

Discovering Instruments in Scores: A Repertoire-Driven Approach to Designing New Interfaces for Musical Expression

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ABSTRACT

This paper situates NIME practice with respect to models of social interaction among human agents. It argues that the conventional model of composer-performer-listener, and the underlying mid-20th century metaphor of music as communication upon which it relies, cannot reflect the richness of interaction and possibility afforded by interactive digital technologies. Building on Paul Lansky’s vision of an expanded and dynamic social network, an alternative, ecological view of music-making is presented, in which meaning emerges not from “messages” communicated between individuals, but instead from the “noise” that arises through the uncertainty in their interactions. However, in our tendency in NIME to collapse the various roles in this network into a single individual, we place the increased potential afforded by digital systems at risk. Using examples from the author’s NIME practices, the paper uses a practice-based methodology to describe approaches to designing instruments that respond to the technologies that form the interfaces of the network, which can include scores and stylistic conventions. In doing so, the paper demonstrates that a repertoire—a seemingly anachronistic concept—and a corresponding repertoire-driven approach to creating NIMES can in fact be a catalyst for invention and creativity.

Author Keywords

NIME, repertoire, scores, composition, performance, Techno

ACM Classification

H.5.5 [Information Interfaces and Presentation] Sound and Music Computing, H.5.2 [Information Interfaces and Presentation] User Interfaces—Evaluation/methodology.

1. INTRODUCTION

This paper is a product of practice-based research, which has recently gained significant attention as a distinct and valuable mode of inquiry that should reside alongside those rooted in scientific or humanistic paradigms. As Carey and Johnston have demonstrated, there is no singular or universal practice-based methodology, but rather a diversity of approaches that are appropriate to different questions or circumstances [7]. These are unified, however, by the role of the “practitioner-researcher,” who “may use their practice

to examine latent research themes, explore developing ideas about practice itself or undertake experiments related to a central topic of interest” [7].

In particular, this paper is motivated by Johnston’s observation that “in NIME research, music as an artform is often spoken of as if it were a static field, where the roles of composer, performer and instrument are well-defined, uncontroversial and unambiguous. The reality, however, is that all of these terms are contingent and dynamic. ‘Instruments’ based on digital technologies can, and often do, change their form and behaviour radically from moment to moment... ‘Composers,’ rather than producing scores, may instead produce interactive systems—instruments of a kind—which structure improvisation. Finally, ‘performers’ using NIME systems seem to consider virtuosity as an increasingly irrelevant concept, and focus instead on exploration and discovery with, and for, audiences” [14, p. 82].

In this statement I recognized themes latent in my own practice, prompting questions about the roles and actors involved in NIME practices in general, as well as the ways that technologies and objects can mediate the relationships between them. The methodology was initially reflective, i.e., looking back on work I completed prior to this project in order to examine its application to these questions. This reflection then spawned focused practical exploration—designing a new interface for musical expression—in response to the developing theory that I outline in the next section. In Section 3, this suite of examples from my own practice, illuminated by antecedents from others’, collectively provide insights into the implications for future practitioners.

What follows, therefore, is not a strictly chronological account of the flows of ideas or practice, but rather an organization of the various threads into what in my estimation creates the most compelling argument while honestly accounting for the variety of forces that informed it. I present the theoretical framework first, followed by accounts of practice, which serve as illustrations of these ideas. Yet, it is important to bear in mind that the so-called “theoretical” and “practical” components are not in actuality distinct contributions, neither logically nor temporally; rather they codeveloped as intertwining lines of a simultaneously prospective and reflective process.

2. MODELING MUSICAL-SOCIAL INTERACTION

The composer Paul Lansky in 1990 presciently observed the obsolescence of what he called “a good simple model of a classical notion of musical-social interaction” [17, p. 103]. This popular model is that of a network consisting of three nodes: composer, performer, and listener. In typical accounts of this traditional paradigm of music, the composer



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NIME’17, May 15-19, 2017, Aalborg University Copenhagen, Denmark.

is a creator, the performer an interpreter, and the listener a more-or-less passive receptor. Curiously, although the composer is situated as the authorial creator, in this model they are not the “maker,” neither of instrument nor of sound. Rather, the composer creates an abstract representation of music, an instruction for execution—a score. Performers in turn interpret the abstracted representations depicted in the score, making the sounds that we listeners hear as music.

Prior even to the problematics introduced by digital technologies, Lansky critiques the composer-performer-listener (CPL) model’s inherent conservatism: “The network needs social institutions to provide a context for this communication and interaction—typically, concerts, in which some play while others listen... From a certain perspective this view describes a very rigid social structure. It is highly conservative in that it provides a conceptual framework which discourages evolution and promotes institutional stability. The degrees of passiveness and activeness of the individual nodes are relatively fixed and the environments in which they behave are designed to accommodate their habits without much fuss or bother. The composer writes, the performer plays, and the listener claps” [17, p. 103].

2.1 Music as Communication

Fundamentally, the CPL model relies on an understanding of musical expression as communication that rose to prominence in the middle of the 20th century alongside the advent of information theory and cybernetics; one that still gains much traction [22, 26]. As Ronald Kline’s recent account demonstrates, these theories have pervaded society and culture, and shaped our fundamental understanding of the world. Kline writes: “The noun information and the prefix cyber- mark the new vocabulary of our time. They inform how we talk, think, and act on our digital present and future, from the utopian visions invoked by the terms information age and cyberspace to the dystopian visions associated with enemy cyborgs and cyber warfare. The traces of cybernetics and information theory thus permeate the sciences, technology, and culture of our daily lives” [16, p. 4].

Examining Shannon’s model of communication (Figure 1), we see that information theory has shaped the way we tend to talk about music too. Shannon’s model defines an information source, which produces a message to be encoded and communicated by a transmitter. That message, along with inevitable noise, is conveyed through a medium to a receiver, then decoded before being delivered to the destination.

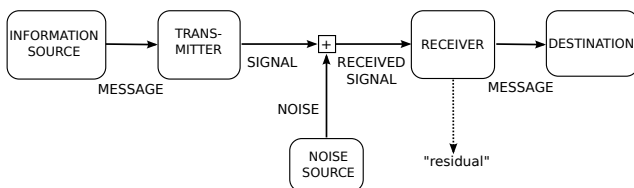


Figure 1: Shannon’s model of communication.

Agre’s theory of *generative metaphors* describes the centrality that metaphors such as “music-as-communication” can have in structuring inquiry in technical fields. Beyond being simply explanatory, the “practical logic” of these metaphors shapes the very nature of the questions a field asks, the techniques for their investigation, and the framework for understanding outcomes [1, p.38]. Harrison, Sengers and Tatar use Agre’s theory to explain the dominance of an information-processing metaphor in HCI, and the corresponding marginalization of areas and modes of inquiry

for which this metaphor does not easily account [13]. Given NIME’s roots in HCI it should not be surprising that a similar information theoretic metaphor should dominate our discourse. But, as Lansky’s article exemplifies, this model of musical communication certainly predated NIME. Published in 1950, just two years after Shannon’s and Wiener’s seminal texts, Roger Sessions’s *The Musical Experience of Composer, Performer, Listener* illustrates the appropriation of a communicative model to describe musical-social interaction: “Does music actually communicate something it is capable of defining clearly? It seems to me quite clear that music, far from being in any sense vague or imprecise, is within its own sphere the most precise possible language” [21, p. 24]. In fact, simply relabeling elements of Shannon’s model in terms of musical agents (Figure 2) yields the standard explanation of music-as-communication that emerged in the second half of the 20th century and still thrives, e.g., [15]. What is encoded in a score by the composer, more than simply a set of instructions for action, is treated as a message, a ground truth. The performer becomes the transmitter of this message, to which he or she injects a kind of expressive “noise”: liberties, distortions or slight deviations from the authoritative statement; their own signal superimposed on top of that of the composer. The listener’s role is to receive this now-distorted version of the message and try to decode the composer’s and performer’s original distinct contributions, and hopefully derive the meanings of both.

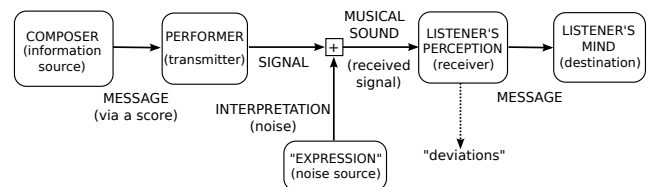


Figure 2: Communicative model of music.

2.2 Critiques and Alternatives

2.2.1 Musicological Perspectives

The implied duality of a musical “text” and the “act” of its transmission, has been roundly critiqued, including prominently by the musicologist Richard Taruskin [24]. Taruskin argues that so-called “authentic” performance practice, which aspires to approach a singular idealized execution envisioned by the composer, is a wholly modern invention divorced from any cultural or social reality. Gurevich and Treviño have written that the uncritical adoption of this information theoretic model of music-making is at odds with the experimentalist and improvisatory traditions that inform contemporary music practices [12].

Christopher Small assails the notions that the value of music inheres in a text, and “that a musical performance is thought of as a one-way system of communication, running from composer to individual listener through the medium of the performer.” This, to Small “suggests also that music is an individual matter, that composing, performing and listening take place in a social vacuum” [23, p. 6]. Instead, according to Small, “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 an individual listener. If we... take in the entire set of relationships that constitutes a performance, we shall see that music’s primary meanings are not individual at all but social... The fundamental nature and meaning of music lie not in objects, not in musical works at all, but in action, in what people do” [23, p. 8].

2.2.2 Expanding the Network

Observing the transformative power of technologies for reproduction, synthesis, and distribution, Lansky argued that the CPL model is now also incomplete. He proposed the addition of two categories, “to more accurately reflect the social consequences of using machines” to make music [17, p. 106]. He called the first role the “sound-giver,” comprising a rough continuum with record producer at one extreme, and a friend giving you homemade nature recordings at the other; mixtapes are somewhere in between. Sharing music, sharing sound, is increasingly a vital part of musical life, one that is distinguished from broadcasting in its peer-oriented, bottom-up nature. Although Lansky was writing in 1990 prior to widespread digital distribution or social media, the sound-giver concept depended on late-20th century innovations in reproduction and portability exemplified by the medium he chose for illustration—the cassette tape.

It is the second node that Lansky proposed to add that is arguably most relevant to NIME: the instrument-builder. Lansky notes that when considered as simply a maker of sound-producing hardware, this category is as old as instrumental music itself. But, he argues, digital technologies have empowered the instrument-builder to transgress the incremental evolution of the musical climate; instrument-builders can be radically transformative and visionary, rebalancing the inherent power structure of the CPL network.

However, the consequences of Lansky’s updated model reach far beyond simply expanding and democratizing the network. Inserting these nodes in fact undermines the categorical distinctiveness of all the roles: “In some ways, composers, performers, and listeners are subclasses of sound-givers. In other ways sound-givers are subclasses of composers and performers. . . In some ways an instrument builder becomes a subclass of composer. In other ways composer becomes a subclass of instrument builder” [17, pp. 107-8]. Indeed, in contemporary practices the necessity and separability of the categories of composer, instrument builder, sound-giver, performer, and listener are called into question. In NIME, which at its core emphasizes digital instrument-making, we frequently observe that these once-distinct roles are often inhabited by just one person, a phenomenon Lansky traces back at least to Harry Partch. I suggest that it is likely more common than not in NIME for a single person to be composer, instrument-builder and performer.

2.2.3 Ecologies and Emergent Meanings

In Lansky’s conception, despite the temptation of the Partchian one-man-show, it is in the increased potential for complex social interactions in this expanded network where the most promising musical opportunities emerge: “Whatever the formalization. . . it is clear that the number of ways in which the nodes are now capable of interacting has increased greatly” [17, p. 108]. A dynamic network of interconnected nodes is substantially richer than that of a directional transmission line. Yet, if the stability of the individual roles and their relationships—and therefore the rigid topology of the entire network—can no longer be assumed, what emerges is a network in which musical meaning no longer resides in the directional messages that flow between the nodes, but instead in the activities that emerge through the interactions between nodes. Several authors have described such a network in ecological terms: an ecosystem that allows for flexible, mutually informing relationships between diverse actors including composers, performers, spectators, instrument makers and digital systems, through which meaning is situated, emergent and spontaneous, and not, as the previous model holds, determined a priori [25]. Agostino Di Scipio frames his *ecosystemic* approach as “a substantial move

from interactive music composing to composing musical interactions . . . a shift from creating wanted sounds via interactive means, towards creating wanted interactions having audible traces. In the latter case, one designs, implements and maintains a network of connected components whose emergent behaviour in sound one calls music” [8, p. 271].

2.2.4 Perspectives from HCI

Sengers and Gaver similarly advocate that prioritizing “multiple, heterogeneous interpretations” over a “single authoritative interpretation” of any designed system allows individuals “to define their own meanings for them, rather than merely accepting those imposed by designers” [20, p. 101]. They provide a number of strategies for doing so, all of which inherently rely upon distributed and mediated interactions between multiple actors. Among these, they highlight the role of *ambiguity*, which Gaver earlier identified as “a property of the interpretative relationship between people and artefacts” [10, p. 235]. Thus, the power for diverse meanings to emerge resides in the diversity of relationships around a technology: “This interpretative relationship is the source of ambiguity’s appeal: by thwarting easy interpretation, ambiguous situations require people to participate in making meaning. . . The artefact or situation sets the scene for meaning-making, but doesn’t prescribe the result. Instead, the work of making an ambiguous situation comprehensible belongs to the person, and this can be both inherently pleasurable and lead to a deep conceptual appropriation of the artefact” [10, p. 235-6].

2.3 Fluid Roles in the Expanded Network

Recent ethnographic studies have observed the fluidity of roles and relationships that Lansky predicted. In their study of the Birmingham Laptop Ensemble, Booth and Gurevich observe that the familiar roles of composer, designer and performer “do not strictly define players’ sole activities but can instead be seen as a dynamic set of orientations, which are adopted at different times.” We use terms such as “composer-as-designer,” and “performer-as-designer” to illustrate this dynamism [4]. Indeed, in Lansky’s expanded network, “instrument design and construction now become a form of musical composition. The vision of the instrument-builder can be idiosyncratic, and even compositional. Playing someone else’s instruments becomes a form of playing someone else’s composition” [17, p. 108].

I wish to highlight in particular that Lansky’s conception of a network of human relationships suggests elaboration on his last statement. We could equally say that performance now becomes a form of instrument design; that playing someone else’s composition becomes a form of playing (or designing) someone else’s instruments. This suggests the intriguing possibility that a composition—a score—can in fact embody or suggest not only a performance—a sound to be made or a set of activities or actions—but an interface or an instrument that is yet to exist.

3. LEARNING FROM PRACTICE

The remainder of this article describes examples from practices that embody the notion of designing instruments in response to scores, and to a non-notated musical style.

3.1 Performing Cage

I arrived at the idea of a repertoire-based approach to NIME through making performances of works by John Cage. In 2012, the year of the John Cage centennial, I led my Electronic Chamber Music ensemble at the University of Michigan in creating new realizations of some of Cage’s classic works for electronics. In researching this project, I was

struck by a letter that Cage wrote to David Tudor in 1958 from Milan about Cage's nearly-finished composition *Fontana Mix*. The piece, Cage wrote, "treats machines as things to perform with" [6, p. 102]. The statement is perplexing, since, at least in its initial conception, *Fontana Mix* was a tape composition: a static recording pieced together from fragments of tape that would ultimately be played back over loudspeakers.

Cage's implication that performing with machines is somehow novel is also curious, considering he had already composed for live turntable performance in *Imaginary Landscape No. 1* in 1939 and for radios in *Imaginary Landscape No. 4* in 1951, not to mention prior tape pieces including *Williams Mix* in 1952. Elsewhere I provide a much more thorough contextualization than I can present here, but the essence of unpacking Cage's statement lies in his aesthetic shift from chance to indeterminacy [11]. Treating machines as *things to perform with* should be understood as a contrast to treating machines as *thing to compose with*.

3.1.1 Williams Mix

In his earlier pieces such as *Williams Mix*, Cage used coin flips to remove his own desires from the compositional process, at least on the first order, but in doing so created scores that he described as "recipes." In other words, performing these scores—in the case of *Williams Mix*, splicing tape according to a visual pattern, "like a dressmaker's pattern," Cage said—was a matter of following simple instructions, with relatively little decision-making by the performer [5, p. 169]. Nonetheless, with *Williams Mix* Cage was already blurring the distinctions between instrument design, composition, and performance: in devising a novel method for creating envelopes through tape splicing, Cage designed a new instrument (composer-as-instrument-builder); in recruiting others to contribute the sound material to realize his score, he invited performers into the domain normally reserved for composers (performer-as-composer); in embodying the composition in a score and not simply a tape, he created the possibility for future performers to devise new technologies for its realization (performer-as-instrument-builder).

It took 45 years, but in 1997 Larry Austin set out to create a new performance of *Williams Mix*, an endeavor that incorporated digitally recording a new set of sounds according to the parameters Cage described in the score, as well as devising a new software program to edit and assemble the recordings in the style of the Cage's composition. Significantly, Austin's and collaborator Michael Thompson's digital system did not enable the reproduction of the parameters of Cage's score exactly. Instead, through study of the score, Cage's original tapes, and other available evidence, the software they called "Williams [re]Mix[er]" modeled Cage's process for generating the score using the *I Ching* [2]. Cage's score therefore provides not only the means for realizing a performance, but for building a new software instrument capable of composing/playing entirely new music with stylistic affinities to *Williams Mix* but also the timbral hallmarks of a contemporary digital instrument. In concerts, Austin presents a digital restoration of the original *Williams Mix* tapes as the first movement of a new composition *Williams [re]Mix[er]*. The subsequent movements generated by his software are described as "variations." Cage's score has since spawned yet another software instrument and sound library, by Tom Erbe, that does follow Cage's score exactly, but is capable also of realizing yet another body of new compositions, performances, and instruments [9]. Are Erbe, Austin, and Thompson composers? Performers? Instrument-builders? Sound-givers?¹

¹Thompson is credited as "Composer-programmer." The

Clearly the answer is yes to all, but this opportunity only exists due to a relationship with Cage mediated by his score. Furthermore, any number of other people could use their instruments and/or sounds to create still more compositions, performances, and instruments in an ever expanding network of social relations.

With his subsequent indeterminate pieces, Cage elaborated upon this dynamic by more explicitly offering multiple unique and distinct ways of performing a piece; in Cage's words, a "shift from [considering] music as structure to music as process" [5, p. 167]. Although Cage himself first realized *Fontana Mix* with tape, the score says nothing about tape splices or sound material, rather it defines a process for making musical decisions among various options, using transparent sheets overlaid against patterns of squiggles, dots, and a grid. Moreover, Cage leaves the question of instruments open-ended. Thus, with *Fontana Mix*, Cage further empowered the compositional activities of the performer, but also opened up the musical-social network to instrument-builders and sound-givers, if not as distinct actors, then at least as roles taken on by the performer. Indeed, the composer-performer Max Neuhaus performed realizations of Cage's score as *Fontana Mix – Feed* between 1964–68 using an electronic feedback system he created. Cage himself used the score to make several subsequent compositions, including *Water Walk* and *Theatre Piece*.

We are left with the tantalizing possibility of rereading Cage's scores for tape or for radio not as instructions for making a tape piece or a radio piece, but as invitations for instrument design as much as for performance. Furthermore, by separating and diversifying the roles—by adding more nodal relationships to the human network—the possibilities for surprise, novelty, and experimentation increase.

3.1.2 Pieces for Tape and Radio

Cage's score for *Rozart Mix* is a reproduction of correspondences with Alvin Lucier through which the pair devised a performance at the Rose Art Museum at Brandeis University in 1965. The score, like several others, including those of the *Variations*, documents a performance that occurred without providing explicit instructions for future ones. The performance described in the score was to involve 12 open-reel tape machines and a supply of at least 88 tape loops. Loops were to be played simultaneously on every machine until they broke, became tangled or otherwise unplayable, with four or more attendants replacing broken loops. The performance would continue indefinitely, until all the loops are broken beyond repair or the audience leaves the venue.

Considering Cage's shift toward indeterminacy, my ensemble read this score not as an instruction to reproduce an event from 50 years in the past, but rather an invitation to consider its meanings, and its technological implications, today. For our performance, which we called *Rozart Mixtape*, we used modified cassette players and cassette tape loops. We used relays and microcontrollers to cut the power to the battery-powered boom-boxes at random intervals, causing the tapes to slow to stop and signaling the performers to change tape loops. We devised an algorithmic process to scrape ensemble members' hard drives for audio files, and digitally splice together fragments to create the source material for the physically-spliced tape loops.

In our performance of *Radio Music*, composed in 1951 for 1–8 performers with portable radios who adjust the tuning frequency of the radios at designated times, we augmented the radioscape by introducing portable FM radio transmitters and spiking the spectrum with our own sounds.

division of effort is unclear, but the hyphenated title further supports the notion that they transcended singular roles.

Two additional performers sampled, looped and rebroadcast live radio broadcasts, effectively remediating the medium. Finally, we reimagined Cage's first tape piece, *Imaginary Landscape No. 5*, a collage for 8 tracks of snippets from 42 jazz records, as a live performance piece where a software program performs the splices and volume envelopes in real time, while performers act as DJs, changing records at designated times. These performances are documented in greater detail elsewhere [11].

In all of these performances, Cage's scores allowed the ensemble members to become composers, performers, sound-givers, instrument-builders, and listeners at various stages. Different individuals took on different roles at different times, and by extension, so did Cage. None of the systems we created resemble a "digital music instrument" in the conventional sense of the term—they are not gestural controllers for real-time DSP which otherwise take the role of a musical instrument—but this is precisely the point. The interfaces were rather devised creatively in response to the broader culturally- and locally-situated context of the performance (a group of university students in 2012 in a credit-bearing course; a performance in an art museum), our readings of Cage's score, and the ensemble members' individual and collective experiences. The microcontroller-controlled cassette-loop players reflected the ensemble members' nostalgia for cassette tapes, while simultaneously providing a bridge to Cage's world of splicing 1/4" open-reel tape, a practice previously foreign and inaccessible to them. We weren't simply "performing Cage;" we were collaborating with him across time through his score, creating an extended social assemblage from which new musical sounds, instruments and meanings could emerge. This, I argue, is precisely the point of NIME. Furthermore, the instruments we built in response to Cage have in turn suggested new possibilities for composition, performance and instrument design.

3.2 Berio's *Altra Voce*

In 2013, I was invited to perform Luciano Berio's *Altra Voce*, scored for flute, mezzo soprano and live electronics. Berio's score provides the electronics performer with instructions to sample specific portions of the other musicians' sounds in real time during the performance, and to play them back at specific times, transpositions, and spatial locations in a multichannel speaker array. Notably absent from the score is an indication of a software and/or hardware instrument for doing so. Berio specifies the sonic outcomes in far more detail than Cage did, but explicitly leaves the question of instruments open-ended. The score "provides all the necessary information for the realization of the electronic part. The instructions are not bound to any specific technology and may be applied to different systems as long as the prescribed parameters and processes are adhered to" [3]. A team at Tempo Reale created the first realization in 2001 with Berio, but the score invites performer-instrument-builders to devise their own.

We performed *Altra Voce* twice, in 2013 and 2014. My instrument was an assemblage of a software system I wrote in Max and existing hardware controllers (a Launchpad and MIDI fader board). The timed transpositions and spatial movements were programmed into the patch. In performance I used Launchpad buttons to record and play back samples at the appropriate timings according to the score. The instrument was admittedly not a radical new DMI, but was most certainly unlike any system that had been used previously for performing the piece. It reflected the local circumstances of our production: whereas the Tempo Reale version was realized and performed by a team, I had to design an instrument that could be managed by myself—

the lone electronics performer—from stage, and I had limited time to do so. The outcome, although not a radical new design, felt very much like an instrument; significantly, as performer-instrument-builder, I developed a performance practice with this instrument through substantial rehearsal.

3.3 New Instruments for Techno Music

As these encounters with scores began to catalyze the ideas presented in the first half of this paper, I observed that many contemporary practices, including in NIME, do not rely on notation. I was prompted to ask if improvisatory, non-notated practices could similarly invite new instruments which would in turn suggest new musical practices. In 2015, I tasked my ensemble with performing music inspired by Detroit Techno—certainly one such tradition. One component of this performance was to be a new digital musical instrument that embodied Techno's musical traditions but deliberately disrupted its tendency toward solitary practice. I insisted that our new instrument had to be made and performed socially, by a chamber ensemble, but still responsive to the work of musicians like Richie Hawtin and Carl Craig.

The outcome is a suite of instruments we called the Candelabras. The Candelabras consist of five nearly-identical "base" modules constructed of stained wood and a 1m length of steel pipe with three branching arms, resembling a candelabra. An insert containing a photocell is mounted in the end of each arm—three per instrument, fifteen in total. Each of the five players has two handheld controllers with five buttons and an LED array. The buttons activate rhythmic pulses in the LEDs, which, when detected by the photocells trigger synthetic percussion sounds. The buttons under each performer's first three fingers cause their lights to flash in quarter notes, eighth notes, and sixteenth notes, respectively. The fourth button is a triplet modifier. The controllers are all synchronized to the same metronome, and the tempo is agreed in advance by the performers. The button under each performer's thumb controls the color of the light, which affects the sensor's dynamic range somewhat but is mostly for visual effect.

Because each light pulse produces a window of continuously variable data at the photocell, rather than simply providing a note-on trigger, the instrument creates a short envelope that continuously controls the dynamics and timbre of each voice. Furthermore, the players can control the peak height and to some extent the shape of this envelope by varying the distance of the controller from the sensor, providing a good degree of articulatory control. Near the limits of the sensor's range of detection, they can even skew the peak-detection algorithm to create rhythmic imperfections, sometimes unintentionally—a challenge that digital controllers for dance music normally do not afford. A performance with the Candelabras that fully illustrates its operation is available in the accompanying video.

As Johnston suggests, one benefit of practice-based research is its inherent demand for symmetrical consideration of new creative musical practices and new instruments design [14]. Of course, electronic dance music already had a wealth of dedicated controllers and instruments, dominated by button matrices like the Monome and Push. These are largely what Magnusson calls "epistemic tools": physical instantiations of interfaces for essentially symbolic interactions [18]. Consequently, both the gestures and the musical outcomes associated with these controllers are non-specific. Musically, our performances are clearly evocative of, but not strictly stylistically consistent with Detroit Techno, nor any other genre of electronic dance music. But this was of course the inevitable and intended outcome of the endeavor, as Techno is never performed by an ensemble of

five musicians. We found that the imperative of a socially distributed performance necessitated a unique design that departed radically from button-matrix controllers and is instead rooted in metaphors reflecting the musical heart of Techno: percussion and drumming. The instruments in turn facilitated new musical tensions and opportunities.

4. DISCUSSION

One unintended consequence of collapsing the social network such that the roles of composer, performer, and instrument builder are inhabited by a single individual can be the failure to create a repertoire. The preceding examples demonstrate ways that instrument-design, performance, and further composition can indeed all ensue from scores, aural traditions, or other artifacts that collective constitute a repertoire. More than a collection of compositions or scores, it is a force upon which future musicians may build, or against which they may react. A repertoire provides a landscape of aesthetic reference points, a shared map among performers, composers, designers, and audiences onto which individual performances can be situated, and around which critical discourses can develop. Performances with new interfaces are frequently documented in video or audio, but these do not provide a sufficient basis for reinterpretation, re-realization or elaboration. With the preceding examples as a point departure, I propose that we consider ways to create scores that facilitate not only performances, but the development of new instruments and interfaces, whereas the process too frequently happens the other way around. A repertoire-driven approach will lead to instruments and performance systems that, owing to their socially-distributed production, inherently possess rather than seek diverse, textured musical meanings.

This claim is in no way meant to denigrate or devalue any NIME practices; certainly practices in the tradition of Partch and Waisvisz enrich the musical landscape as much as others. Rather it is a suggestion that in our quest for new modes of musicking that can emerge with interactive technologies we not throw out the baby with the bathwater, as the expression goes, by eliminating notated practices altogether. As I have shown, practices that increase the possibilities for human interactions in the musical-social network—whether mediated by scores, instruments, aural traditions or software programs—even those that blur the categorical distinctions of traditional roles, only enhance the richness of this possibility space. Nor do I claim to be alone in exemplifying this practice. As just one example among many, Ouzounian, Knapp, and Lyon’s recent account of their work as the BioMuse Trio describes a similar outlook: “There are no directives in the composition that are instrument specific. It is all about annotating gesture... Everything we do is hardware agnostic. You could see the piece being performed twenty years from now with a whole other piece of software but the same gestures” [19].

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