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Breaking Out: The Trip Back

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The author discusses how sound was used in early Turbulence Internet works (1996–1998) and musical collaborations distributed between multiple physical performance venues (1998–1999). Focusing on the open composition, the article addresses the challenges of Internet-based musical interaction, including asynchronous time, lag and technical glitches. The latter part of the article focuses on the advent of mobile devices and wireless networks and the migration of computing out of the desktop computer into the physical world, and the resulting changes in musical experience. As composers and non-composers encourage active 'audience' participation in the realization of the work, the accepted nature of performance is called into question and a shifting relationship between the artist (composer), artwork (composition) and audience is introduced.

Keywords: Internet Art; Networked Performance; Streaming Media; Open Work; Latency; Bandwidth

Introduction

The history of networked computer music begins long before I became involved with the Internet, with the League of Automatic Music Composers that later evolved into The Hub.[1] This article, however, is not about the history of networked music, but about my experience, both as a participant in its more recent history, and as the director of the Turbulence.org website, which has commissioned artists to create art for the Internet since 1996. In the latter capacity, I have come to know musicians and composers, whose names may not be so well known as those who are remembered as part of the earlier history. The work of some of these has become the subject of the first part of this article, which reaches back to 1996 and ongoing struggles with so-called 'limitations' of the Internet and its evolving technologies. The article also gives voice to my interest in seeing composers and musicians use these limitations rather than avoid them, and to an even greater interest in the possible transformations music itself might undergo in the digital realm.

The advent of mobile devices and wireless networks has precipitated a sudden explosion of just such transformations and the latter part of this article is based on my observations of developing trends, which I have not had the good fortune to

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experience first-hand, but rather have come to know about through Turbulence's networked performance blog (http://turbulence.org/blog/). My observations focus on some of the ways and areas in which the experience and context of music is changing. The title derives from the fact that so much of today's new ways of working and experiencing originate from the ephemeral practices of the 1950s and 1960s—from the work of John Cage, Robert Rauschenberg, the artists of Happenings and Fluxus and so on—in which the open work is central, allowing for shifts in the traditional paradigm: artist, artwork, audience.

Looking Back

I was recently asked whether my background in radio conditioned the type of Internet art projects commissioned for the Turbulence site (http://turbulence.org) over the years.[2] The answer is of course 'no'. Turbulence does not favor sound art. It encourages exploration, the dissolution of traditional boundaries and the collaborative process; its commissions are eclectic. The question, however, reminded me of how supremely difficult, if not impossible, it was in 1996 and for several years thereafter to achieve anything approaching 'quality sound' and how frustrating some composing artists found this, including initially myself. Technological innovations in sound, as argued by Rick Altman (1980) and Mary Ann Doane (1980a, 1980b) in their 1980s film sound studies, derive from the felt need to suppress the noise of the system and the apparatus in order to present as 'natural' that which is a product of ideology. On the 1996 Internet progress toward this goal, the elimination of noise and other artifacts of the network had only just begun. Moving, as I did, from radio to the World Wide Web was moving from an evolved radio technology capable of delivering the seamless beauty of carefully composed ambient and instrumental sound and vocal narration to an unevolved technology in which sound jerked and staggered into the ears with a crackle, hiss and pop.[3]

Audio on Web Pages, 1996–1999: Strategies for Mitigating Network Limitations in Web Works

The one Internet-savvy artist commissioned in Turbulence's first year, Marianne Petit, optimized her multimedia work (*The Grimm Tale*, 1996; see http://turbulence/Works/grimm/index.htm) for a 28.8 band modem and devised strategies that would not place excessive demands on bandwidth. MIDI, which abstracts the control information from the actual sound, was her solution to the problem of sound quality. Because the files were small, they added little to download time; and because they were embedded in an invisible browser frame, the audio was continuous across multiple pages.

Another strategy, employed a year later by poet/composer, John Hudak (*Artifacts*, 1997; see http://turbulence.org/Works/Hudak/index.html), was to use small compressed sounds. Hudak, whose work was based on pictures and sounds from the

Internet and organized into framed moments, used small, highly compressed audio-only Quicktime-.mov files that would loop with the GIF images in his work, but were not embedded in them. Not embedding them allowed for variations in synchronization between the visual and audio.

The use of short sounds with deliberate breaks between was another strategy. In 1999, when I was invited by the Walker Art Center to review the *PHON:E:ME* soundtrack by Eric Belgum (see http://phoneme.walkerart.org/), I was impressed with its success. It was both a composed and open work: it could include the impact of net congestion and the efforts of the RealPlayer to minimize lost or temporarily missing packets of sound (crackle and pop). In addition, each time buffering[4] occurred, the piece was reconfigured. What you heard was not what I heard. The *PHON:E:ME* soundtrack was a different composition each time it was played, authored, as it were, by the composer, the ever-changing Internet environment, the protocol for data transmission and the RealPlayer's efforts to deal with its errors.[5] It was also, I discovered, 'accidental' in the sense that the composer had not dealt with the Internet before, and while his composition suggested a successful strategy for dealing with the Internet's evolving technologies, the work was composed apart from them—it could have been a work for radio or CD-Rom—and with little knowledge of the difficulties the network presented to the 'ideologized ear'. It was an acoustic composition transferred into the digital realm.

It was only with John Neilson's *Radio_stare*,[6] a 1997 Turbulence commission, that one got the sense of a more open approach to unplanned sound. Neilson set out to create an audio-based work that was unique to the World Wide Web. For him, the Web offered a way to make 'a sound art installa- tion that combined elements from remote locations into a work that was accessible world-wide and presented a unique experience to everyone who spent the time'.[7]

Someone once said that there is no such thing as sitting tranquilly in front of an Internet art page the way one sits in front of an art object. At the core of the Internet art experience is the hand that is always moving you on to the next step. A psychology of impatience prevails. *Radio_stare* is an invitation to a more tranquil experience. As a passenger in Neilson's vehicle, you watch the night highway stretch out in front of you; but you are a passenger, not the driver, and you move at Neilson's pace, slowly. The work opens with the graphic of a radio tower against a night sky; a few beeps are heard. Then as the graphic scrolls to the top of the page and the tower disappears, another screen opens. You are in a car. The headlights pick up the centerline; the road is otherwise dark and empty. Now and again you pass a radio tower. It is as this second screen opens that the browser downloads a Quicktime MIDI file and you hear the slow, steady rhythm of a drum combined with the mellow sound of a synthesizer. The music is intentionally repetitive and bland. Simultaneously, the browser opens up the RealAudio Player to receive a live stream from a police scanner site. Instructions tell you to adjust the volume of the RealAudio Player, turn off the lights and listen.

So here it is, a work designed to meet the limitations of the medium. A small compact Quicktime MIDI file for the looped music that added little to download time,

and even more importantly, played simultaneously with the RealAudio stream[8]—and an outside source, the scanner, that uses a steady stream of bandwidth, but is live, readily available and completely unpredictable—not even the police can anticipate all that is transmitted by their network. It is this outside source—well beyond the control of the composer—that determines 'the feel' of the work and in the process captures the unpredictable nature of the networks it employs.[9]

Networked Performances: Linking Musicians

From 1997 onwards, I anticipated an interest on the part of composers and musicians in using pops and crackles and even more particularly, network latency as part of their work. And I began to look forward to a time when networked music would become more than a recapitulation of acoustic music. In early 1998, Jesse Gilbert and I initiated what we called the 'Online.Arts' project. This was a direct result of our experience with the online *Adrift* performances, where three artists (Gilbert, Marek Walczak and myself), working from three different geographical locations and out of three different computer environments (text, sound and VRML), created an evolving work that came together (as the result of some magnificent Java scripting on our server) and was delivered simultaneously to online audiences and to audiences in various geographical locations. *Adrift* was premiered at the Ars Electronica Festival in September 1997 and performed monthly from then until April 1998. Its final iteration was at the New Museum in New York City in 2001.

Adrift made us all acutely aware of how few art sites were equipped to receive or participate in online performance events. The Online.Arts project was begun in the Spring of 1998 to help deal with this problem. As Gilbert and I both had backgrounds in music and sound, we elected to work initially with sound/music organizations and help make as many of them as possible 'broadcast-enabled'. Harvestworks, Inc., the Pauline Oliveros Foundation and Mills College were the first we approached. Others were expected to take part later in the year. The idea was to develop each site so that artists could collaborate over space and over time in the creation of medium-specific work. This included the development of a schedule of regular, coordinated performances that would be made available simultaneously to local and Internet audiences. The archives of these events would be permanently available on the Turbulence website.

What happened was, of course, something else. In 1998, we were successful in producing a series of three distributed musical performances: *Loose Ends/Connections* (September 1998; see http://turbulence.org/Works/loose/index.html), *Feedback* (December 1998; see http://turbulence.org/Works/feed/index.html) and *Spaces* (1999; see http://turbulence.org/Works/spaces/index.html), each with seven or eight participating musician/composers. All of the performances originated from the same three locations: Mills College in Oakland, California; Harvestworks, Inc. in Soho, New York City; and the Morton Street Studio in the West Village, New York City. The Morton Street Studio was the hub location, where incoming streams from the other sites were mixed with live and prerecorded music and sound, and the final mix

converted to RealAudio and streamed back to the server and onto the participating sites and the Internet. The online audience could listen either to a high or low bandwidth version.

Loose Ends/Connections included Pauline Oliveros, Maggi Payne and Brenda Hutchinson performing from Mills College with both acoustic and electronic instruments, and Beth Coleman and Zeena Parkins performing from Harvestworks, Inc. Scott Rosenberg, Jesse Gilbert and I added our input at the Morton Street Studio and created the final mix. As determined by the musicians prior to the performance, the piece was an improvised one with only the vaguest suggestion of a framework. It included the use of acoustic and electronic instruments. Insects, howling wolves, distorted voices, water drops, drum beats, saxophones and clarinets all appeared within the mix. A slide show of video stills from Mary Lucier's 1998 *Summer, or Grief* with text from *A Conversation* by Allen Grossman accompanied the work, but was not synchronized to the performance, thus allowing audience members to move around in it at will during the performance. As described by Peter M. Traub in his Master's thesis in Electro-Acoustic Music, *bits and pieces*, *Loose Ends/Connection* 'had a meditative feel, changing very gradually. It also appeared to draw parallels and contrasts between technology and nature.' However, as he also observed: 'Natural sounds such as animals, waves, and wind combined or juxtaposed with their electronically processed counterparts has been a common theme in electro-acoustic music for many years.'[10]

The second piece, *Feedback*, was performed a few months later on 6 December 1998. Once again it was an improvisational work with only the simplest of instructions (which site would initiate the performance was one of them, as I remember). In it, composer/performers Pauline Oliveros, Maggi Payne and Brenda Hutchinson performed on long tubes, conch shells, and flute and used their voices. At Harvestworks, Shelley Hirsch and Jim Pugliese performed using voice and percussion, while at the Morton Street Studio, Scott Rosenberg played live saxophone and Gilbert and I added prerecorded music and did the mix. This time, instead of a slide show, an interactive painting tool, created by poet and animator Neil Zusman, was available and audience members were encouraged to paint to the music. The music was stylistically similar to the music of the first piece. 'Taken just as music,' Traub wrote, 'these pieces are nothing new aesthetically. Taken as a whole, however, they represent a new movement in electronic arts and electronic music. What they attempt to do technically is facilitate live interaction between musicians in different places. They also add graphical elements. Furthermore, the output is potentially audible to anyone on earth with an Internet connection.'

Loose Ends/Connections and *Feedback* were baby steps in the progress toward something new.[11] New forms of expression were my primary interest; and my focus during the Online.Arts project was on what might happen if the assembled composer/musicians opened their work to the unpredictable latencies and limited bandwidth challenges to real-time interactions and worked with them. Prior to performances, network characteristics were discussed; as performance considerations they went

unattended. The focus of the performers for these works was on the possibility, pleasure and excitement of remote participation.[12] In the end, the Online.Arts project was successful only in decoupling the spatial framework; it introduced a number of musicians to the networked process and enabled them to act and perceive without the familiar framework. However, in the performances, as Traub observed, we essentially recapitulated the familiar acoustic process.

Steps Along the Way

Gilbert went on to address the central question raised by these earlier performances: How do we move beyond the amorphous Internet 'jam session' by engaging strategies that acknowledge the challenges of Internet-based musical interactions, yet are not limited by them? In *Finding Time* (2000),[13] he and composer/performer Scott Rosenberg addressed the issue of clarity of communication and coordination and sought to provide a framework for musical collaboration across multiple sites by focusing on the link between visual materials and sonic expression. Instrumentalists on each of the six populated continents were connected through the Internet in an evolving composition that included a blend of notated and improvised elements coordinated in time and communicated through a graphic or visual score. The score was visible to the audience, and while their interaction was limited, they could watch the whole score, or by clicking on a number watch the score as it affected individual performers.

In *interaXis* (2001, 2002; see http://turbulence.org/Works/interaxis/index.html), Gilbert, along with Mark Trayle and Wadada Leo Smith, addressed the challenge of the multiple times and dislocations introduced with networked technologies, and how the audience, whose perceptions are conditioned by the conventions of the live performance medium, attempts to unify them into a single moment. 'Often,' Gilbert noted, 'when presenting networked performances in real time to a live audience, the sounds coming from remote locations are indistinguishable from the contributions of on-site performers, creating an ambiguous space that confuses rather than elucidates the interaction between the dispersed ensemble.' In each of the two *interaXis* performing spaces, Los Angeles and New York, the live performers were in static positions while the remote performers were presented through a spatializing system, thus creating a perceptual distinction between the two halves of the ensemble and an aural analog for the streaming process, symbolizing the movement of the audio stream between the sites. The spatialization system was networked and allowed for independent operation or linked operation that controlled spatial parameters of sounds in both spaces. As a result, the spatial configurations became a part of the performance. For the first performance, a symbolic text score was also created and used by the performers; for the second, Carole Kim created a video score that was projected in both physical spaces and was visible to the musicians and the audience. The scores functioned as raw materials for the performances, which were constructed spontaneously by the performers. The scores also governed transitions between behavioral states of the spatialization software.

Breaking Out

More recently, similar issues have been taken up by John Roach, who like myself was neither trained in music nor in performance. As he says of himself:

> I . . . come to this idea of networked performance with the desire to capitalize on its shortcomings. . . . How can the undesirable elements of electronic communication (delay, instability) be made to shape the final product? Turning the network into an active player in the process may be the only way of using the medium in a manner that doesn't simply reflect the countless other kinds of performance or information delivery formats that already exist elsewhere.[14]

The aleatoric aspect of networked performance, Roach goes on to say, is really one of its greatest strengths and 'a perfect extension of John Cage's ideas of indeterminacy: create a structure and then open it up to chance operations and other outside influences'.

Roach's first networked performance, *Negative Space*, introduced him to the limitations of streaming media, the difficulties they create and the possibilities he was able to envision as a result. Lag and flux became the starting point of his second work, *Simultaneous Translation*, which draws connections between language and the Internet. In it, the idea of flux and slippage is compared to the slippages and mutations of language as it evolves. Another point of comparison is the delays that occur on the Internet as data passes from router to router. Roach's collaborator, Willy Whip, has designed a software application for this project. The Sim-Trans software examines the trace routes[15] between the remote participants and the host (or hub) location. It then uses that data to affect the participants' audio streams in some way. If, for example, there are persistent delays in the router hops between one participant and the host location, 'the audio might be shifted to the right speaker, or its volume decreased or an effect manipulated. The goal is to enable the delays and fluctuations of the Internet to become active players in the shape of the sounds that emerge.'

The shape of the final piece, then, is determined partly by human intentionality and partly by machine (the Sim-Trans software), which acts outside of the control or desires of the participants, introducing into the work modifications deriving from Internet delay and instability.

The idea of an open work is implicit in much of the work composer and media artist Jason Freeman designs. Freeman's work combines mathematical structures, musical intuition and live performance in such a way as often to blur the boundaries between art and technology and between composer, performer and listener. Freeman's goal is to engage a broad public in 'playing with' sound. In many of Freeman's recent works, technology is a powerful tool for facilitating collaboration with the public. Instead of composing a conventional score, he develops computer software that plays the role of the composer, generating music according to his instructions and the activities of others. *Glimmer* (2004)[16] is an example; it engages the concert audience as musical collaborators who do not just listen to the

performance, but actively shape it. Each audience member is given a battery-operated light stick which he or she turns on and off over the course of the piece. Computer software analyzes live video of the audience and sends instructions to each musician via multi-colored lights mounted on each player's stand.

About this work, Freeman wrote:

> [I] have given up a tremendous amount of control. . . . I cannot . . . predict the notes which will be played, or the order in which they will be played, or the times at which various sections of the orchestra will play. I have given up fine-level control and instead defined a process and created a general structure. By doing so, I hope that interesting and maybe even wonderful things will emerge at the performance, things which I never could have predicted or imagined myself. Glimmer is . . . an experiment in reshuffling the roles of composer, performer and listener a little bit, so that they can have something more to do with each other, so that they can all be a part of the same moment. We are sitting in a room—together—so why not?[17]

In his *New York Times* review of the performance at Zankel Hall in January 2005, Anthony Tommasini (2005) wrote:

> As people flicked their lights in swirling, jabbing and jittery patterns, the musicians played riffs, chords, sustained tones, honks, squiggles and whatnot. . . . The problem was, the light show was infinitely more interesting than the music. Still, the audience seemed elated by the experience.

In other of his works, Freeman has dispensed with conventional performing ensembles and performance venues altogether in favor of a single group of 'users', formerly performers and listeners, who interact with the software to help create the music they hear. *N.A.G. (Network Auralization for Gnutella)* (2003), a Turbulence commission, is a perfect example. While Freeman describes its ideal user as 'someone who has at least some familiarity with what file sharing is . . . and maybe some background in music', *N.A.G.* is user-friendly and easily navigable by even novice computer users (MacBlane, 2003). What *N.A.G.* users are given is a post-Napster file-sharing tool that 'turns the process of searching for and downloading Mp3 files into a chaotic musical collage'.[18] The user has only to type in one or more keywords and *N.A.G.* begins the search for matches on the Gnutella network and downloads the files in which the keywords are found. *N.A.G.* checks the downloads, prioritizing them for real-time playback according to their speed. Users can alter Freeman's algorithm, select how many songs they want to play simultaneously, how quickly the software moves from one to another, and whether the software varies the speed and volume of song snippets as it downloads. The result is a remix of files in real time that is based on the state of the Gnutella network and user settings.

Auracle,[19] conceived by Max Neuhaus and realized collaboratively by Neuhaus, C. Ramakrishnan, Kristjan Varnik, Jason Freeman, Phil Burk and David Birchfield, is one of Freeman's most recent undertakings. Neither webpage nor distributed performance in the sense that it does not link musicians at venues in distant cities, *Auracle* is 'geared toward a broader base of ''performers'' and an ongoing, rather than

one-shot, performance event'.[20] It is 'a collaborative, networked, voice controlled group instrument', and its purpose is to make possible 'real time, interactive, distributed music-making over the Internet', in which 'distributed' means that the work engages a broad public in 'playing' with sound. To participate, one need only launch the application in a Web browser, join a group of up to five players called 'Ensembles', and then use your voice. The instrument analyzes the vocal sounds and transmits them over the Internet to control a synthesizer.

Bandwidth and latency were issues in designing *Auracle*; indeed, according to Freeman, the whole analysis/transformation/resynthesis structure of the project began with bandwidth concerns. They were resolved by sending control data over the network rather than streaming audio. Latency was an ongoing issue and in the end rather than trying to minimize it, they increased it: first, when using *Auracle*, users do not send data continuously, they only send it once a full vocal gesture has been detected. This creates what Freeman calls a 'call and response kind of environment: the user makes a sound, waits a second, and then hears *Auracle*'s transformation of it'. Second, a simple event distribution algorithm was developed that minimizes the overlap of gestures from different players. When the texture gets dense, gestures get delayed longer than latency time, and sometimes get time-compressed as well. Once again the result is something like a conversation between players.

New Contexts for Music Creation

Interactive and participatory systems, like those seen in *Auracle* and *Glimmer*, collapse distinctions between audience and performer and introduce a shifting relationship between the artist, artwork and audience. Central to this shift is the focus on process rather than art object (composition), participation rather than passive reception, and perception—the work consists of how it is received and experienced (e.g., 'the audience seemed elated by the experience'). All are attributes of the Open Work as introduced by John Cage, but while works like Freeman's exhibit these characteristics and concerns, both his work and the other networked performances referred to above, excluding only the work of John Roach, remain securely within the traditional paradigm, which distinguishes between arts disciplines and practices. The category to which they belong is music.

It is only with the recent migration of computing out of the desktop computer and into the physical world that an explosion of new projects has occurred in which different works calling for different categorization models have begun to appear. Far and away the most outstanding example is *Sonic City*. While it might be described as 'generative music', it also shares with numerous other recent non-musical works, interest in public space, mobility and everyday behavior, thus enlarging ideas of how music is generated and where. Its designers write:

> We have developed a system that enables users to create electronic music in real time by walking through and interacting with the urban environment. We explore the use

> of public space and everyday behaviors for creative purposes, in particular the city as an interface and mobility as an interaction model for electronic music making. (Gaye et al., 2003)

Designers Gaye, Mazé and Skoglund have broken out of the traditional context for making music and begun to think of mobile behaviors and urban conditions as musical parameters. In addition, rather than focusing on concert-based performances and professional performers, they have integrated music making into 'everyday life, familiar places and natural behaviors'. The city acts as the interface; the music is created by the user's mobility in the city—the contexts in which one places oneself, the events that occur accidentally or as a result of one's behavior. It is a co-production, by city and user, for personal musical expression. The user is the listener; the user is the audience.

Body sensors and a wearable computer make *Sonic City* possible. Its first implementation was a 'one-size-fits-all' jacket[21] designed to incorporate all of the system hardware: a set of environmental and biometric sensors, a BasicX-24 micro-controller, a USB-MIDI converter, a small laptop running the interactive music programming environment PD, a stereo microphone and headphones. Context and user action are mapped to sound processing parameters and turn live concrete sounds into music.

Wearables, like the *Sonic City* jacket, are physical interfaces, clothing and jewelry, that are screens, receivers and transmitters worn on the body. Using input devices, these garments and accessories receive, react and transmit. They perform and in the process create personally invested relationships to environments and individuals. Die Audio Gruppe, a Berlin-based art group, for instance, builds flamboyant electro-acoustic clothes and performs them. The clothes, equipped with movement and light sensors, radio receivers, sound generators, samplers, amplifiers and loudspeakers, produce sounds in response to the performers' movements and by interacting with the environment.

In one of Benoît Maubrey's more recent performances, *Audio Peacock* (2003; see http://www.turbulence.org/blog/archives/000563.html), the wearable electronic instruments were constructed from polycarbonate Plexiglas material shaped into a peacock's fan-like plumage. The Plexiglas surface was equipped with 16 loudspeakers (150 watts power), amplifiers and rechargeable 12-volt batteries, while the 'audio-plumage' was highly directional and functioned like an electro-acoustic radar dish. Aesthetically the *Audio Peacock* clothing 'has much in common with the way a peacock parades itself in front of the pea-hen (the audience)'. An *Audio Peacock* can either amplify its own electronic instrument and voice or receive sounds from outside sources via a transmitter/receiver and disseminate them in a space by orienting his high-tech 'plumage.' Four *Audio Peacock* units can be acoustically choreographed as a mobile quadraphonic loudspeaker system."[22]

Heat and the Heartbeat of the City, a 2003 Turbulence commission by Andrea Polli with scientific collaborators Cynthia Rosenzweig, David Rind and Richard Goldberg; *The Cloud Harp Project*, developed by Nicolas Reeves and the NXT

GESTATIO Design Lab; and *Ground Station*,[23] an installation by Daniel Jolliffe and Jocelyn Roberts are also worthy of mention as works that expand our notion of how music is created and what creates it. *Heat and the Heartbeat of the City* presents the climate change in New York's Central Park from the 1990s to 2080 in sound. The sound, or 'musical compositions', as Polli calls them, are created by a process called 'sonification' that translates data directly to sound. Each of the four compositions available on the site represents an intensification of heat that is translated into pitch, the loudness and the speed of the sounds. The 1990's composition was made by using actual temperatures; the other compositions are predictions based on a climate model of the region. As you listen to them in sequence, you can hear the intensification of the heat in sound.[24]

The Cloud Harp Project (1997–ongoing) converts in real-time the height, density, structure, luminosity and meteorological conditions of clouds into sounds and musical sequences. Each cloudscape produces its own musical sequence. As described on the project's website: 'The Harp is polyphonic: it can sing on many different voices simultaneously, each one being mapped on a specific altitude range. It sings 24 hours a day, 365 days a year, by any weather. When the sky is blue it remains silent.'[25]

Ground Station,[26] produces music in real time

> by following the current azimuth, elevation and signal strength of twenty-seven Global Positioning System (GPS) satellites. Ground Station (GS) is in a sense an audible reflection of the activities of the GPS network it watches. Whereas GPS was developed as a positioning technology to aid in warfare, GS inverts the traditional use of this data by watching the positions and movement of the satellites themselves. As GPS data is fed into GS, it is processed by an algorithm designed by the artists that filters and transcodes this into musical notation. This unique, continuous musical score is then played live on a Dysklavier piano.

The artists write:

> There are two sets of authors for the music: the artist-programmers who create and contextualize the work, and the military infrastructure that maintains and oversees the GPS network. . . . The role of Schriever Air Force Base . . . is indirect yet significant, as the music produced by GS depends on satellite trajectory, which is under direct military control. Without this ground control, the music produced by GS would eventually fade and cease, in parallel with the decay of the satellites themselves.

As collaborators, Jolliffe and Roberts have little interest in the aesthetics of the 'music' produced by the Dysklavier. They think of its music as 'a product of the time and place in which it is produced, rather than its formal or syntactical qualities'.

The trajectory towards context-aware computing environments and ambient/responsive media spaces is reflected in *Dry Translator*,[27] a sculptural installation piece by Sabrina Raaf. Here Raaf creates an environment 'so sensitive to human presence that a touch to its walls sends resonant vibrations throughout the bodies of its occupants'. It allows people 'to engage with walls in newly intimate ways such as touching, beating and even ''playing'' the walls as instruments'.

> *Dry Translator* includes two custom designed audio vests . . . and an interactive wall. Essentially what occurs with this piece is that when a participant touches the wall in the gallery, they hear the sound of their touch not locally where their fingers hit the wall, but actually on their own torso (via the vest). Inside of the wall there are several wired tentacles that act like stethoscopes that are able to pick up the slightest vibrations within the drywall material. Sounds from participants touching the wall are greatly amplified and transmitted wirelessly to the vests. The wall becomes a skin-like extension of the participant's own body. In touching the wall, they touch their self. Participants may also record a series of touches or gestures on the wall via an interactive consol and thereby leave a message for the next participant to play back on the vest.[28]

The boundaries between previously discreet fields are dissolving. The processes of combining and restructuring disciplines are already underway. So too is the movement away from human-computer interaction toward environment-inhabitant interaction. Increasingly, as a result of ubiquitous/pervasive/ambient computing paradigms and wireless sensing, artifacts, objects and physical space itself are being charged with properties traditionally associated with living bodies (Salter, 2004). A city makes music; clothing receives and transmits music; walls become musical instruments. How will we listen tomorrow? What will we hear? Where will we hear it?

Notes

[1] According to a recent communication from Scott Gresham-Lancaster, one of the founding members of The Hub, they are beginning to work again and will give their first performance in the Tesla concert series at the Podewil in Berlin in June 2005.

[2] Turbulence has commissioned and exhibited Internet art since its founding in 1996 (see http://turbulence.org).

[3] Pops and crackles indicated that not all the material has arrived and that the Player, using a complex buffering system, was reconstructing the audio from the data it had.

[4] In computing, a 'buffer' is a portion of memory set aside to store data; in this case, data is stored in the buffer before it is sent to an external device such as the RealPlayer. This allows timing corrections to be made on the incoming data stream.

[5] RealAudio was originally transmitted using the UDP protocol. Unlike TCP, UDP does not do error correction (i.e., it does not ensure that the files that are received are the same as those on the server and that all the bytes of the file are present). At the time, it was ideal for data streaming because it did not take the time required for error correction.

[6] Neilson's work is no longer available for the reasons mentioned in the text, but a part of it may be seen online at: http://turbulence.org/Works/radio_stare/radio_stare.swf.

[7] Interview with Peter Traub, available online at: www.fictive.org/%7Epeter/bits/thesis/chapter3.html#Anchor-John-35882.

[8] Radio_stare is no longer accessible due to the greediness of newer versions of the RealAudio players that grab the whole sound card, so that it will no longer play MIDI and RealAudio streams at the same time. In 1997, QuickTime MIDI files and RealAudio streams would play together with most sound cards.

[9] 'It is also interesting,' as Peter Traub writes in his MFA thesis, 'to consider the network relationships that pervade this piece. The individual police officers each comprise a node attached to the central hub, which is the dispatcher. As they move about the area, they each report back their experiences and actions. Their sonic output is mixed in a collage of

communication that each officer hears. That collage is then sent out over the Web through a scanner site, appropriated in a work of art, and sent back out over the Web to a new group of nodes, the audience. *Radio Stare* is successful because it uses the Web's communication potential in such a simple but profoundly thought provoking way. Through its use of the police scanners, it becomes a work about the communication network it utilizes.'

[10] http://www.fictive.org/%7Epeter/bits/thesis/chapter3.html#Anchor-Various-11481.

[11] E-mail interview conducted by Peter Traub for his thesis, available online at: http://www.fictive.org/%7Epeter/bits/thesis/appendixA.html#Anchor-Helen-6296.

[12] Many of the artists have gone on to do other distance projects, including Pauline Oliveros with *Echos from the Moon*. Multi-site performances are ongoing at Mills College, Oakland, California; Rensselaer Polytechnic Institute, Troy, New York, and elsewhere.

[13] A full description of this work can be found at: http://turbulence.org/Works/ftime/index.html.

[14] E-mail correspondence with John Roach, April 2005.

[15] A utility called 'traceroute' is available that probes the paths that data packets take through the Internet, recording all the 'hops' (routers) along the way (see http://www.traceroute.org).

[16] In 'About the Piece', available online at: http://www.jasonfreeman.net/PDF/scores/glimmer-score.pdf.

[17] 'Swooping the Orchestra', available online at: http://www.americancomposers.org/freeman_essay.htm.

[18] http://www.jasonfreeman.net/Catalog/electroni/nag.html. The work is available online at: http://www.turbulence.org/Works/freeman/.

[19] 'The Architecture of *Auracle*: A Real-Time, Distributed, Collaborative Instrument' and other articles on *Auracle* can be found online at: http://www.auracle.org/furtherreading.html.

[20] E-mail correspondence with Helen Thorington, 20 April 2005.

[21] The jacket was designed with sensors as 'plug-and-play' elements so people could isolate and easily reconfigure their own interaction and sonic variables. Electronic components were removable for easy software calibration.

[22] For a list of other performance wearables by this group, see http://home.snafu.de/maubrey/phonoma.html.

[23] http://www.turbulence.org/blog/archives/000533.html; http://www.finearts.uvic.ca/~jolliffe/sdn/sdn.htm.

[24] Polli has also created a system using the Lorenz attractor as a structure to guide human/computer musical improvisation (1992), as well as a long-running performance project, Intuitive Ocusonics (1996-ongoing): a system for performing sound using eye movements.

[25] http://www.cloudharp.org/. The Harp is also called the 'Keplerian Harp' after the German astronomer, who was one of the first to try and transpose natural phenomenon into music.

[26] http://www.turbulence.org/blog/archives/000533.html; http://www.finearts.uvic.ca/~jolliffe/sdn/sdn.htm.

[27] http://www.turbulence.org/blog/archives/000514.html; http://www.raaf.org/Electronic_Works/Electronic6/ Electronic6.html.

[28] http://www.turbulence.org/blog/archives/000514.html; http://www.raaf.org/Electronic_Works/Electronic6/Electronic6.html.

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