Ambiguous Devices: Improvisation, agency, touch and feedthrough in distributed music performance

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This article documents the processes behind our distributed musical instrument, *Ambiguous Devices*. The project is motivated by our mutual desire to explore disruptive forms of networked musical interactions in an attempt to challenge and extend our practices as improvisers and instrument makers. We begin by describing the early design stage of our performance ecosystem, followed by a technical description of how the system functions with examples from our public performances and installations. We then situate our work within a genealogy of human–machine improvisation, while highlighting specific values that continue to motivate our artistic approach. These practical accounts inform our discussion of tactility, proximity, effort, friction and other attributes that have shaped our strategies for designing musical interactions. The positive role of ambiguity is elaborated in relation to distributed agency. Finally, we employ the concept of 'feedthrough' as a way of understanding the co-constitutive behaviour of communication networks, assemblages and performers.

1. INITIAL MOTIVATIONS AND EARLY DEVELOPMENT PROCESS

Ambiguous Devices is a distributed musical ecosystem (Bowers 2002; Waters 2007), a network of interconnected music-making machines, people and ideas. The project began in 2011 out of a mutual desire to explore non-linear and resistive forms of networked musical interactions in an attempt to challenge and extend our existing practices as improvisers and instrument makers. *Ambiguous Devices* emerged from three extended visits between Sonic Arts Research Centre (SARC), Queen's University Belfast and Bournemouth University (BU) and four months of remote sessions between the Centre for Computer Research in Music and Acoustics (CCRMA), Stanford University and BU. As part of the developmental process, *Ambiguous Devices* has been presented in several public contexts: a concert between CCRMA and BU (2012); an installation and concert as part of NIME 2012; an installation between SARC and BU (2013); a performance at INTIME 2013, Coventry; and a performance at Re-new 2013 in Copenhagen. The project continues to evolve across different registers (e.g., technical, performative, discursive) and has informed a number of related research activities, including a two-day symposium on *Interagency in Technologically-Mediated Performance* at BU (2016),[1] a workshop on *Distributed Agency in Performance* at ICLI 2016,[2] an AHRC-funded research network on *Humanising Algorithmic Listening* (2017),[3] *The Feral Cello* project (Davis 2017), a workshop on *Collaborating with Machines: Exploring Agency through Instrument Design* at Resonate Festival in Belgrade,[4] and a number of other ongoing collaborations.

When we began the project in 2011, one of our initial motivations was to rethink the ways in which presence is conveyed in the performance of network music. For us, it was not particularly interesting to see performers in different geographical locations attempting to play together across the internet with as little latency as possible. Such performances commonly aim for the network to *disappear*, simulating the experience of making music in the same concert hall. Indeed, we were not particularly interested in streaming audio and video as a way of conveying presence between sites. Instead, we asked: what types of *being present* might networked music interactions afford that are not available during other types of music-making? How might physical presence be simultaneously communicated through and augmented by the body of an instrument or a player? What presence emerges as we attempt to literally *intertwine* our performance systems? We wanted to find new ways to enhance the type of presence that is experienced as touch and movement – to push and to be pushed back. We valued the resistive and complex behaviours of the network, our instruments and each other. We aimed to

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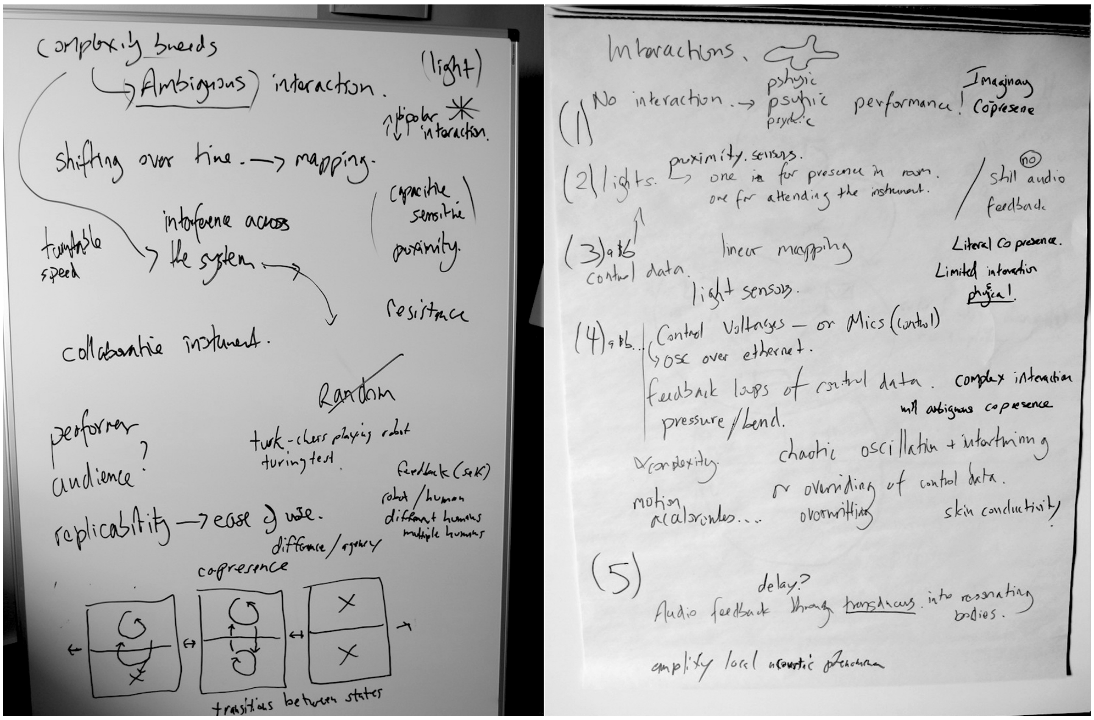

Figure 1. Brainstorming networked interactions.

actively sabotage communication technologies that were designed for transparency, while highlighting our mutually constituting relationship with technology in performance. We were curious to explore what happens at the edge of networked interactions, at the failure and breakdown of communication between performers, and to better understand how the technology used to facilitate networking could actually play a role in reconfiguring improvised musics. We desired to further embrace ambiguity and allow new behaviours to emerge. As such, we were not interested in conveying the presence of performers directly, but rather a sense of co-presence emerging from networks of tangible and resistive assemblages.

These motivations and curiosities led to the development of *Ambiguous Devices*, a distributed musical ecosystem of disparate interconnected parts. The development of this intentionally overly complicated instrument began with an initial design phase that included brainstorming, physical sketching, workshopping, prototyping and iterating on this process. Figure 1 documents some of our early brainstorming sessions.

These notes reflect our primary interests in co-presence, feedback and resistance, while revealing a stage in our planning that attempted to go back to very basic forms of interaction. We started with a thought experiment: what is the minimum amount of information that must be exchanged between two sites to constitute a distributed performance? Is it enough to merely think that you are performing at the same time as another person with no other interaction between sites, a kind of telepathic telematic performance with imaginary co-presence? We then discussed what types of interaction would take us just over the threshold of extrasensory perception to the sensorially perceivable. Next we prototyped technology that would enable communication between two physically separate performers that had no visual or audio connections; a light would increase in intensity to indicate to a local player the proximity of a physically distant collaborator to their instrument, and vice versa, with no other exchange of information across the network. Figure 2 shows a quick mock-up that allowed us to send control data between two sites over the network and test this interaction.

From there, we progressively built up the complexity of possible interactions between the two sites (in this case two separate rooms at SARC), gradually adding the sensing of performative movements on one site translated back into physical action through the instrument on the other. We initially developed linear mappings that communicated somewhat literal musical gestures through the distributed nodes of the instrument (e.g., a percussive hit in one site triggers a solenoid in another site, which in turn creates a percussive hit). We then moved on to a prototype that employed more complex interactions of feedback

Figure 2. Motion-to-light network sketch.

loops through modular sections of the instrument, resulting in a mix of predictable and less predictable behaviours (see Figure 3).

In Movie example 1, a metallic resonance chamber with strings is struck. The sound is amplified by a contact microphone connected to speakers in the same room. The microphone signal is also converted to OSC messages and sent over the network to a different room. The data are utilised to alter the rate of a motor that drives a modified turntable. A vinyl record is amplified by a tone arm and stylus connected to a transducer located beneath the turntable. A small magnet is attached to the edge of the record. On each rotation the magnet generates a signal through an electromagnetic pickup mounted on the turntable. This signal is converted to control data and sent back over the network to drive a solenoid, which in turn strikes the strings on the resonance chamber. This process creates a feedback loop, which can be calibrated, adapted and interacted with in a variety of ways (as shown in Movie example 2). The end of the second video also documents one of the more interesting methods of interaction that emerged during this stage: altering the position of the performer's body can manipulate audio feedback that causes a resonance chamber to sound and in turn alters the playback speed of a turntable.

During this stage of development, we began to conceive of *Ambiguous Devices* as one distributed acoustic instrument constructed from modular artefacts spanning two locations. Each performance node has a number of devices for the creation of sound, including parts of Paul Stapleton's Bonsai Sound Sculpture[5] and a number of other objects constructed by Tom Davis. As an instrument it can be played by one or two people, or it can even play itself. Although it is an amalgamation of digital, electronic, mechanical and acoustic objects, the overarching sound generation is through acoustic means and the interaction between the two nodes is primarily through (or via proximity to) the bodies of physical objects. Figure 4 shows one possible configuration of *Ambiguous Devices*, although its physical construction and the connectivity between elements often changes depending on the performance context.

In this example, both nodes have string-based elements, resonant metal chambers or plates, thumb pianos, and chimes or bells. Performers make use of mallets, bows, drumsticks and brushes to activate these acoustic objects. Stapleton's instrument is unique in employing a turntable and he also often performs with the use of small electronic devices that can be amplified through a microphone. There are a number of simple sensors and actuators attached to both nodes of the instrument and it is these that intertwine the distributed nodes, making it feel and act as one instrument. The sensors here are contact microphones, electromagnetic pickups and sonar distance sensors, and the actuators are basic motors, solenoids and a repurposed printer mechanism. Although the mappings between sensors and actuators are designed to be complex and non-literal in nature, thought has gone into balancing complexity and control between the two nodes. The mappings of interactions can also be further complicated by a performer moving the actuators to other parts of the instrument mid-performance.

Communication between the two sites is mediated at each end by an Arduino microcontroller with an attached Ethernet shield. Sensor data is captured on the Arduino, then scaled and sent as control data via OSC to drive an actuator on the other site. The use of microcontrollers allows the instrument to function without resorting to any extra computing power. In most multisite performance scenarios, we also support the physical interaction provided by the instrument with audio feedback transmitted via JackTrip (Juan-Pablo and Chafe 2009). As part of the design decision to focus on the interaction and conveyance of presence *through* the instrument, video broadcasting of the performers between sites is never used for *Ambiguous Devices*.

2. PLAYING AT A DISTANCE: MULTISITE PERFORMANCES AND INSTALLATIONS, AND CO-LOCATED PERFORMANCES

The first public showing of *Ambiguous Devices* took place on 27 April 2012 in the form of a network music concert hosted between CCRMA at Stanford

[5]Created in collaboration with Neil Fawcett. See www.paulstapleton.net/portfolio/bonsai-sound-sculpture-boss.

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Figure 3. Feedback network prototype.

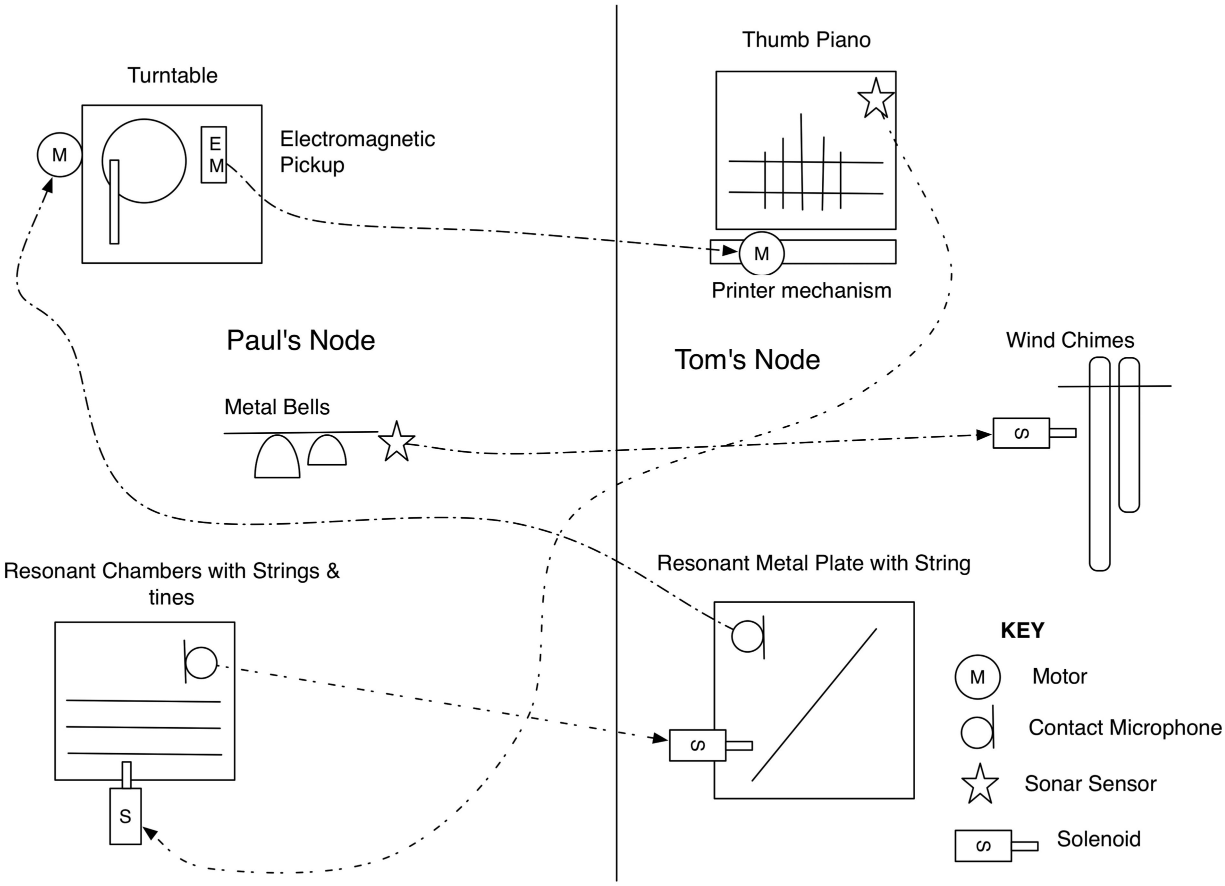

Figure 4. One possible configuration of *Ambiguous Devices.*

University and the Experimental Media Research Group (Emerge) at Bournemouth University. The event was part of *LIVEness* – a one-day intensive multidisciplinary exchange laboratory for practitioners exploring concepts, philosophies and technologies of *the live*. In this duo performance, we were geographically separated (i.e., Stapleton at CCRMA and Davis at BU) but connected physically through the two nodes of our distributed instrument. From the audience's perspective at either of the two sites, it could easily

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Figure 5. Performance at NIME 2012, Stapleton (left) and Davis (right).

have been misunderstood that we were each giving a solo performance while parts of our instruments were being mechanically manipulated by a mysterious form of automation. As we were on this occasion less interested in the mystery produced by this type of illusion, we decided to contextualise our performance ecosystem in a preconcert talk that was heard by audiences in both sites. We hoped that a basic understanding of the system, combined with an acknowledgement of our remote presence in the absence of visual representations, might help audience members focus more directly on the musicality of our collaboration. A similar configuration of *Ambiguous Devices* was later presented at the International Conference on New Interfaces for Musical Expression (NIME) in 2012 as a network music concert between University of Michigan (UoM; Stapleton) and BU (Davis) (Figure 5). For this performance we decided to project a live video of Stapleton's local setup to make parts of the action more visible to the UoM audience. This video was not broadcast to BU; only low latency audio and control data was streamed between the two sites.

Movie example 3 intercuts between synchronised extracts from both performance sites, where Movie example 4 provides a different view of the full performance from the perspective of the audience at UoM. This performance was focused on the musical result rather than functioning as a demonstration of the workings of our system. The documentation videos reveal this priority, as they feature aspects of our performance styles that can be found in our collaborative improvisations with other instruments and musicians. At times our cumulative playing is frenetic and highly physical and at other moments we are fragile and sparse, which again is not particularly unusual in improvised music contexts. Yet, the system appears to be augmenting our playing, not just through generating new mechanically driven musical gestures but also through encouraging a different type of listening. Both the frequency of synchronisation and fragmentation felt significantly amplified within this performance ecosystem. Performance habits and techniques were often disrupted physically, such as when vinyl record scratching gestures were complicated by sudden bursts from a belt-driven motor. From where did this motorised action originate? Owing to the pace of the improvisation, there was no time to contemplate such a question while performing; we were instead occupied with rapid and overlapping cycles of listening, adapting and responding. The least familiar factor here is that this adaptation was at times in response to physical changes from within each of our performance setups, caused by a mix of distant and local forces. This intertwining of forces resulted in a strong sense of both temporal and tangible co-presence between us as performers across a significant geographical distance.

Instead of providing contextual information through a preconcert talk, audience members at UoM had the opportunity to interact directly with our performance system through an installation version of *Ambiguous Devices* that was running throughout the NIME conference. Participants were invited to interact with Stapleton's performance setup. Certain actions resulted in non-linear reactions in Davis's node at BU, which in turn resulted in solenoids firing or motors spinning back in UoM, thus creating temporary feedback loops in the control data. Davis would at times reconfigure or play with his performance setup, creating further alterations in the control data being passed between the two sites. During these interactions, participants were wearing headphones that provided a mix of the audio streams between the two sites, which were primarily generated from amplified acoustic sources.

For this installation version of *Ambiguous Devices*, little to no explanation was given as to how the system worked until after the initial interaction. This commonly resulted in participants asking one or several of the following questions:

Figure 6. Installation between SARC (left) and BU (right) in 2013.

- Is the system playing back pre-recorded sounds based on my actions?
- Am I listening to acoustic or electronic objects being triggered in another space?
- Who or what is moving the instrument?
- Am I playing together with a machine or another human?

In order to better understand how these questions emerged, and how they might be interesting for performers and audiences of future iterations of *Ambiguous Devices*, we decided to run an informal study version of the installation between SARC and BU in 2013 (Figure 6).

Movie example 5 shows extracts from two participants interacting with the installation across two different sites, with audio from both sites mixed over loudspeakers. Each participant is initially unaware that another person is interacting with them in a different location in real time. After some time was spent interacting with the installation, participants were given a paper and pen and asked to describe their experience of the installation. Descriptions revealed a compelling level of ambiguity as to how the system was responding to their presence and actions. One participant described 'the system's "responses" [as] musically convincing' while noticing that 'the behaviour seems to change either depending on the performer's input or randomly. As a result one cannot control or even predict the electronic part.' They equated this to being 'just like improvising with a human performer'. Another participant interpreted the interaction on a spatial level, describing the 'interesting use of extended space as your own sound reflects back'. A third participant perceived a separate agency at work: 'The "other side" [which was how I conceived of what was happening automatically, or in response] was providing plenty of sonic variation and "apparent listening".' At the SARC site, the loudspeakers were hidden behind a large white curtain. This may have contributed to the account of one participant who questioned if they were playing with someone or something in the same room: 'It was genuinely unclear to me whether there was human agency "behind the curtain" … Eventually I looked behind the curtain just to verify that there was, in fact, no other human agency involved.' The ambiguous nature of the 'hidden agent' is reminiscent of Alan Turing's (1950) now classic test for machine intelligence, as well as the older eighteenth-century 'autonomous' chess playing machine known as *The Turk* (Levitt 2000). In the latter, participants are under the illusion that they are playing a game with an intelligent machine, when in fact this machine is being operated by a hidden human player. In *Ambiguous Devices*, we were happy to further complicate this question of agency through its distribution across the networked human–machine–environment.

While we were interested in the challenges and opportunities raised by playing together across geographically separate locations, we did not view *long-distance playing* as a necessary component of *Ambiguous Devices*. We were also interested in performances that intertwined our instruments while we were *co-located* on the same stage. We began to develop this new configuration in 2013 through a design and performance workshop session at SARC, which included performing with our system along with other improvising musicians. Our aim here was to foreground collaborative music-making over the novelty that arguably still motivates much of telematic performance. Our first co-located public performance took place at *INTIME 2013* – a symposium on adaptive and assistive technologies in music at Coventry University. Shortly after we performed with the same setup in the less academic setting of the Re-new Digital Arts Festival in Copenhagen (Figure 7).

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Figure 7. Co-located concert at Re-new 2013, Copenhagen.

Movie example 6 shows short extracts of us rehearsing with a co-located version of *Ambiguous Devices*. Our individual performance nodes remain networked together through an architecture similar to that employed in our previous long-distance configurations. The use of acoustic feedback became more prominent in these performances, both as a method to drive behaviour in the system and as a desirable musical material in its own right. Another meaningful difference between this configuration and previous setups was the intermingling of unamplified acoustic sounds across the two nodes. This shared acoustic environment and the spatially conditioned use of feedback combined in unexpected ways, in turn disrupting the calibration of sensors and actuators, resulting in newly emergent behaviours across the wider ecosystem.[6]

3. A BRIEF GENEALOGY OF HUMAN–MACHINE IMPROVISATION

In this section we aim to situate our work within a genealogy of human–machine improvisation, while highlighting specific values that continue to motivate our artistic approach. The fusion of improvisation and technological innovation can be found in a broad range of cultural and historical practices. The work of jazz band leader and afrofuturist Sun Ra sheds meaningful light on the possibilities of this relationship. Influenced by 'Scriabin's use of colored lights to reinforce and correlate with specific sounds' (Szwed 1998: 262), Sun Ra developed and employed new machines such as the Sun organ 'which played colors as well as sound, the low notes deep blue and dark hues, the high notes oranges and yellows' (ibid.: 210). Musicologist John Szwed also documents Sun Ra's collaborations with a variety of inventors, including the Chicago Musical Instrument Company, to make new instruments such as the Spacemaster, an organ that was described as sounding 'like a theremin or bagpipes' (ibid.: 226). Like many other composers interested in the possibilities afforded by music-making machines, Sun Ra's development of instruments was motivated by new timbral and textural possibilities; however, his application of these new musical resources was not formalist in nature. Sun Ra's prophetic interest in the space race, which played out in the late 1950s and 1960s against the backdrop of the African-American Civil Rights Movement, was based on the myth-making possibilities of technology, both musical and extraterrestrial. As Szwed puts it, 'Space was also a metaphor which transvalues the dominant terms so that they become aberrant, a minority position, while the terms of the outside, the beyond, the margins, become the standard' (ibid.: 140). For Sun Ra, the critical possibilities embodied in the combined practice of improvisation and instrument design offered up the possibility to challenge social norms through the act of music-making itself. Ultimately, Sun Ra contributes a form of music that is both a socially aesthetic and a transgressive activity.

Michel Waisvisz, former artistic director of the Studio for Electro-Instrumental Music (STEIM), championed the role of 'touch' in the development and performance of electronic music. Waisvisz was working from a position often marginalised by the digital music industries as well as technologically minded

[6]Further documentation and updates on future work can be found online at www.paulstapleton.net/portfolio/tomdavis.

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composers such as Pierre Boulez and Karlheinz Stockhausen. For Waisvisz and his colleagues, 'The problem in too much academic music of the sixties and seventies was precisely a loss of trust in hands and ears' (Norman, Waisvisz and Ryan 1998). His argument that physical effort and risk should be valued over painless control and predictability in performance led him to advocate that composers working with new technologies should also be disciplined performers who are able to improvise with their technological innovations. In an earlier 1990 interview (Krefeld 1990), Waisvisz discusses his views on the interconnected nature of the roles of musical instrument inventor, composer and performer. Again, here he stresses that composers of electronic music must also be performers who are capable of making musical decisions in response to real-time phenomena rather than only predetermined musical forms.

Liveness, dialogue and risk between composer–performers and their instruments are values shared by Waisvisz and Sun Ra. In both we find artists who understand technological innovation as a means to developing real-time music that is simultaneously intellectual and sensual in nature. However, this philosophy of music-making is not only found in the fields of tangible electronic music and space jazz. Notable examples of the composer–improviser–inventor can be found in the acoustic instrument domain, such as the work of Harry Partch, Bart Hopkin, Max Eastley, Tom Nunn and Peter Whitehead. Although the motivations of each of these artists are specific to their own practices, they all share an extended view of music-making that necessarily includes the creation of new instruments accompanied by sustained performance practices. Their impulse to create instruments does not appear to be motivated by either novelty or mass production; rather, they seem called to make objects with which they continue to engage in highly personal long-term musical relationships.

Relevant to our discussion here is not only the practice of inventing new instruments from scratch but also the reappropriation and reduction of existing technologies for performance. This activity is most visible in hardware hacking and DIY electronic music culture, a field that is documented in compelling detail by Nicolas Collins in the DVD accompanying *Handmade Electronic Music: The Art of Hardware Hacking* (Collins 2009). Here we find a democratisation, as well as a subversion, of technological resources for making music. The resulting soundworlds often bear little relationship to conventional musical structures, and can rarely be described accurately by notational systems. This absence of formal precision is not for lack of intellectual rigour or physical discipline, as such performance practices generally demand significant improvisational ability. Perhaps surprisingly, the most successful custom-made and augmented instruments, in terms of their long-standing use, are often more constrained than open-ended in their potential for interaction. The creative potential born of instrumental constraint has been conceptualised and studied (Bowers and Archer 2005; Gurevich, Marquez-Borbon and Stapleton 2012). Likewise, Waisvisz's championing of effort and resistance in improvised performance suggests that subservient instruments are less interesting than ones that on some level complicate and restrict the will of performers. It is this challenge, entering into a deliberately symbiotic relationship with chaos and uncertainty, that is embraced by many DIY electronic musicians.

Industrial and punk musics have also made important contributions to the practice of technological reappropriation and improvisation. The early work of Einstürzende Neubauten, in particular the textural and percussive performances of N. U. Unruh and F. M. Einheit combined with the extended vocals of Blixa Bargeld, displays a level of risk and physical effort rarely present in academic musical circles. Einheit's use of electric drills against large metallic springs and Bargeld's use of an air compressor to augment his voice are two examples of an approach to performance that is both significantly reduced as well as fully saturated. Einheit's ability to intelligently transfer his brutalist approach to performance to other improvisational contexts is evidenced through his long-term collaboration with guitarist Caspar Brötzmann (son of saxophonist Peter Brötzmann). Likewise, Ikue Mori, who is perhaps best known for her reappropriation of drum machines in free improvised music contexts with performers such as Fred Frith and Evan Parker, began her musical career as a punk drummer. The raw intensity of her earlier music is still perceptible in the tense and disciplined listening she employs in her drum machine performances.

Mori (drum machine), alongside Christian Marclay (turntable) and Toshimaru Nakamura (mixing desk), provides an iconic example of how to disrupt the intended design of specific music technologies. These practices reveal a discomfort with the proclivity for homogeneity found in the music technology industry, as well as the tendency of improvising artists to go beyond perceived limits and cultural conventions – a kind of hacker's extended technique. Additionally, each of these performers marks their technological subversions through the development of highly individualised performance practices. The privileging of difference over standardisation remains a significant feature of this form of improvised music.

Much of the innovation that has taken place in what we are describing as 'human–machine improvisation' has happened outside the academy. This multifaceted scene is propagated by growing international communities of designer-makers (e.g., MakerFaire.com, GetLoFi.com),

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as well as by geographically specific activities such as Berlin's Echtzeitmusik scene (Beins et al. 2011; echtzeitmusik.de) and San Francisco's Bay Area Improviser's Network (bayimproviser.com). We are active participants in these contexts, and this participation continues to shape our understanding of our own artistic and research motivations. These diverse communities are by no means reducible to a set of principles; however, in such settings it is not uncommon to find evidence, tacit or otherwise, of the values outlined in this brief genealogy. It is these values that underpin our strategies for designing musical interactions.

4. AMBIGUITY BEGETS AGENCY

In this section we discuss the positive role of 'ambiguity as a resource for design' (Gaver, Beaver and Benford 2003), and point to the role that ambiguity can play in the emergence of distributed agency in musical ecosystems. Bill Gaver et al. argue that 'things themselves are not inherently ambiguous' but rather ambiguity is created through an 'interpretative relationship between people and artefacts' (ibid.: 235). This definition is attractive as it highlights the temporal and subjective nature of ambiguity, as something that is constructed in the moment through engagement with an object or situation. As Gaver et al. note, these ambiguous encounters elicit personal responses as they provoke 'users' to formulate their own understanding of 'artefacts', and thus establish a deeper relationship to wider 'systems' (ibid.: 233). As such, ambiguous encounters impel 'users', be they performers or audience members, to assess the situation for themselves, to construct a personal understanding and connection to objects, and to question the function of these objects within their contexts of use.

A level of ambiguity in the behaviour of instruments often has implications for how they are perceived by both musicians and audiences during performance. Media artist Nell Tenhaaf (1998) argues that people have a pervasive tendency to attribute agency to technological devices spontaneously without consideration. This tendency to attribute agency to machines may emerge from what philosopher Daniel Dennett (1971) describes as one's 'intentional stance' towards an object: 'the strategy of interpreting the behavior of an entity (person, animal, artifact, whatever) by treating it as if it were a rational agent who governed its "choice" of "action" by a "consideration" of its "beliefs" and "desires"' (Dennett 2009: 339). In this interpretation of the human–machine relationship, the agency of technology exists because it exists for the observer or user of the device. Ferguson, in 'Imagined Agency: Technology, Unpredictability, and Ambiguity', shares audience feedback from one of his performances with instruments designed to exhibit ambiguous traits, in which they are described as 'compelling as a lion-tamer to watch' (Ferguson 2013: 140). In this instance the audience appear to be interpreting the instrument as a separate entity that has its own agenda – that sometimes does and sometimes does not bend to the will of the player. As such the musical instrument takes on a level of agency that is palpable to both audience and performer.

Stapleton has previously explored similar notions of instrumental agency in his article 'Dialogic Instruments: Virtuosity (Re)Located in Improvised Performance' (Stapleton 2008). Here he characterises a level of resistance designed into his acoustic instruments to promote music-making where the goal 'is not homogeneity or the resolution of difference, but instead a form of *convivencia* (a tense but productive co-existence)' (2008: 4). In this sense the music is not made with or through a passive instrument, but rather in dialogue with an instrument. This represents a reconfiguring of the relationship between performers and instruments such that a group of musicians respond not only to each other but also to the instruments themselves. Ferguson makes a similar observation:

> through performance, it is possible to imbue meaning into a system that always remains essentially playable, but offers enough sense of its own agency to surprise and challenge (both performer and audience alike!). In this case, one performer is not just in dialogue with another, or internally with themselves, but also with a third element, an invisible and unpredictable presence that acts to stimulate and extend dialogue. (2013: 144)

David Borgo and Jeff Kaiser extend this view of the relationship between performers and instruments by drawing on the concept of *configuration* as described in 'Actor Network Theory' (Law 1999; Latour 2005). Borgo and Kaiser define configuration as 'a mutually constitutive process through which users, technologies, and environments are dynamically engaged in refashioning one another in a feedback loop' (Borgo and Kaiser 2010: 1). In this sense Borgo and Kaiser characterise improvisation not as a conversation between parties, or even as a dialogue, but as a 'mutual configuration of a shared sonic and behavioral space' (ibid.: 2). Within this idea of *configuration* the technology is not a passive intermediary of the intentions of the musician(s); in fact, since the technology and the human parts are co-constituting, it is better to understand the human–machine–environment relationship not as a trichotomy of separate parts but as one co-constituting assemblage. Such a conception resonates with Evan Parker's (1992) description of the saxophone as an extension of his body: 'In the end the saxophone has been for me a rather specialized bio-feedback instrument for studying and expanding my control over my

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hearing and the motor mechanics of parts of my skeletomuscular system and their improved functioning has given me more to think about.' One should not confuse Parker's account as simply an *embodiment of the tool*, along the lines of Heidegger's 'ready-to-hand' (Heidegger 1962). Rather, Parker's musical identity evolves through his ongoing symbiotic relationship to his saxophone, which in turn shapes his audience's understanding of what a saxophone can be.

Continuing in this vein, we follow philosopher Andrew Feenberg (1992) in taking a non-deterministic stance in our understanding of our relationship to technology. Feenberg's notion of a 'critical theory of technology' (Feenberg 1991) situates technology not as a neutral tool but rather as something that shapes and is shaped by cultural practices. In this conception, the developmental progression of technology is open to being influenced and changed by individuals and social groups who in turn are also shaped through their interactions with technology. In the context of performing music together across geographically distant locations, it is clear that treating the network as a neutral tool commonly results in impoverished aesthetic experiences, particularly when attempting to closely simulate the experience of playing together in a less physically distant setting, that is, the network in itself will not save us! We thus call for greater recognition of the specific agencies that human–machine assemblages exhibit during the structuring of relationships within networked performance environments. As artist Agostino Di Scipio notes, adopting such a non-deterministic stance presents 'an opportunity to challenge established and uncritically accepted practices and theories, the known modalities of personal or shared modalities of music making' (Di Scipio 1997: 64). This is an opportunity in which we can both resist and be resisted, be pushed and push back, and in this process cease from viewing musical instruments and performance environments, as well as our own identities, as merely static and inert possessions.[7]

5. TOUCH, FEEDTHROUGH AND CO-TUNING

So what might it *feel* like to be within a co-constituting assemblage of music-making humans and machines? And what is the role of feeling, or *touch*, in the creation of distributed musical agency? In 'Touching at a Distance: Resistance, Tactility, Proxemics and the Development of a Hybrid Virtual/Physical Performance System', Simon Waters gives an account of embodied relationships between instruments and performers, focusing on how the peculiarities of early flute designs were exploited by composers. For Waters it was the 'difficulties' and 'resistances' in playing with early instruments that ultimately gave 'the repertoire its character and "meaning"' (Waters 2013: 124). Waters employs a similar logic in his discussion of more recent music-making activities:

> One of the benefits of hybrid (physical/virtual) systems is their very impurity: their propensity to suggest or afford rich unforeseen behaviours which engage the player (and the listener) at a variety of levels: sonic, tactile, and dynamic. And through our engagement with the unfamiliarities presented by such systems we become aware of the extent to which the bodily (and embodied knowledge) is implicated in our conduct with respect to, and understanding of, instruments in the broadest sense. (Ibid.: 125)

Waters's description resonates with our experience of developing *Ambiguous Devices*, a process that has required us to think more critically about the roles of touch and resistance when designing networked musical interactions. In doing so we find our work aligning with the practices of other instrument-maker-performers such as Waisvisz, who stress the importance of the *haptic* channel and its connection to listening. Our work also builds on the past few decades of research into the potential of 'haptic feedback' in 'computer-based musical systems' (O'Modhrain 2001) and in interaction design more generally.[8] However, while sonic and tactile feedback can undoubtedly provide meaningful information to performers, we have become increasingly interested in better understanding how our physical presences are mediated and reconfigured through our interactions with *Ambiguous Devices*, resulting in a form a tactility that is less direct and more distributed than feedback.

Originally developed in the context of Computer Supported Cooperative Work (CSCW), Alan Dix introduces us to the concept of *feedthrough*, stressing the importance of updating the artefact of interaction in order to communicate information to other users (Figure 8). For Dix, feedthrough 'effectively creates an additional channel of communication through the artefacts themselves' (Dix 1997: 148). Dix notes that this sort of communication – communication through the object – is often more important than direct communication. He cites the example of moving a large piano: 'You may say things to each other – "move your end up a bit", "careful of the step" – but in fact the most important thing is the feel of the other person's movements through the movements

[7]Here we are drawing on Judith Butler's study of moral philosophy where she describes 'our willingness to become undone in relation to others' as an opportunity 'to be addressed, claimed, bound to what is not me, but also to be moved, to be prompted to act, to address myself elsewhere, and so to vacate the self-sufficient "I" as a kind of possession' (Butler 2005: 136). Stapleton (2013) has elsewhere developed this line of thinking in relation to improvised music and musical identity.

[8]See, for example, the annual International Conference on Tangible, Embedded and Embodied Interactions (https://tei.acm.org/).

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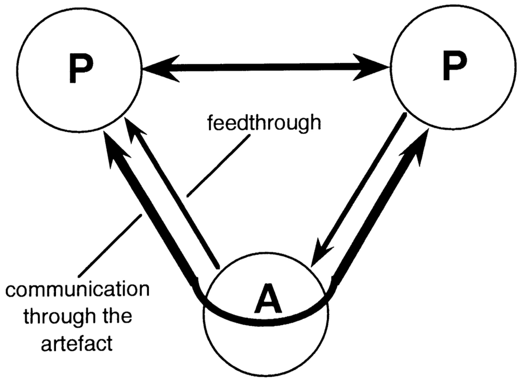

Figure 8. Feedback and feedthrough (Dix 1997: 148).

of the piano' (ibid.). For Dix, the communication through the piano, or through the instrument of interaction, is more effective because it is 'unconsciously noticed and acted upon' (ibid.).

In *Ambiguous Devices*, the nodes of the instrument are networked together to allow for a sense of the other performer's presence through their touch and movement, felt through the physicality of the instrument. However, it is not always clear which actions in one node result in the movement of actuators in another node. Causality is observable to a degree, but the behaviour of the wider ecosystem retains a level of ambiguity. Equally, it is not always clear who (or what) is 'touching' whom, as the musical interactions at play are often more precarious than the action of moving a piano across a room.

Steve Benford, who has published widely in the area of mixed-reality performance, critiques the current lack of feedthrough in commercial electronic instruments despite the possible benefits to player collaboration. He also notes that 'a host of CSCW systems and related studies have highlighted the benefits of also providing a feedthrough channel by embodying users within the digital space of the interface itself' (Benford 2010: 54). The importance of feedthrough is further highlighted when modes of direct communication are not present. In the case of *Ambiguous Devices*, when we are performing in separate spaces, visual cues are missing. Feedthrough can provide an alternative approach to communicating across a network by providing a sense of a remote performer's presence within the instrument: an embodiment of performance interaction. This indirect interaction can supplement audio feedback, providing another creative avenue of communication in a networked performance context.

We recognise certain limitations in describing human–machine improvisations in terms of communication models. Musical meaning is perhaps better understood as emerging from an individual's experience of a musical event, rather than something that is communicated between performers through an artefact. However, in our work feedthrough serves not only to connect the geographically distant performers but also to highlight the active nature of the instrument. Thus, performances with *Ambiguous Devices* are able to rehearse different conceptions of instrumental interaction: the instrument as a conveyor of physical presence between performers; the instrument as a resistive agent with its own emergent behaviour; and the instrument and performers as a single co-constituting music-making entity.

A similar elaboration of mutual constitution is also found in the work of philosopher Shaun Gallagher based on the enactivist position[9] that 'the organism and environment are not two things that are merely causally related to each other, but are mutually constituted in this relation—organism-environment … The organism is not a cognitive agent before coupling to an environment; the environment is an essential, constitutive, element in making the organism what it is' (Gallagher 2014: 120). Likewise, the environment does not exist as a distinct entity, separate from its own inhabitants. In the context of *Ambiguous Devices*, we conceptualise the action of mutual constitution across the human–machine–environment ecosystem as *co-tuning*, which flattens the hierarchical relationship between human and non-human actors. Co-tuning is a process of becoming, of music-making practices gradually formed through cycles of exploration, discovery and adaptation. This is a type of tuning that employs and shapes not only the ears but also the hands, our sense of multimodality and the many resistances across an ever-updating network of human and non-human relations. The specificity of a musical ecosystem only comes into existence through the co-tuning of all participants, including instruments, audience members, architectural spaces and social places. The aim is not equilibrium; rather, co-tuning is a process imbued with a level of uncertainty and ambiguity that requires skilful adaptation, out of which musical meaning is personally made.

The initial aim of the project was to challenge and extend our practices as improvisers and instrument makers. Through this project and our related research we continue to ask, 'how can we move past the design motivation of interface transparency towards a recognition and celebration of resistance, instability and co-tuning?' (Stapleton, Waters, Ward and Green 2016: 329). In doing so we hope to contribute towards a culture of music-making that abandons control of objects, others and self as the primary goal of performance, in

[9]The relationship between enactivism and ecological psychology (Gibson 1979) in the context of musical instrument design and performance has recently been investigated by Rodger, Stapleton, van Walstijn, Ortiz and Pardue (2020).

favour of something less tedious and anti-social. To be clear, we are not advocating for the rejection of cultural traditions and techniques developed through physical discipline; improvisation is perhaps at its best when the skills developed from practice are at times deployed, deferred and transgressed in a radical openness to the present.

SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit https://doi.org/10.1017/S1355771821000054

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