivionalis***

> "For anyone who has to do with the past professionally, anxiety about oblivion is a nonsensical attitude. For the most part, this anxiety in any case reveals itself to be anxiety about being forgotten oneself."
>
> Siegfried Zielinski, "An (An-)Archive"

5.1 I

Edmond Cuchot points out that "when writing was invented, over five thousand years ago, it was not used to record the memorable events lived through by a community, but to improve the methods used by the great religious centers to administer their landed property." ([44] p.85) The ability to point to a clearly articulated patrilinear chain, to feel the gathering of historical momentum leading directly to the palace in which you now stand in the present moment was a distinction that separated one from the chaos of unlanded plebian breeding. Our modern knowledge of the doings of specific families in England 500 years ago is largely a result of those families working to make sure their children continued to own the same land they owned. The drop-off in our awareness of specifics of the rest of society is precipitously steep.[1]

> Even if we consider only the previous thousand years, then estimates indicate that around three to seven percent of our analog heritage has been preserved. Even if we take the higher estimate of seven percent, it is clear that massive selection has taken place, that an enormous amount has been forgotten. In ancient Egypt it was not buildings or landscapes that were conserved, but people. Naturally, not all people—and that is very instructive: "preservation" is invariably linked to an enormous pressure of Darwin-like selection. The aim is always to preserve a very special subject for posterity—a Pharaoh for example. ([191] p.183)

As it goes for people, so it goes for the objects those people kept around them:

> With respect to the sacred art of the late Middle Ages, which appears to be present in no small degree in European museums, reliable sources estimate that a mere two percent of the original body of work has survived. As soon as one turns one's attention towards objects that do not belong to ecclesiastic or court life, one rapidly enters fractional percentages. ([192] p.125)

The Catholic Lenten axiom, *Memento, homo, quia pulvis es, et in pulverem reverteris*[2] rings somewhat disingenuous in this context: perhaps *you* the churchgoer are destined to become dust, but *we* The Church plan to continue using a significant percentage of our available resources to secure our immortality upon this planet.

[1] An amazing exception is Iceland, the population of which, being small and isolated, had a rather urgent need to keep the available genes in the pool circulating as widely as possible. The *Islendingabok* database (see: https://www.islendingabok.is/) now boasts records for 95% of Icelandic people born since 1700. [197]

[2] "Remember, man, you are dust, and to dust you will return."

But with the democratization of advanced remembering tools has come the democratization of memory. Ancestry.com now advertises that it has over 13 billion ancestral profiles, or 1.6 ancestral profiles for every human now alive. [43] This urge to track everything may be born of our historical awareness that immortality via collective memory has always been impossible for most people but our astonishing feats of digital remembering have also spurred on a kind of "reverse porting" back into the analog realm. We now subject the objects around us to the same will to preserve that we have unleashed upon our digital photos, videos, and emails. The U.S. census bureau reported a growth in spending on the building of self-storage units from less than $50 million a month in 2013 to over $450 million a month in 2018 [75], creating over 50,000 self storage facilities around the United States, more than all of the Starbucks, McDonalds, Dunkin Donuts, Pizza Huts and Wendy's combined (see Figures 5.1 and 5.2). Put another way, there are now enough individual self storage units in the United States that every human in the country could have one as a walk-in closet. [10] Forbes projects that this spending will continue, and declares self-storage to be an excellent real estate investment, if you can manage to break into this particularly tight wing of the real estate market. [113]

The problem is obvious. For the same reasons that amassing piles of recorded music rendered individual recordings commercially worthless, the hoarding of every shred of *potential* future cultural heritage renders the entire collection meaningless.

Announcing that "the very urge to make recorded music is a

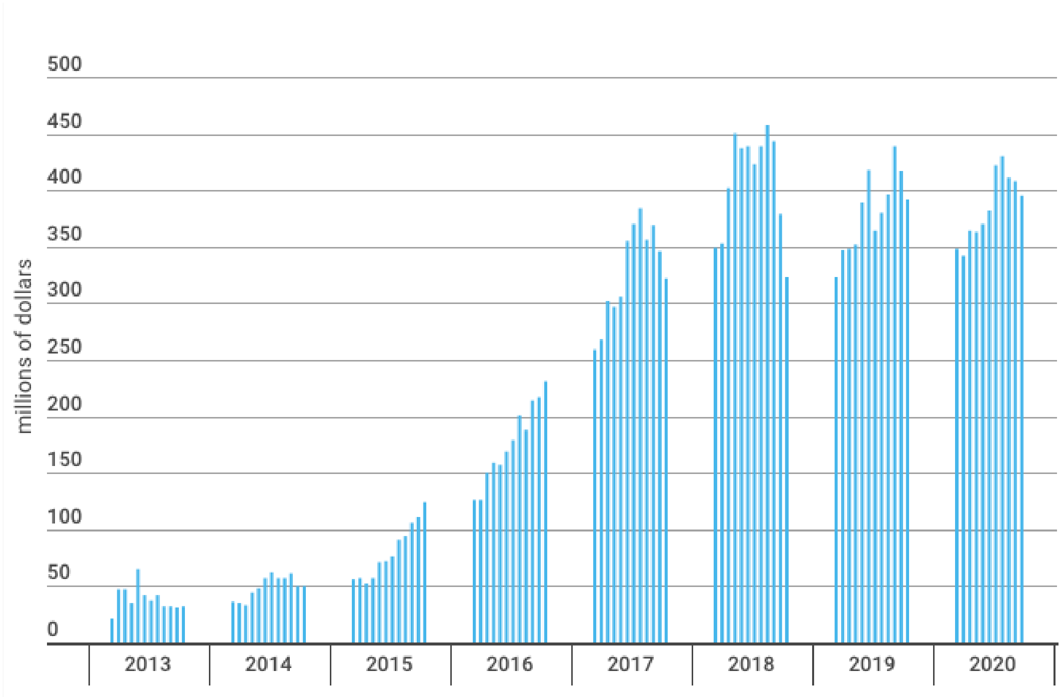

Figure 5.1. Annual spending on self storage construction in the United States, according to the U.S. Census Bureau. [75]

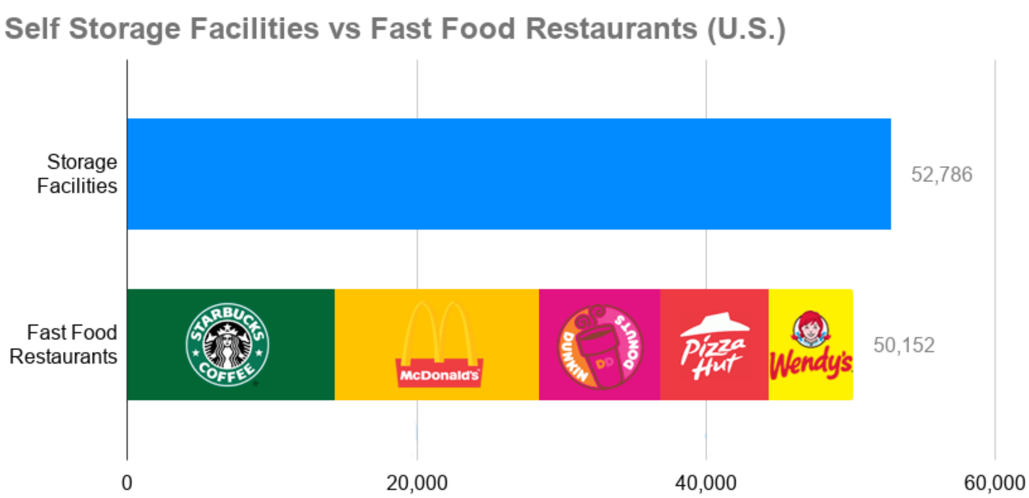

Figure 5.2. A comparison of total self storage facilities in the United States vs. total number of locations of several major fast food chains. [123]

> redundant and creative dead end," artist Bill Drummond polemically calls for the deletion of all recordings. He predicts that the sheer ubiquity of recordings will inspire forward-looking music-makers to explore different ways of creating music and that "the very making of recorded music will seem an entirely two-dimensional twentieth-century aspiration to the creative music-makers of the next few decades." "They will," he says, "want to make music that celebrates time, place, occasion." ([103] p.214)

The urge to make anew, to celebrate our own times and our own places is part of the human condition. Mix that urge with our newfound ability to hang on to every bit of detritus left behind from those celebrations and we find ourselves awash in a pseudo-cultural Great Pacific Garbage Patch of...objects. In the same way that we can't figure out what to do with our unreadable CD-Rs, our ability to store things is growing faster than our ability to understand what it means to keep so much stuff. In a speech to the United Nations titled "Against the loss of memory," Umberto Eco states:

> The history of civilizations is a sequence of abysses into which tons of knowledge went missing. The Greeks were already incapable of recovering the mathematical knowledge of the Egyptians; the Middle Ages lost Greek science, all of Plato (except for one dialogue) and half of Aristotle. Some of these losses were merely accidental (it was a pity to have lost, let us say, Mesopotamian mathematics, if there was such a thing), some were due to censorship, some parts of the lost wisdom was in some way rediscovered later, but in general the function of social and cultural memory is to act as a filter; it's not to preserve everything. [52]

The ICOM even now publishes guidelines on how museums should practice forgetting when faced with too many artworks to manage. [130] Klaus Weschenfelder believes this to be, in fact, a vital function of museums:

> Amnesia is a characteristic feature of the museum, as is the construction of memory. "Digital amnesia" is also to be situated in this context. The approach to ephemeral phenomena in contemporary art and the treatment of new art forms, which are time-dependent and at the same time placeless, demands revising the notion of the work in art, and examining the role of the museum as the location for a collection of works. ([192] p.136)

Future curators should be taught not just to create a linear heritage of objects received that inform a chain of newly made objects *ad infinitum* on into the foreseeable future, but also to forget vast swaths of the work they encounter. We must relearn to forget.

5.2 II

> Amongst the Greeks, Themistocles the Athenian is reported to have possessed an incredible compass of understanding and genius; and a certain person of learning and singular accomplishments is said to have gone to him, and offered to teach him the art of memory, an art then first made public. When he inquired what that art could do for him, the professor replied, that it would enable him to remember everything; when Themistocles rejoined, that he would oblige him much more if he could instruct him how to forget, rather than to remember, what he chose.
>
> Cicero, *De Oratore, Book 2*

At the beginning of this document, I speculated about a time wherein composition would be obsolete. I do not mean to say that human music making could ever somehow be "obsolete," but that the Western European practice of premeditating a specific sound world and rigorously writing down the instructions necessary to recreate precisely that sound world in a hyper-specialized semaphoric language, which then requires highly trained and specifically literate practitioners to read and realize will, I believe, become an obsolete cultural practice in the not distant future. In our current moment, universities, the location where such practices are most highly concentrated, are questioning the cultural hegemony implicit in teaching "standard" notational practices. [140] The rise of such organizational platforms as Score Follower[3] have themselves seemed to spawn a revitalization in thinking about the possibilities of graphic score representation.[4] A growing understanding of music as "sound" instead of "notes" has lead to an increased need to find alternative methods of ordaining sets of notational instructions. Coupled with the steady adjunctification of university labor [28] (which translates directly to the disappearance of stable sources of income for specialists in "standard" music notation), and the growing need for computer music specialists at enormous corporations (Spotify / Google / Meta / Amazon), we can reasonably postulate that we are living through a major shift in the locus of musical-cultural import. Again, this is

[3]Score Follower is a new-music organization that makes "videos of contemporary music scores that turn pages along with the accompanying recordings. You can find our videos on our two YouTube channels: SCORE FOLLOWER and INCIPITSIFY, as well as our TIKTOK account where we transcribe the noise of the internet. We curate, license, and produce all of our videos in house and receive permission from all involved parties. Find our complete collection at the Score Follower Library to filter through our public archive of works. We also help build the new music community through social media like YouTube, our Discord server, Facebook, Twitter, and Instagram. Our activities encourage exposure for new music composers, performers, publishers, and recording labels alike, through a meeting place on the internet that is accessible to all." They have over 15 thousand Youtube subscribers, run several annual calls for submissions, and as they grow in popularity as a vehicle for dissemination of notated music, are decidedly influencing a particular direction of its development. See: https://www.scorefollower.org/ for more information.

[4]To say nothing of how music making was forced into radical computerization during the 2020 - 202x pandemic.

not to say that Western musical practice is vanishing, but that the practice of using standard notation may be waning in its vitality.[5] Training in Western notational practices will undoubtedly continue for those who want to study and perform historic musics created at the height of that era, but for that strain of individual interested in unexplored possibility (horizons formerly occupied by "composers"), there is little to be gained by continuing to cultivate a hyper-specialized expertise in that language. In the future, we may look back at the "New Complexity School" as the apotheosis of this particular cultural practice.[6] And, as mentioned elsewhere throughout this paper, the imaginative sound diffusion promises made by the Philips Pavilion have never been realised on a mass scale outside of Hollywood movies. Whereas efforts in notational composition have created increasingly limited possibility for reception by sinking deeper into arcane practice, possibilities in computer music creation are limited for the same reasons they always have been: limited access to equipment.

[5]Centers of music making in Western Culture have tended to orbit like small moons around centers of power and wealth: case in point the Notre Dame School in Paris, St.Mark's Basilica in Venice, the Medici dynasty in Florence, the Esterhazy Palace outside Vienna, Pompideu's IRCAM, etc. For a time, it seemed like the American University was taking up this mantle, but that time seems to be on the wane, and with it, the priorities of the practice that thrived in that environment. The priorities of the next generation of musical exploration in the U.S. is being driven by the priorities of the aforementioned enormous corporations.

[6]Here could ensue a discussion of the bizarre implications of a cultural practice in which failure at the practice is encoded into the practice. For a more boots-on-the-ground discussion of this topic, see Martin Iddon's comparison of the Darmstadt Summer Festival with the Whitby Goth Weekend and the significant degrees of socio-economic overlap between them. Discussing the "professional" new music ensembles that specialize in performing complexly notated music and that make up the core group of performers at Darmstadt and other similar festivals, Iddon notes that "the funding which makes it possible for these ensembles to be professional rather than semi-professional is largely from the state or from charitable foundations with an interest in new music...Doubtless, such centralised funding is on the wane, as might ultimately be the continuing viability of such ensembles as genuinely professional entities. I do not even believe that this moment is all that far away." [83]

Despite our current efforts to the contrary, most of what we have created will be forgotten, lost either through personal negligence or corporate indifference. In analog times, this was a given. In the same way that the post-World War II decades were a historical blip of unprecedentedly high taxation and general prosperity in the West ([144] p.30), the "need" to collect everything that we've watched grow along with the sudden ubiquity of digital tools may also be a kind of bubble, a momentary fixation created by the novelty of newfound possibilities. Even now, digital messaging platforms and services are together the largest generator of communications data [134], and along with the meteoric rise of social media platforms specializing in ephemeral communications [165] there is a collective assertion that a not-insignificant user group would prefer to regard these communications the way we used to regard conversations, as fleeting, momentary. My earlier conjectures about the merit of the blockchain with regard to cultivating artistic aura are thrown into question if you consider the wild expense associated with a phenomenon like cryptocurrency mining. Such an activity is worse for society than the transition from subsistence farming to cash crop farming, in that literally nothing whatsoever comes from the massive energy expenditure required for the practice, except for a highly volatile and speculative form of wealth for the miners, individuals and corporations already endowed with enough capital to undertake the mining in the first place.[7]

•

[7] The New York times reports, "The process of creating Bitcoin to spend or trade consumes around 91 terawatt-hours of electricity annually, more than is used by Finland, a nation of about 5.5 million." [82]

Most of what I have created will be forgotten. My commissioned re-imagining of Nam June Paik's *Something Pacific* will exist for some time, perhaps a decade or two, and then, like LeWitt's wall drawings, will be painted over by the next generation, likely with technology that is unavailable to me now. I proceed with my work as in a ephemeral dance of creation and renewal. So it is with *The Wind Garden* and *The Place*. Imagine a scenario wherein historical data was used to recreate the sonic environment of *The Wind Garden*. This would be a very large data set. An entire year of data could be mapped to the following year, so that days and times of days, including daylight transitions, would be basically aligned. The resulting 8766 hours of sound could be looped indefinitely. The loop would be utterly imperceptible, unless an observer were to visit *The Wind Garden* at the same time on the same day, and had a remarkable ability to perceive the sameness at the distance of a year. Since the pitch spectrum of *The Wind Garden* is fixed, and it already runs in daily cycles, it might be difficult to perceive if it was actually the same or just in a state of its ongoing self similarity. Eliminating the need to refer to specific local wind conditions, and rendering the work as a recording would eliminate nearly all of the problems of maintaining the software and eventually porting it onto new hardware. It would be static in a way that *Dream House* is static. But surely a keen observer who understood the conceit of the piece (wind activity = sound) could discern whether or not this 8766 hour loop of sound was actually responding to the wind, or at least could perceive that there was no plausible relationship between the two. Perhaps on many days it would be "close enough." But there would undoubtedly be anomalies that betrayed the (lack of?) homunculus working inside the chess playing machine. As Adams pointed out, this was not the goal of the piece, "It had to have the ring of truth." The ringing of which he speaks is the sound of isomorphic translation of environmental phenomenon to *sound object*.

These works are etudes in the forgotten. The data that has been rendered in sound that is the experience of the piece is not saved. Most of what *it is* is forgotten. In the overall life of these pieces, they cannot be saved; attempting to do so would destroy them. Forgetting is built in. Forgetting must be built in. The music of these pieces is as transient as the experience of visiting the piece, or any piece, or any place. From the epigraph that opens this document, "how many more times will you remember a certain afternoon of your childhood, some afternoon that's so deeply a part of your being that you can't even conceive of your life without it?" And why would you attempt to recall more than a few that happen to be charged with some deep but momentary emotional import: a marriage proposal, the birth of a child, learning of a recent death. We think of static art as "static" in that it can be revisited, but our experience of a piece of static art is as locked in the moment of the experience as is our experience of time-based arts. Some of these experiences will stay with us, most will be lost forever.

"Ce n'est pas rien d'être grains de poussière en ce monde."[8] Our efforts to maintain these ideas, to see them into the future, to share them with others who may perhaps be similarly so delighted are not a misguided grasp at immortality;

[8]"It is not nothing, to be specks of dust in this world." (Tesson, *Dans Les Forêts de Sibérie* [181])

they are a manifestation of our realization that undertaking artistic endeavors has always been a glorious privilege, and they are a realization of our sense of artistic responsibility, a byproduct of our real—if forever fleeting—interactions, of our friendships, tiny ephemeral tokens of love for people who have inspired us and whom we hope to inspire.

Bibliography

[1] *Rights of certain authors to attribution and integrity, 17 U.S.C. § 106A*. https://www.law.cornell.edu/uscode/text/17/106A, 1990.

[2] Beth Accomando. “John Luther Adams’ ’The Wind Garden’ Challenges Expectations On What Art Is ”. *KPBS Midday Edition*, August 8 2017. https://www.kpbs.org/news/midday-edition/2017/08/08/john-luther-adams-wind-garden-challenges-expectati.

[3] John Luther Adams. *The Place Where You Go To Listen, In Search of an Ecology of Music*. Wesleyan University Press, Middletown, CT, 2009.

[4] Theodor W. Adorno. *Critical Models: Interventions and Catchwords*, chapter On Subject and Object. Columbia University Press, New York, 1998.

[5] Asma Afsaruddin. “The Great Library at Alexandria”. *The American Journal of Economics and Sociology*, 49(3):291–292, July 1990. https://www.jstor.org/stable/3487006. Accessed: 2022-4-1.

[6] Louis Aguilar. "As Detroit’s Population Keeps Falling, How Did We Get Here?". *Bridge Detroit*, August 24, 2021. https://www.bridgedetroit.com/as-detroits-population-keeps-falling-how-did-we-get-here/. Accessed: 2022-4-1.

[7] Radomir Mihajlovic Aleksandar Mihajlovic, Ivica Stankovic. “Digital Dark Ages as a Major Cyber Security Threat”. *International Journal of Economics and Law*, 5(13), 2015.

[8] Project Antony. Projet Antony. https://musinf.univ-st-etienne.fr/recherches/antony/context.html, 2021. Accessed: 2022-18-01.

[9] Artforum. “Mela Foundation Launches Campaign to Save La Monte Young’s New York Dream House”. https://www.artforum.com/news/mela-foundation-launches-campaign-to-save-la-monte-young-s-\new-york-dream-house-83568. Accessed: 2022-4-2.

[10] Self Storage Association. “Industry Fact Sheet”. http://www.selfstorage.org/ssa/content/navigationmenu/aboutssa/factsheet/. Accessed: 2022-4-1.

[11] Jacques Attali. *Noise: The Political Economy of Music.* Univ Of Minnesota Press, Minneapolis, MN, 1985.

[12] Philip Auslander. *Liveness: Performance in a mediatized culture, 2nd ed.* Routledge, London & New York, 2008.

[13] Backblaze. “Backblaze Hard Drive Failure Rates for 2021”. https://www.backblaze.com/blog/backblaze-drive-stats-for-2021/. Accessed: 2022-3-3.

[14] Jeff Barr. “AWS News Blog: Amazon S3 Reduced Redundancy Storage (RRS)”. https://aws.amazon.com/blogs/aws/new-amazon-s3-reduced-redundancy-storage-rrs/, May 18, 2010. Accessed: 2022-4-1.

[15] Mary Livingstone Beebe. *Landmarks, Sculpture Commissions for The Stuart Collection at the University of California, San Diego - The Art of Paying Attention.* Rizzoli International Publications, New York, NY, 2020.

[16] Walter Benjamin. *Illuminations*, chapter The Work of Art in the Age of Mechanical Reproduction, pages 253–265. Schoken Books, New York, 1968.

[17] John Bergsagel. “Cordier’s Circular Canon”. *The Musical Times*, 113(1558):1175–1177, 1972.

[18] Florent Berthaut, Mark Marshall, Sriram Subramanian, and Martin Hachet. “Rouages: Revealing the Mechanisms of Digital Musical Instruments to the Audience”. page 6, 05 2013.

[19] Michael Betancourt. *The Critique of Digital Capitalism.* Punctum Books, Goleta, California, 2015.

[20] Janet Blake. “On Defining the Cultural Heritage”. *The International and Comparative Law Quarterly*, 49(1):61–85, 2000.

[21] Bloomberg. “U.S. official: Napster should be liquidated”. *Ventura County Star*, Sep 09 2002. https://www.proquest.com/newspapers/u-s-official-napster-should-be-liquidated/docview/2599604851/se-2?accountid=12536. Accessed 2022-4-30.

[22] Kurt D. Bollacker. “Computing Science: Avoiding a Digital Dark Age”. *American Scientist*, 98(2):106–110, 2010.

[23] Kurt D. Bollacker. “The Boundaries of Preservation and Conservation Research”. *Libraries & the Cultural Record*, 46(2):220–229, 2011.

[24] Georgina Born. *Rationalizing Culture, IRCAM, Boulez, and the Instatutionalization of the Avant-Garde*. University of California Press, Berkeley, CA, 1995.

[25] Paul Bowles. *The Sheltering Sky*. The Ecco Press / HarperCollins, New York, NY, 2000.

[26] Stewart Brand. *The Clock Of The Long Now: Time And Responsibility*. Basic Books, New York, NY, 1999.

[27] Raisa Bruner. “What’s a Jellicle, Anyway? Everything You Need to Know About Cats Before You See the Movie”. https://time.com/5628824/cats-movie-musical-explained/. Accessed: 2022-4-2.

[28] Kevin Carey. “The Bleak Job Landscape of Adjunctopia for Ph.D.s”. *The New York Times*, March 5, 2020. https://www.nytimes.com/2020/03/05/upshot/academic-job-crisis-phd.html. Accessed: 2022-4-1.

[29] Jen Carlson. "The Demolition Of The Old Penn Station". https://gothamist.com/arts-entertainment/videos-the-demolition-of-the-old-penn-station, July 31, 2012. Accessed: 2022-4-1.

[30] Damian Carrington. “Newly Waterproofed Arctic Seed Vault Hits 1m Samples”. *The Guardian*, Feb 24, 2020. https://www.theguardian.com/environment/2020/feb/25/newly-waterproofed-arctic-seed-vault-1m-samples-climate-change. Accessed 2022-04-01.

[31] L. Ceci. “Worldwide gross app revenue of the Apple App Store from 2017 to 2021”. https://www.statista.com/statistics/296226/annual-apple-app-store-revenue/. Accessed: 2022-4-2.

[32] Storm King Art Center. "Storm King Wavefield Conservation". https://stormking.org/wavefield/. Accessed: 2022-4-1.

[33] Vint Cerf. “Digital Vellum and Archives”. https://nitrd.gov/nitrdgroups/images/4/48/DigitalVellumAndArchives.pdf, August 2016. Accessed: 2022-4-1.

[34] Michel Chion. *Audio-Vision. Sounds on Screen.* Columbia University Press, New York, NY, 1994.

[35] John Chowning. “Method of Synthesizing a Musical Sound”, U.S. Patent 4018121, April. 1977.

[36] Michele V. Cloonan. *Women, Art, and Technology, ed. Judy Malloy*, chapter The Boundaries of Preservation and Conservation Research. MIT Press, Cambridge, MA, 2003.

[37] Marisa Leavitt Cohn. *Media Infrastructures and the Politics of Digital Time*, chapter Unruly Bodies of Code in Time, pages 191–204. Amsterdam University Press, Amsterdam, The Netherlands, 2021.

[38] Stuart Collection. “Nam June Paik Something Pacific (1986)”. https://stuartcollection.ucsd.edu/artist/paik.html. Accessed: 2022-4-1.

[39] Paul Conway. “Preservation in the Age of Google: Digitization, Digital Preservation, and Dilemmas”. *Libraries & the Cultural Record*, 80(1):61–79, 2012.

[40] Paul Conway. “Preventing Digital Casualties: An Interdisciplinary Research for Preserving Digital Art”. *Leonardo*, 45(5):472–473, 2012.

[41] Baude Cordier. *Manuscript Chantilly*, volume 564, fol.12, chapter Tout par compas. Musée Condé, 1350-1400.

[42] Baude Cordier. Tout par compas, 2018. https://www.academia.edu/35696265/Baude_Cordier_Circle_Canon_Tout_par_compas_suy_composes_three_realizations_with_text_translations_Source_late_14th_century_Manuscript_Chantilly_Mus%C3%A9e_Cond%C3%A9_564_fol_12_. Accessed 2022-4-2.

[43] Ancestry Corporate. “Company Facts”. https://www.ancestry.com/corporate/about-ancestry/company-facts. Accessed: 2022-4-1.

[44] Edmund Couchot. *Digital Art Conservation*, chapter Historical Time and Uchronic Time: A Different Way of Conceiving of Memory and Forgetting, pages 85–90. Ambra | V, Vienna, Austria, 2013.

[45] Rodrigo Carrizo Couto. “A magic sound across the centuries”. https://www.swissinfo.ch/eng/a-magic-sound-across-the-centuries/7897614. Accessed: 2022-4-2.

[46] Peter Crimmins. “The History of Electronic Music is Inside a Warehouse in Harleysville, Pa.”. *WHYY.org*, August 18, 2021. https://whyy.org/articles/the-history-of-electronic-music-is-inside-a-warehouse-in-harleysville-pa/. Accessed 2022-04-01.

[47] France Ministère de la Culture. "Lascaux”. https://archeologie.culture.fr/lascaux/en. Accessed: 2022-4-2.

[48] Gilles Deleuze and Félix Guattari. *A Thousand Plateaus: Capitalism and Schizophrenia*. Bloomsbury Publishing, London, 1988.

[49] Public Delivery. “Nam June Paik’s TV Buddhas – His best-known work”. https://publicdelivery.org/nam-june-paik-tv-buddha/, October 9, 2021. Accessed: 2022-4-1.

[50] Cahteau des Briottières. “Apocalypse Tapestry”. https://www.briottieres.com/en/activities/apocalypse-tapestry/. Accessed: 2022-4-17.

[51] Cenre des Mouments Nationaux. “History of the Monument”. http://www.chateau-angers.fr/en/Explore/History-of-the-monument. Accessed: 2022-4-2.

[52] Umberto Eco. “Against the Loss of Memory”. https://www.whileiremember.it/against-the-loss-of-memory-umberto-eco/, 2021. Accessed: 2022-18-01.

[53] Electronic Music Education and Preservation Project. “About EMEAPP”. https://emeapp.org/https://emeapp.org/. Accessed: 2022-4-1.

[54] Elephant. “OOO! The Return to Objects”. https://elephant.art/return-of-objects/. Accessed: 2022-4-2.

[55] Robin Engelman. “John Cage Goes As Slow As Possible in Halberstadt, Germany”. https://robinengelman.com/tag/halberstadt/. Accessed: 2022-2-12.

[56] Brian F. Fitzgerald. “Software as Discourse: The Power of Intellectual Property in Digital Architecture”. *Cardozo Arts and Entertainment Law Journal*, 18(2):337, 2000.

[57] National Endowment for the Arts. “National Endowment for the Arts Appropriations History”. https://www.arts.gov/about/appropriations-history. Accessed: 2022-4-17.

[58] Dia Art Foundation. “Dia Art Foundation Acquires Dream House by La Monte Young, Marian Zazeela, and Jung Hee Choi”. https://www.diaart.org/about/press/dia-art-foundation-acquires-dream-house-by-la-monte-young\-marian-zazeela-and-jung-hee-choi/type/text. Accessed: 2022-4-2.

[59] Long Now Foundation. “The Clock of the Long Now”. https://longnow.org/clock/. Accessed: 2022-4-17.

[60] Mela Foundation. “Dream House Sound and Light Environment”. https://www.melafoundation.org/. Accessed: 2022-4-2.

[61] Israel Gat. “Special Issues on Technical Debt”. *Cutter IT Journal*, 23(10), 2010.

[62] Pallab Ghosh. “Google’s Vint Cerf Warns of ‘Digital Dark Age”’. *BBC News*, Feb. 13, 2015. https://www.bbc.com/news/science-environment-31450389. Accessed: 2022-4-1.

[63] James J. Gibson. *The Ecological Approach to Visual Perception.* Houghton Mifflin, Boston, 1979.

[64] Galindo Girón and Gómez-Gómez. “Assessment of the subjective perception of reverberation in Spanish cathedrals”. *Building and Environment*, 171, 2020.

[65] Johannes Goebel. “The Computer as Universal Time Machine”. https://empac.rpi.edu/sites/default/files/research-documents/JohannesGoebel_UniversalTimeMachine_Timecapsules_2021.pdf, 2021. Accessed: 2022-04-03.

[66] Peter Golding. “World Wide Wedge: Division and Contradiction in the Global Information Infrastructure”. *Monthly Review*, 48(3):70–85, 1996.

[67] Kenneth Goldsmith. “About UbuWeb”. https://ubuweb.com/resources/about.html. Accessed: 2022-4-1.

[68] Kenneth Goldsmith. “UbuWeb Resources”. https://ubuweb.com/resources/. Accessed: 2022-4-1.

[69] Nelson Goodman. *Languages of Art: An Approach to a Theory of Symbols*, pages 128, 178, 221. Hackett Publishing Company, Inc, Indianapolis, IN, 1968.

[70] Lester Graham. "Detroit’s Last Spike in White Flight". *Michigan Radio*, December 14, 2017. https://www.michiganradio.org/politics-government/2017-12-14/detroits-last-spike-in-white-flight. Accessed: 2022-4-1.

[71] Elizabeth Grenier. “The John Cage work Performed Over 639 Years”. https://www.dw.com/en/the-john-cage-work-performed-over-639-years/a-54804501. Accessed: 2022-2-1.

[72] Nebraska Acoustics Group. "Reverberation”. https://www.concerthalls.org/?page_id=84. Accessed: 2022-4-1.

[73] Constellation Guide. “Lyra Constellation”. https://www.constellation-guide.com/constellation-list/lyra-constellation/. Accessed: 2022-4-1.

[74] Sterling Hall. “Resonating Ontologies: The Illusory Nature of the Confrontation Between Žižek’s Ontology and Speculative Realism”. *International Journal of Undergraduate Research and Creative Activities*, 4(2), June 7, 2012.

[75] Alexander Harris. “U.S. Self-Storage Industry Statistics”. https://www.sparefoot.com/self-storage/news/1432-self-storage-industry-statistics/, January 27, 2021. Accessed: 2022-4-1.

[76] Rebecca Hersher. “Amazon And The $150 Million Typo”. *NPR, The Two Way*, March 3, 2017. https://www.npr.org/sections/thetwo-way/2017/03/03/518322734/amazon-and-the-150-million-typo. Accessed: 2022-4-1.

[77] Bernd Herzogenrath. *The Farthest Place: The Music of John Luther Adams*. Northeastern University Press, Boston, Massachusetts, 2012.

[78] Catherine Hickley. “A 639-Year Concert, With No Intermission for Coronavirus”. *The New York Times*, September 7, 2020. https://www.nytimes.com/2020/09/07/arts/music/john-cage-as-slow-as-possible-germany.html. Accessed: 2022-4-1.

[79] Lee A. Hollaar. “IV.E.7.e. Code as Speech”. http://digital-law-online.info/lpdi1.0/treatise50.html. Accessed: 2022-3-11.

[80] Joel Hopkins. “Worlds Greatest Game Room”. https://youtu.be/Ox7En_cYAa8. Accessed: 2022-4-1.

[81] Moretti Howard. *Sound and Space in Renaissance Venice: Architecture, Music, Acoustics*. Yale University Press, New Haven, CT, 2010.

[82] Jon Huang, Claire O’Neill, and Hiroko Tabuchi. “Bitcoin Uses More Electricity Than Many Countries. How Is That Possible?”. https://www.nytimes.com/interactive/2021/09/03/climate/bitcoin-carbon-footprint-electricity.html. Accessed: 2022-5-01.

[83] Martin Iddon. “What Becomes of the Avant-Guarded? New Music as Subculture”. *Circuit*, 24(3):51–68, 2014.

[84] Don Ihde. *Technology and the Lifeworld: From Garden to Earth*. Indiana University Press, Bloomington, IN, 1990.

[85] Roman Ingarden. *The Work of Music and the Problem of Its Identity*, chapter The Musical Work and its Score. Palgrave Macmillan, London, 1986.

[86] Perla Innocenti. “Preventing Digital Casualties: An Interdisciplinary Research for Preserving Digital Art”. *Leonardo - Journal of the International Society for the Arts, Sciences and Technology*, 45(5):472–473, 2012.

[87] Canadian Conservation Institute. “Longevity of Recordable CDs, DVDs and Blu-rays”. January 7 2020. https://www.canada.ca/en/conservation-institute/services/conservation-preservation-publications/canadian-conservation-institute-notes/longevity-recordable-cds-dvds.html. Accessed: 2022-5-01.

[88] Stuart Jeffrey. “A New Digital Dark Age? Collaborative Web Tools, Social Media and Long-term Preservation”. *World Archaeology*, 44(4):553–570, 2012.

[89] John Cage Orgel Stiftung Halberstadt. “Die Klangwechsel im ersten Teil, bis 2071”. https://aslsp.org/klaenge.html. Accessed: 2022-4-20.

[90] Sonia Katyal. “Technoheritage”. *California Law Review*, 105(4):1111–1172, 2017.

[91] Kevin Kelly. “Clock in the Mountain”. https://longnow.org/ideas/02011/06/16/clock-in-the-mountain/, Jun 15, 02011. Accessed: 2022-4-1.

[92] Eileen Kinsella. “A Prized Basquiat Owned by Billionaire Mega-Collector Yusaku Maezawa Could Fetch More Than $70 Million at Auction This Spring”. *Artnet News*, February 28, 2022. https://news.artnet.com/market/yusaku-maezawa-basquiat-2078087. Accessed: 2022-4-1.

[93] Nick Kirkpatrick. “Found By Accident: Some of the World’s Inadvertent Archaeological Discoveries”. *The Washington Post*, July 10, 2014. https://www.washingtonpost.com/news/morning-mix/wp/2014/07/10/found-by-accident-some-of-the-worlds-inadvertent-archaeological-discoveries/. Accessed: 2022-4-1.

[94] Friedrich Kittler. “There is No Software”. https://web.stanford.edu/class/history34q/readings/Kittler/There_is_No_Software.html. Accessed: 2022-04-03.

[95] Elizabeth Kolbert. *The Sixth Extinction*. Henry Holt and Co, New York, NY, 2014.

[96] Rosalind Krauss. “Sculpture in the Expanded Field”. *October*, 8:30–44, 1979.

[97] Philippe Kruchten, Robert L. Nord, and Ipek Ozkaya. "Technical Debt: From Metaphor to Theory and Practice". *IEEE Software*, 29(6):18–21, 2012.

[98] Raymond S. R. Ku. *Cyberspace Law: Cases and Materials, 5th edition.* Wolters Kluwer, Alphen aan den Rijn, Netherlands, 2020.

[99] Terry Kuny. "A Digital Dark Ages? Challenges in the Preservation of Electronic Information". In *Proc. of the 63rd IFLA General Conference*, NordiCHI, Copenhagen, Denmark, 1997. IFLA.

[100] Miwon Kwon. "One Place after Another: Notes on Site Specificity". *October*, 80:85–110, 1997.

[101] MIT Media Lab. "Hyperinstruments". https://www.media.mit.edu/projects/hyperinstruments/overview/. Accessed: 2022-4-2.

[102] Pip Laurenson. "Authenticity, Change and Loss in the Conservation of Time-Based Media Installations". https://www.tate.org.uk/research/tate-papers/06/authenticity-change-and-loss-conservation-of-time-based-media-installations. Accessed: 2022-3-30.

[103] Noel Lobley. "Sound Galleries: Curating the Experience of Sound and Music In and Beyond Museums". *Music in Art*, 39:243–255, 1997.

[104] Stephen Lukasik. "Why the Arpanet Was Built". *IEEE Annals of the History of Computing*, 33(3):4–21, 2011.

[105] Macdowell.org. "Emmanuel Ghent". https://www.macdowell.org/artists/emmanuel-ghent, 2022. Accessed: 2022-4-1.

[106] Lauren Mafeo. "Google's Vint Cerf On How to Prevent a Digital Dark Age". *The Guardian*, May 29, 2015. https://www.theguardian.com/media-network/2015/may/29/googles-vint-cerf-prevent-digital-dark-age. Accessed: 2022-02-13.

[107] New York Magazine. "The Cathedral of St. John the Divine". https://nymag.com/listings/attraction/cathedral-of-st-john-the-divine/. Accessed: 2022-4-1.

[108] Francis Marchese. “Conserving Digital Art for Deep Time”. *Leonardo*, 44(4):302–308, 2011.

[109] Karl Marx. *Capital, vol.1: A Critique of Political Economy.* Progress Publishers, Moscow, USSR, 1867.

[110] Clare McAndrew. “The New York Art Market Report”. *Independent*, 2022. https://nyartmarket.independenthq.com. Accessed: 2022-4-1.

[111] Karen McVeigh. “Detroit Mired in Fresh Controversy Over Sale of 60,000-Piece Art Collection”. *The Guardian*, August 14, 2013. https://www.theguardian.com/world/2013/aug/14/detroit-controversy-art-collection-sale-suburbs. Accessed: 2022-4-1.

[112] Mark Memmott. “Woman Who Ruined Fresco Of Jesus Now Wants To Be Paid”. *NPR, The Two Way*, September 20, 2012. https://www.npr.org/sections/thetwo-way/2012/09/20/161466361/woman-who-ruined-fresco-of-jesus-now-wants-to-be-paid. Accessed: 2022-4-1.

[113] Scott Meyers. “Four Reasons Investors Are Looking At The Self-Storage Industry Right Now”. *Forbes*, October 21, 2020. https://www.forbes.com/sites/forbesrealestatecouncil/2020/10/21/four-reasons-investors-are-looking-at-the-self-storage-industry-right-now/?sh=660a032158fe. Accessed: 2022-4-1.

[114] Romain Michon. “Faust Tutorials”. https://ccrma.stanford.edu/~rmichon/faustTutorials/#what-is-faust. Accessed: 2022-4-1.

[115] Evgeny Morozov and Yanis Varoufakis. "Crypto, the Left, and Techno-Feudalism : Yanis Varoufakis and Evgeny Morozov in Dialogue". *Meta Centre for Post-Capitalist Civilization*, 2021. https://metacpc.org/en/crypto-blockchain/. Accessed: 2022-4-1.

[116] Margaret Morse. *Women, Art, and Technology, ed. Judy Malloy*, chapter The Poetics of Interactivity. MIT Press, Cambridge, MA, 2003.

[117] Jennifer Mundy. Lost Art: Richard Serra. https://www.tate.org.uk/art/artists/richard-serra-1923/lost-art-richard-serra. Accessed: 2022-4-1.

[118] Morris Museum. “The Murtogh D. Guinness Collection”. https://morrismuseum.org/mechanical-musical-instruments-automata/. Accessed: 2022-4-1.

[119] Katja Müller. *Digital Archives and Collections: Creating Online Access to Cultural Heritage*, chapter 3. Berghan Books, New York, NY, 2021.

[120] Katja Müller. *Digital Archives and Collections: Creating Online Access to Cultural Heritage*, chapter 1. Berghan Books, New York, NY, 2021.

[121] James G. Neal. "Preserving the Born-Digital Record". *American Libraries*, June:30–33, 2015. https://www.jstor.org/stable/26372135. Accessed: 2022-01-20.

[122] James G. Neal. "Libraries as Convener, Enabler, Distributor, Advocate, and Archive in the Future Knowledge Economy". In *Roll with the Times, or the Times Roll Over You*, Charleston Conference Proceedings, Charleston, NC, 2016. Against the Grain Press.

[123] Neighbor.com. "Self Storage Industry Statistics (2020)". https://www.neighbor.com/storage-blog/self-storage-industry-statistics/, December 18, 2019. Accessed: 2022-4-1.

[124] Shaun Nichols. 'AWS's S3 Outage Was So Bad Amazon Couldn't Get Into its Own Dashboard to Warn the World". *The Register*, March 1, 2017. https://www.theregister.com/2017/03/01/aws_s3_outage/. Accessed: 2022-4-1.

[125] The Metropolitan Museum of Art. "Play it Loud: Instruments of Rock n Roll". https://www.metmuseum.org/exhibitions/listings/2019/play-it-loud. Accessed: 2022-4-1.

[126] The Metropolitan Museum of Art. "The Collection, Musical Instruments: Harpsichord, Late 17th century". https://www.metmuseum.org/art/collection/search/503625. Accessed: 2022-4-1.

[127] National Women's Hall of Fame. "Laurie Spiegel". https://www.womenofthehall.org/inductee/laurie-spiegel-2/, 2019. Accessed: 2022-4-1.

[128] University of Missouri Libraries. "The Battle of Milvian Bridge and the history of the book". November 1, 2012.

[129] The Museum of Modern Art. *MOMA Highlights*. The Museum of Modern Art, New York, NY, 1999, rev. 2004.

[130] International Council of Museums. “ICOM Guidelines on disposing of collections: 2.13 Deaccessioning from Museum Collections”. https://icom.museum/wp-content/uploads/2019/10/Guidelines-on-Deaccessioning-of-the-International-Council-of-Museums.pdf. Accessed: 2022-4-1.

[131] International Council of Museums Committee for Conservation. “Definition of the profession (1984)”. https://www.icom-cc.org/en/definition-of-the-profession-1984. Accessed: 2022-4-1.

[132] Catehdral of St. John Divine. "New York Philharmonic at the Cathedral: Memorial Day Concert". https://www.stjohndivine.org/calendar/38536/new-york-philharmonic-at-the-cathedral-memorial-day-concert. Accessed: 2022-4-1.

[133] Jake Offenhartz. “These NYC Zip Codes Saw The Most Pandemic Move-Outs”. April 9, 2021. https://gothamist.com/news/map-these-nyc-zip-codes-saw-most-pandemic-move-outs. Accessed: 2022-4-1.

[134] Vermont State Highway Safety Office. “World Wide Texting Stats”. https://shso.vermont.gov/sites/ghsp/files/documents/Worldwide%20Texting%20Statistics.pdf. Accessed: 2022-4-1.

[135] Yann Orlarey. “De la nécessité d’intégrer la question de la préservation dès la conception des outils de création”. Colloque international ANTONY - Préservation collaborative pour la musique avec électronique, Résumés des interventions du jeudi 21 octobre 2021. https://musinf.univ-st-etienne.fr/recherches/antony/bios-abstracts.html. Accessed: 2022-4-1.

[136] Barnard Oroleva. “Sound properties in pre-Roman Etruria: an archaeoacoustic analysis of the Etruscan tomb space”. *The Journal of the Acoustical Society of America*, 150(A249), 2021.

[137] Jeremy Orosz. “Dua Lipa’s “Levitating” Plagiarism Lawsuit Could Change Music Forever”. *Slate*, March 17, 2020. https://slate.com/culture/2022/03/dua-lipa-levitating-copyright-infringement-plagiarism-case.html. Accessed: 2022-4-1.

[138] Bob Ostertag. “Human Bodies, Computer Music”. *Leonardo Music Journal*, 12:11–14, 2002.

[139] Bob Ostertag. *Creative Life: Music, Politics, People and Machines*, pages 159–162. University of Illinois Press, Chicago, IL, 2009.

[140] Ian Pace. "The insidious class divide in music teaching". *The Conversation*, May 17, 2017. https://theconversation.com/the-insidious-class-divide-in-music-teaching-77574. Accessed: 2022-4-1.

[141] Patrick Panos. “The Internet Archive: An End to the Digital Dark Age”. *Journal of Social Work Education*, 39(2):343–347, 2003.

[142] Michael Perelman. “Natural Resources and Agriculture under Capitalism: Marx’s Economic Model”. *American Journal of Agricultural Economics*, 57(4):701–704, 1975.

[143] Eric Phetteplace. “Speculative Realism: Resources on an Emerging Discipline”. *College & Research Libraries News*, 71(6):305–313, 2010.

[144] Thomas Picketty. *Capital and Ideology*. Harvard University Press, Cambridge, MA, 2020.

[145] Samuel Pluta. *Laptop Improvisation in a Multi-Dimensional Space*. Columbia University, New York, 2012.

[146] Edgar Allen Poe. “Maelzel’s Chess Player”. *Southern Literary Messenger*, 2(April):318–326, 1836.

[147] Jason Ponce. *The Wind Garden Technical Manual v1.2*. Unpublished, 2017.

[148] Sarah Posman, Anne Reverseau, David Ayers, Sascha Bru, and Benedikt Hjartarson. *The Aesthetics of Matter: Modernism, the Avant-Garde and Material Exchange*, chapter The Materiality of a Contemporary Avant-Garde? De Gruyter, Berlin, Germany, 2013.

[149] Associated Press. "U.S. Statement on UNESCO". *The New York Times*, Section A:4, December 30, 1983. https://www.nytimes.com/1983/12/30/world/us-statement-on-unesco.html. Accessed 2022-04-01.

[150] Associated Press. "Slowly Does it: Chord Changes in John Cage's 639-year-long Organ Piece". September 5, 2020. The Guardian, https://www.theguardian.com/world/2020/sep/05/slowly-does-it-chord-changes-in-639-year-long-organ-piece. Accessed: 2022-4-1.

[151] Michael Pretorius. *Syntagma Musicum.* Zea Books (2014), Lincoln, Nebraska, 1640-1620.

[152] Christopher J. Prom. *Hacking the Academy: New Approaches to Scholarship and Teaching from Digital Humanities*, chapter Reimagining Academic Archives. University of Michigan Press, Ann Arbor, MI, 2016.

[153] Miller Puckette. "PD Repertory Project". http://msp.ucsd.edu/pdrp/latest/doc/, Version 13: 2021.03.24. Accessed: 2022-4-1.

[154] William A. Real. "Toward Guidelines for Practice in the Preservation and Documentation of Technology- Based Installation Art". *Journal of the American Institute for Conservation*, 40(3):211–231, 2001.

[155] Kingpin Market Research. "Global Linux Operating System Market Development Strategy Pre and Post COVID-19, by Corporate Strategy Analysis, Landscape, Type, Application, and Leading 20 Countries", July 15, 2021. https://www.kingpinmarketresearch.com/global-linux-operating-system-market-18749053. Accessed: 2022-4-1.

[156] Richard Rinehart. "The Media Art Notation System". *Leonardo - Journal of the International Society for the Arts, Sciences and Technology*, 40(2):181–187, 2007.

[157] Lúcia Lima Rodrigues and Russell Craig. "Recovery amid Destruction: Manoel da Maya and the Lisbon Earthquake of 1755". *Libraries & the Cultural Record*, 43(4):397–410, 2008.

[158] Christine Rosa. "Preserving New Media: Educating Public Audiences through Museum Websites". *Journal of the Art Libraries Society of North America*, 34(1):181–191, 2015.

[159] Terez Rose. "John Cage's 'As Slow As Possible"'. http://www.theclassicalgirl.com/john-cages-as-slow-as-possible/. Accessed: 2022-4-2.

[160] Alex Ross. "Song of the Earth". *The New Yorker*, 84(13):76, 2008.

[161] Fernando Domínguez Rubio. “Preserving the unpreservable: docile and unruly objects at MoMA”. *Theory and Society*, 43(6):617–645, 2014.

[162] Heather Ryan. “#nodigitaldarkage?”. *Longnow.org*, February 10, 2016. https://longnow.org/ideas/02016/02/10/nodigitaldarkage/. Accessed: 2022-4-1.

[163] Paul Sanden. Liveness in modern music: Musicians, technology, and the perception of performance. *Liveness in Modern Music: Musicians, Technology, and the Perception of Performance*, pages 1–206, 01 2013.

[164] Joseph Santiago. "The ’Blurred Lines’ of Copyright Law: Setting a New Standard for Copyright Infringement in Music". *Brooklyn Law Review*, December 12, 2017. https://brooklynworks.brooklaw.edu/blr/vol83/iss1/18. Accessed: 2022-04-01.

[165] Startup Sapience. “Snapchat — The Rise and Fall and Rise Again”. https://startupsapience.medium.com/snapchat-the-rise-and-fall-and-rise-again-20980128be5b. Accessed: 2022-4-1.

[166] Tatja Scholte. *The Perpetuation of Site-Specific Installation Artworks in Museums: Staging Contemporary Art*, chapter Ernesto Neto’s Célula Nave Extending the Lifespan of a Temporary, Site-Specific Installation in a Museum Context. Amsterdam University Press., Amsterdam, The Netherlands, 2022.

[167] Tatja Scholte. *The Perpetuation of Site-Specific Installation Artworks in Museums: Staging Contemporary Art*, chapter Site-Specific Installation Art in Historical Perspective. Amsterdam University Press., Amsterdam, The Netherlands, 2022.

[168] Harold Schonberg. “A Long, Long Night (and Day) at the Piano; Satie’s ’Vexations’ Played 840 Times by Relay Team”. *The New York Times*, page 45, 1963.

[169] Bernhard Serexhe, editor. *Digital Art Conservation, Preservation of Digital Art: Theory and Practice*. Ambra | V, Vienna, Austria, 2020.

[170] Stephen Siwek. The True Cost of Motion Picture Piracy to the U.S. Economy. *Policy Report 186 ed. N.p.: Institute for Policy Innovation*, 2006.

[171] Christopher Small. *Musicking: The Meanings of Performing and Listening*. Wesleyan University Press, Middletown, CT, 1998.

[172] L. F. Smith, J. K. Smith, and P. P. L. Tinio. "Time spent viewing art and reading labels". *Psychology of Aesthetics, Creativity, and the Arts*, 11(1):77–85, 2017. https://doi.apa.org/doiLanding?doi=10.1037%2Faca0000049. Accessed: 2022-4-1.

[173] Roberta Smith. "In Detroit, A Case of Selling Art and Selling Out". *The New York Times*, September 11, 2013. https://www.nytimes.com/2013/09/11/arts/design/in-detroit-a-case-of-selling-art-and-selling-out.html. Accessed: 2022-4-1.

[174] Spotify. "About Spotify". https://newsroom.spotify.com/company-info/. Accessed: 2022-4-1.

[175] Tom Standage. *The Turk, The Life and Times of The Famous Eighteenth-Century Chess-Playing Machine*. Walker Publishing, New York, NY, 2002.

[176] Jonathan Sterne. *Sound Souvenirs: Audio Technologies, Memory and Cultural Practices*, chapter The Preservation Paradox in Digital Audio. Amsterdam University Press., Amsterdam, The Netherlands, 2009.

[177] Caleb Stuart. "Damaged Sound: Glitching and Skipping Compact Discs in the Audio of Yasunao Tone, Nicolas Collins and Oval". *Leonardo Music Journal*, 13:47–52, 2003. Accessed: 2022-4-1.

[178] Carey Stumm. "Preservation of Electronic Media in Libraries, Museums, and Archives". *The Moving Image: The Journal of the Association of Moving Image Archivists*, 4(2):38–63, 2004.

[179] Yevgeniy Sverdlik. "AWS Outage that Broke the Internet Caused by Mistyped Command". *Data Center Knowledge*, March 2, 2017. Accessed: 2022-4-1.

[180] Jonathan Takiff. "Spotify up; Napster's Gone", Dec 01 2011. =https://www.proquest.com/newspapers/spotify-up-napsters-gone/docview/907741457/se-2?accountid=12536. Accessed: 2022-02-11.

[181] Sylvain Tesson. *Dans les Forêts de Sibérie*. Penguin Books, New York, NY, 2011.

[182] Return to UNESCO. "United States' Return to UNESCO". *The American Journal of International Law*, 97:4, October, 2003.

[183] Marc Treib. *Space Calculated in Seconds: The Philips Pavilion, Le Corbusier, Edgard Varèse*. Princeton Architectural Press, Princeton, NJ, 1996.

[184] Frank Trocco Trevor Pinch. *Analog Days: The Invention and Impact of the Moog Synthesizer*. Harvard University Press, Cambridge, MA, 2004.

[185] UNESCO. "Concept of Digital Heritage". https://en.unesco.org/themes/information-preservation/digital-heritage/concept-digital-heritage. Accessed: 2022-4-1.

[186] UNESCO. "Our Expertise". https://www.unesco.org/en/our-expertise. Accessed: 2022-4-1.

[187] Yanis Varoufakis. "Techno-feudalism is Taking Over". *Project Syndicate*, June 28, 2021. https://www.project-syndicate.org/commentary/techno-feudalism-replacing-market-capitalism-by-yanis-varoufakis-2021-06. Accessed: 2022-4-1.

[188] Antoine Vincent, Bruno Bachimont, and Alain Bonardi. "Préserver les øuvres musicales créées avec dispositif numérique par l'étude du processus compositionnel". *Les Cahiers du numérique*, 8(4):91–118, 2012. https://www.cairn.info/revue-les-cahiers-du-numerique-2012-4-page-91.html. Accessed 2022-04-01.

[189] Glenn Watkins. *The Gesualdo Hex, Music, Myth, and Memory*. W.W. Norton and Company, New York, NY, 2010.

[190] Marc Weber. "Self-Fulfilling History: How Narrative Shapes Preservation of the Online World". *Information & Culture: A Journal of History*, 51(1):54–80, 2016.

[191] Peter Weibel. *Digital Art Conservation*, chapter The Digital Oblivion. Towards a Material History of the Media, pages 183–196. Ambra | V, Vienna, Austria, 2013.

[192] Klaus Weschenfelder. *Digital Art Conservation*, chapter Museum and Amnesia. An Attempt at a Review, pages 125–136. Ambra | V, Vienna, Austria, 2013.

[193] Wikitubia. “List of most-viewed YouTube videos”. https://youtube.fandom.com/wiki/List_of_most-viewed_YouTube_videos. Accessed: 2022-4-20.

[194] Samuel H. Williamson. “Seven Ways to Compute the Relative Value of a U.S. Dollar Amount, 1790 to present”. *MeasuringWorth.com*, 2022. https://www.measuringworth.com/calculators/uscompare/result.php?year_source=1978&amount=123850000&year_result=2020. Accessed: 2022-4-17.

[195] Laura Zattra. *Live Electronic Music*, chapter Collaborating on Composition: The Role of the Musical Assistant at IRCAM, CCRMA and CSC, pages 59–80. Routledge, London, 2017.

[196] Siegfried Zielinski. *Digital Art Conservation*, chapter An-)Archive. The Abolition of the Present and the Archive of the Future, pages 91–108. Ambra | V, Vienna, Austria, 2013.

[197] Íslensk erfðagreining ehf. and Friðrik Skúlason. “Íslendingabókur, We Are All Related”. https://www.islendingabok.is/. Accessed: 2022-4-1.

[198] Slavoj Žižek. *Slavoj Žižek and Dialectical Materialism, ed. Agon Hamza and Frank Ruda*, chapter Objects, Objects Everywhere, pages 177–192. Palgrave Macmillan, Houndmills, Basingstoke, Hampshire, 2016.