Visceral Mobile Music Systems

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Abstract. This paper describes a second-generation mobile music system that adds qualities of physical interaction to previous participative, networked, multi-user systems. We call upon traditions in interactive sensor music instrument building to inform this process. The resulting system underscores its dual personal/community context awareness with a technique of *hybrid audio display*. This allows the system to exhibit qualities of *reflexive social translucence* providing a view of the group all while giving each member of the group a responsive sense of agency. The visceral mobile music system was tested in a theatre environment with manageable location tracking and creative non-musical test subjects. The combination of musical practice and interaction design establish artistic creativity as an important component of the research process.

Keywords: mobile music, sensor instruments, network audio.

1 Introduction

Mobile electronics have had an indelible impact on culture and society. Artists have exploited this to conceive of new forms of cultural production. One of the areas often evoked is that of creating new forms of music. We seek to identify the musical potential of networked, mobile systems, and describe the conception and design of a *visceral mobile music* system. The system is mobile, multi-user, and is sensitive to both personal and community context as captured through location information and sensor data. To arrive at a result that musically fulfills the potential of the technology, we retrace related fields of interactive and network music to inform and motivate the design specification.

Personal music players revolutionized the notion of pervasive music over 25 years ago. The Walkman allowed the music lover to bring his/her music with him wherever he went, and allowed him to create a private aural sphere, defining his own musical environment while on the move, all while not disturbing those around him. Today's personal music systems have merged with recent developments in networked information access. The *container* of the music has gone from physical media such as the cassette or CD to data files. The storage capacity of modern personal music players is vast enough for a user to carry his whole music collection with him at all times. Meanwhile developments in peer-to-peer file sharing and social networking sites like MySpace have been seized upon by musician and music fans alike in new modes of music distribution, leading to heightened grass-roots inter-user interaction. These networks have been enhanced by

information retrieval techniques to generate recommendations based on personal musical taste with sites like LastFM [1]. The way that music is distributed and consumed, have undergone a fundamental shift in the last decade. Despite these technological shifts, music as an art form has not changed correspondingly. This chapter investigates ways in which mobile ubiquitous systems could be designed to directly engage with and drive the creative process of music making.

Mobile systems allow increasingly rich media experiences on portable electronics devices. The cell telephone evokes a sense of mobility plus a sense of connectivity. Localization technologies such as GPS enable navigation systems allow geographic interaction. These are the ingredients that have been used in new fields of artistic practice, notably *locative media*. As a researcher, I was interested to see if we could conceive of a form of location-based music. As a composer, I was interested to see if there was a way to preserve the richness of musical interaction we know from instrumental performance. What elements from traditional musical performance, or from previous work in computer based music could be used to enhance the musicality of mobile media systems? Could this contribute ideas to fields such as Human Computer Interaction (HCI) or Ubiquitous Computing? The approach described here sits at the intersection of several fields of research and creative practice.

We first describe the field of new instrument design in interactive music. We then consider the history of network music as precursors to the present work. Section 4 introduces the nascent field of mobile music. We then present the visceral mobile music system and describe field trials. Section 7 introduces the notion of *reflexive translucence* to describe ways in which the system musically portrays community activity. We finish with concluding remarks.

2 Sensor Instruments

One branch of computer music that is directly concerned with human-computer interaction is that of New Interfaces for Musical Expression (NIME). NIME began as a workshop at CHI 2001 [2] and has since evolved to sustain an annual international conference [3]. As its nature implies, NIME is the discipline concerned with interaction in music. It is a field that specializes in creating interactive music systems using sensors and networks. Its activities can be described as those of instrument building, or *lutherie*. The typical context of a NIME system is to build a system for concert performance. A NIME system is conceived by an instrument builder, contextualized by a composer, to be used by a musician who is able to attain a profound level of interaction with the system through his/her virtuosity. As a field of practice, NIME is therefore specialist oriented.

The design process of NIME, then, while rich for interactive possibilities in sound manipulation, do not address typical end users. The richness of a successful NIME instrument is not necessarily in the efficiency of interaction or the optimization of task performance. In classical HCI research, controlled experiments tend to focus on task performance optimization. With a musical instrument, on the other hand its operation has less to do with optimization and more to do with the expressivity of the system which may arise out of idiosyncrasies of the system. In musical composition this is referred to as the *idiomatic* voice of an instrument. From the HCI point of view, this can be viewed as a form of *seamful design* [4]. A good instrument is not always considered to be perfect

– it is said to have *character*. The identity of an instrument is established not only by the range of sounds it is capable of, but also as a function of its limitations. Successful compositions for instruments make use of both limitations and possibilities of an instrument, similar to the notion of seamful design.

Instrument building and subsequent composition and performance are activities central to NIME. Data from sensors that capture movement, gesture, or real world phenomena are mapped to sound synthesis or high level musical parameters. Information from a gyroscope, for example, might be used to capture free-space orientation, and gradually modulate the frequency of an oscillator. A number of artist-oriented platforms exist at the time of writing, including the *Arduino*, *I-Cube*, and *Phidget* that allow the artist to quickly experiment with different types of sensors as input to an interactive digital system. The arrival of the *Nintendo Wii* has brought this kind of interaction to the consumer gaming world, enabling the user to become physical in front of a video game. This hardware is a ready made, low cost device that integrates sensors like accelerometers and infrared cameras and has been seized upon by artists wishing to explore gesture and interactive media.

While the Wii's availability has been taken up by artists as an accessible platform, the history of work in this area pre-dates the Arduino, the Wii, and the NIME conference itself. The use of technology to capture gesture for musical ends can be retraced to the 1920's with the *Theremin*. The Theremin, and other instruments of its time like the *Ondes Martenot* used analog electronics to capture performer gesture to modulate electronic sound [5]. More recently, Max Mathews, one of the forefathers of computer music, created the *Radio Baton*, a continuous percussion surface that could monitor position and gesture of two radio transmittor batons over an playing surface comprised of an antenna grid[6]. Michel Waisvisz, the musician and composer most closely associated with the Studio for Electro-Instrumental Music (STEIM) in Amsterdam performs on *The Hands*, an instrument that uses mercury switches and ultrasound sensors to capture relative hand position, orientation, and distance to perform digital music [7].

These were works that inspired *Sensorband*, a trio ensemble in which three musicians, Edwin van der Heide, Zbigniew Karkorwski, and the present author, perform on instruments comprised of gestural interfaces. The three instruments in the Sensorband instrumentarium all allow free space gestures of the musician to be captured via a sensor system to articulate digitally synthesized sound on the computer. Each instrument, however, has its distinct mode of operation, be it ultrasound, infrared, or biosignal sensing. The similarities and differences among the instruments give them at once musical coherence and distinct identity. They are members of a single instrument family, much in the way that traditional instruments constitute families such as the stringed, woodwind, brass, and percussion instrument families. These three members of the *sensor instrument* family demonstrate their own uniqueness, each one distinguishing itself from the others by mode of operation, articulation, and ultimately voice [8].

Gestural interaction with electronic sound creates a compelling experience as it a mode of interaction that approaches, in HCI terms, *direct manipulation* of the medium. These sensor instruments have to be responsive and satisfying enough for musicians for whom the gold standard of expressivity is the richness of traditional musical instruments. At the same time, digital instruments' programmable mapping means that complexity can be tempered, making sensor instruments accessible to non-musicians more easily than traditional instruments.

Fig. 1. Sensorband (*left to right*, Edwin van de Heide, Zbigniew Karkowski, Atau Tanaka) in concert at Paradiso in Amsterdam during the Sonic Acts Festival, 1994

3   Network Music

Musicians have a long tradition of appropriating communications technologies for musical work. The first communications technology to be broached artistically was radio. Germany was a fertile ground for early radio art, culminating in 1928 in the seminal *Wochenende* (Weekend) of Walter Ruttmann. Berthold Brecht was an important instigator in this era, calling for public participation to turn a state controlled distribution system into a social communication system. These views were corroborated by Kurt Weill in his call for an *absolute radio art* [9] and Walter Benjamin's essay *Art in the Age of Mechanical Reproduction* [10]. Cologne and the studio of the WDR (West German Radio) under Klaus Schoening became a focal point in the *Neues Hörspiel* movement of the 1960's, already renowned as a pioneering center for electronic music with its Studio for Electronic Music. Schoening commissioned an important body of work, including *Roaratorio* by John Cage, *New York City* by Richard Kostelanetz, and *Ein Aufnahmezustand* by Mauricio Kagel [11].

As radio is typically a state controlled medium, at the level of infrastructure and often at the level of content, independent artists wishing to exploit the medium needed to find tactical strategies. This includes a rich history of pirate radio, and of a school of do-it-yourself microradio transmitter building by Tetsuo Kogawa and others [12]. With the democratization of the Internet, network audio streaming made independent broadcasting

possible. This was seized upon by artists for a host of net radio projects including Radio Qualia [13].

Beyond radio, composers like Max Neuhaus have also worked with telephone networks. He has continued his activities in music with his networks or broadcast works: virtual architectures which act as a forums open to anyone for the evolution of new musics. With the first *Public Supply* in 1966 he combined a radio station with the telephone network and created a two-way public aural space twenty miles in diameter encompassing New York City.

Performing musicians have used network technology to create distributed musical processes amongst musicians on the same stage. The Hub was a collective in the San Francisco area that performed with an on-stage data sharing network [14]. The use of communications networks to transpose auditory environments from one space to another range from functional demonstrations of remote musical rehearsal [15, 16], to artist projects by composers like Luc Ferrari who piped in sounds from the Normandy coast to envelope the Arc de Triomphe in Paris with seaside ambiences. This notion of streaming continues today with artists research projects such as the arts research group Locus Sonus [17].

3.1 Network Concerts

My first attempts to practice music on networks was in organizing long-distance performances in the 1990's. By using ISDN networks and videoconferencing technology, I was able to connect concert spaces in two cities, where performers at each site were able to see and hear the musicians at the other site. Inasmuch as the network was an *enabling technology* collapsing the distance between two geographically separated locations, the nature of the audiovisual communication created perturbations in the musicians' habits. The first challenge was to find a way to maintain eye-to-eye contact when the act of sharing a single stage was extended by a pair of video cameras and video projectors.

Musicians have the reflex to adjust their playing style to the reverberant acoustic of the space in which they play. I wanted to extend this musical instinct to respect the acoustics of physical space and apply it to the time latency of network space. To me it was somehow appropriate that a given music could not simply be transplanted and successfully performed on a network infrastructure. The time characteristic of that infrastructure becomes the acoustic. I have referred to this network transmission latency in other texts as the *acoustic of the network* to be recognized and exploited as one does when composing for specific resonant spaces [18].

3.2 Network Based Installations

While it was a musician's instinct to try to perform on any new infrastructure, these experiments underlined the fact the Internet was a medium perhaps not suited for live performance. This is borne out in the failure of early interest in Internet multicast technologies to transmit live events. In the multicast heyday of the mid-1990's, stadium rock concerts were imagined to be simulcast for viewing over the Internet. This has never taken off, but a deferred time interest in near-live transmission remains in events like the 2008 U.S. presidential debates over YouTube, a less time critical store-and-stream infrastructure.

As the temporal characteristics of networks posed significant challenges, I began to question whether networks were not better suited for musical activities other than real-time performance. I wondered if spatial aspects might hold more promise, and created works that were not concert pieces, but gallery and web-site based installations.

Fig. 2. *Constellations* installed at the Webbar, Paris, 1999

Constellations is a gallery installation whose aim was to juxtapose the physical space of an art gallery with the so-called *virtual* space of the Internet. Five computers in a gallery space, each connected to the Internet and each with its own speaker system. Gallery visitors use the interface to invoke the streaming of MP3 sound files from the Internet. And as the speakers of each of the computers played out into the physical space of the gallery, there was also a spatial, acoustic mix. These two levels of sound mixing – Internet mixing and acoustic mixing, constitute the dynamic at the core of the work. In *MP3q*, I abandoned physical space altogether and focused on the notion of the Internet as a collaborative space. The software is viewed on a standard web browser. An upload feature in the software allows listeners of the piece to send in URL links sound files and contribute to the evolution of the piece. In fact in its initial state, the piece is *contentless*, it is only a scaffold waiting for contributions from the web visitors. The spectator's role shifted to that of an active participant who heard her contributions in context with the others'.

3.3 Hybrids

Networks introduced the spatial and participative dimension but lacked the visceral element of sensor instruments. *Global String* is a network based installation work that uses sensors. The concept was to create a vibrating *string* of monumental proportions that would span the distance between two cities, traversing physical and network space [19].
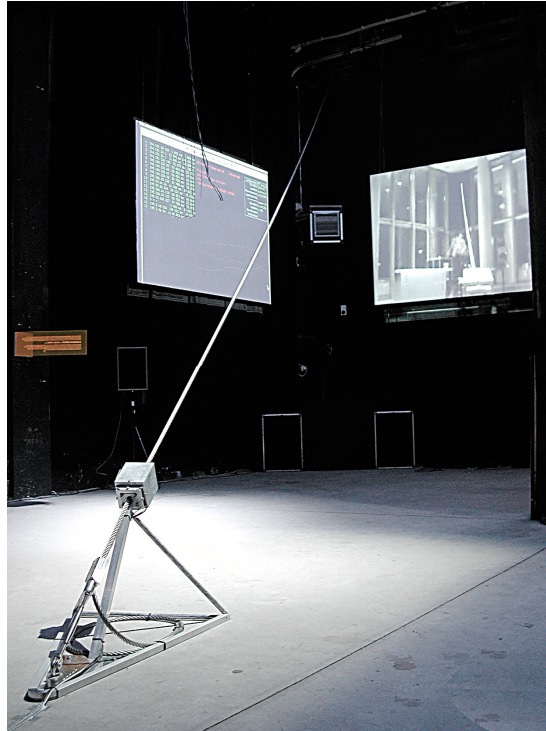
Fig. 3. *Global String* at Dutch Electronic Arts Festival (2000) at V2 in Rotterdam, with traceroute output on left screen and remote site at Ars Electronica Center in Linz Austria on right screen

As a hybrid work, it combined the approaches of sensor instruments and network music, and served to bring back the satisfaction and visceral sense in a networked environment.

At each site, the endpoints of the string were physical cables. The use of sensor-actuators in conjunction with networks allowed me to make physical action the musical information transmitted on the network. It is the mixture of the virtual and the real; the network acts as its resonating body, with network traffic conditions captured by the *traceroute* Unix command tuning parameters affecting physical model based sound synthesis.

4 Mobile Music

Mobile music is an all-encompassing term that implies deployment of audio and sound on portable electronics. It has been used by commercial products to refer to offerings that combine personal music player functionality on mobile telephones. Products like Apple's iPhone have brought music and video to the mobile phone. However they do little to extend the notion of a PDA and do not integrate the communicative possibility of a mobile phone and the Apple's companion iPod music player. More relevant to the work

presented here, Mobile Music refers to an international research committee in creative musical practice on mobile computing technologies. It is a field of practice that is at the intersection of NIME, CHI, and Ubicomp. The community hosts an annual international conference, the Mobile Music Workshop (MMW) [20], one of which has been held in conjunction with a NIME conference.

TuNA is a system based on PDA's and ad-hoc Wi-fi networks to connect listeners in close proximity [21], allowing one listener can "tune" into what another is listening to. *Sonic City* is a headphone-based system equipped with sensors that put the personal music player in interaction with its surrounding environment [22]. Yolande Harris' work uses GPS in a sound art context. She exploits the supposed precision of GPS systems to *sonify* the jitter in a seemingly static source and creates exhibition and performance works that put the spectator or performer in musical interaction with the drift inside location sensing technologies [23].

4.1 Locative Media

Locative media is a recent field of artistic practice incorporating geography as source of creative production. Projects by the art group Blast Theory are references in this field, and succeed in creating compelling experiences by extending notions of theatrical production into the urban sphere [24]. Pervasive gaming is an active area with projects like *Big Urban Game* [25] transposing the dynamics of board games into urban geography. Geotagging is another area linking user to environment. Socialite [26] is one of several systems that allows the user to use a mobile device to annotate physical space by that user or to share annotations with others. Research platforms like *Mediascapes* [27] have made it practical for content creators to author location aware multimedia content.

4.2 Ubiquitous Music

With *Malleable Mobile Music*, the goal was to see how interactive music techniques might be applied in a ubiquitous computing context [28]. For this, the musical example was simplified to remixing an existing pop song. Each participant was assigned a part in the music and their relative proximity in urban environment drove an evolving re-mix of a song. From a musical point of view, this was as if each participant became an instrument, or *rack* in the whole. From a human-interaction point of view, it was to see if a musical entity could represent the presence and proximity of a person. For this, I coined the term, *musical avatar*. Ultimately the question was to see if music could become a carrier of social information.

Taking these ideas in an artistically more abstract direction, I developed *Net_Dérive* in collaboration with Petra Gemeinboeck and Ali Momeni [29]. The goal was to use strategies from Locative Media to create a fluid musical work. We sought to use off-the-shelf components such as mobile telephones and GPS devices. At the same time, we wanted to take the mobile phone out of its typical cultural association. For this, we created a sort of wearable computing object, a white scarf in which were housed two mobiles and the GPS device.

The piece allowed three participants each wearing the wearable system to wander around in the neighborhood surrounding the gallery where the exhibition was taking

Fig. 4. Net_Dérive, with GPS and mobile phones contained in wearable scarf-like object

place. The camera automatically took photos every 20 seconds along the walk, geo-tagged them with the GPS data, and uploaded them over mobile wireless data networks to the server in the gallery. An abstract audiovisual feed was created from this data in the gallery, and streamed back to the participants. The work put in place a system for abstract visualization and sonification of urban navigation. The images we places along a satellite map, creating a collage of Google Earth satellite imagery and the live uploaded photos from the intertwining paths walked by the three participants. This very information was used musically, to create an ever-evolving pulsing polyrhythm representing the proximity of the walkers.

5   Visceral Mobiles

Much in the way that *Global String* was a sensor-network hybrid work that reconciled the visceral nature of gesture with the communicative potential of networks, we now describe an experimental system that configures a mobile system to merge locative media and gestural elements. The goal was to build a system where the music became a dynamic media flow that represented the collective action of a community of participants. At the same time the music represented group activity, each user needed to have a sense of his part in the whole. By balancing these two requirements, we hoped to address the issue of reconciling local activity with social connectivity. We will introduce the notion of *reflexive translucence* as a technique of audio display to address this.

The desire to detect individual and group dynamic delineate two distinct contexts – personal context and community context. These two contexts must be aggregated and feed process generating the musical output. The dispatching of this contextual information needs to be agnostic of the information architecture of the system. That is to say, the message passing needed to work both in a client-server model or a peer-to-peer model, with the possibility of a hybrid architecture, to function at all points across the networked system.

5.1   Sensing and Localization

Sensing personal context was achieved via on-device sensors. We used NIME instrument building techniques described above, to equip a portable electronics device with several types of sensors. A data-acquisition back plane was created in a way to dock onto the back of the device. The data acquisition card could accept up to eight analog 0-5V inputs from sensors, digitize them, and send the information to the device over USB. We used five sensor channels – two force-sensing resistors (FSR) as pressure sensors, a two-dimensional accelerometer, and a gyroscope. The FSR's were placed on the device so as to detect user grip pressure holding the device. The data from the accelerometers were filtered so as to report tilt of the device, and the gyroscope reported rotation around one axis of the device to report higher frequency rhythmical movement.

These sensors picked up listener gesture on the device. We sought to detect sub-conscious user participation, as well as volitional actions of the listeners. For example, the intensity with which a listener held the mobile device could be translated into the timbral brightness of the music; the rhythm the user made as he tapped along with the music could drive the tempo of the music. The angle the device was held at could seek and scrub back and forth.

While on-device sensors picked up the personal context, location of the users would give the community context. The relative geographies of users in the group drives the mixing of the different musical modules. Similar to *Malleable Mobile Music*, as a listening partner gets closer, their part is heard more prominently in the mix.

A host of movement and localization sensing technologies are available. While GPS was used with *Malleable Mobile Music* and *Net_Dérive*, there remained several unresolved issues. One was the coarseness of GPS location information. The GPS device reports the user's location about once per second. Another problem was that of scale. While it is interesting to conceive of a system where traversing a city block modulates a musical parameter, in reality it was questionable whether the scale of mapping (for example 100 meters to 100 Hertz) was perceivable and meaningful to the participant and spectators. To better understand the dynamics of how topology could be mapped to music, we used a controlled black box environment (15m x 15m) and visual tracking using the *Eyesweb* environment [30]. We used the glowing LCD screens of the handheld devices as the object to be tracked by an overhead video camera. Each screen was programmed to emit a different color, allowing the system to track several users.

The location data was used to control the audio synthesis in a number of ways. The position of tracked objects were used to route the signal from the contact microphones on the tables to varying resonance models. This allowed a smooth interpolation from one sound to another as a tracked object was moved from one to the other side of the space. This technique provided interesting opportunities for promoting collaborative performance: as one performer moved to various areas in the space, others could serve as inputs to the audio processes. The voice of one actor then, could be processed and modulated by the movements of another. Depending on the location and movement of a participant, sounds could be triggered, attenuated, altered using DSPs and placed anywhere inside the space defined by the quadraphonic audio system. Mapping from contextual information to musical information was done much in the same way as the sensors data mapping was.
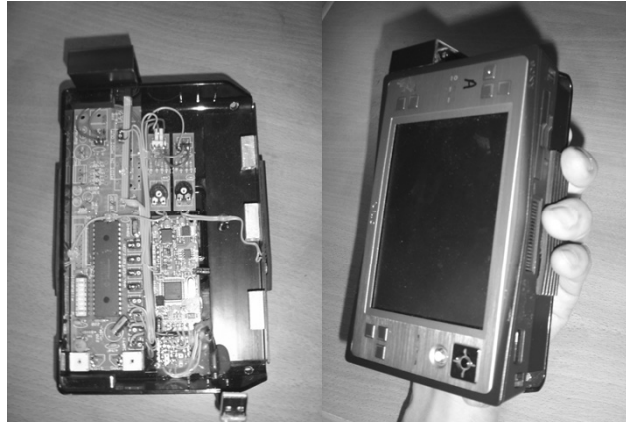
Fig. 5. Visceral mobile system, with sensor acquisition sub-system (*left*) with accelerometers, pressure sensors, and gyroscope, and Sony Vaio U-71 handheld host computer (*right*)

5.2 Local/Remote Hybrid Rendering

We developed a *music engine* to generate a music based on the contextual information. The musical result would then be rendered as a flow of digital audio data, to be delivered to each connected destination. Since all processes, from incoming contextual information, to outgoing audio delivery, take place over the network, there is inherent latency and transmission delay. This would have an impact on the feel of the system for each user

The music engine was conceived that could be instantiated and deployed either at the server level, or on the client devices. Audio was rendered either played locally, in the case of the clients, or streamed out to the network, in the case of the server. The music generation engine is controlled by information coming from the sensors or localization system. Gestural input from each member of the group arrives over the network as UDP packets in Open Sound Control (OSC) format [31]. Similarly, location data from Eyeweb is transmitted to the system over OSC. The engine reconciles the multiple control inputs to generate several parallel music channels that are sent to local sound output or network streamed up to an Icecast type audio relay [32]. The modularity of the engine architecture meant that it could be instantiated in a centralized server-based way (to represent community context), or on the mobile device of each user (for personal context). Any instantiation of the engine could play locally or make their output available as a network stream. To achieve the hybrid rendering effect, we concurrently ran a server-side engine alongside peer-based engines on the mobile terminals.

A single movement by one user could be mapped to several different parameters either on the server, or on the local device of several different audio processes.
The audio output of any instantiation of the music engine could be the network or a local soundcard. Likewise, the engines were able to render any incoming network audio stream, and mix it with locally synthesized sound. Not only could the clients run the same software as the server, but any peer could be a sender or a receiver.

The sound output of the server was mapped to a quadraphonic surround sound speaker system. The loudspeakers were arranged in a square around the perimeter of the test

space. Amplitude panning across these four outputs permitted placing a virtual sound source at any point in the environmental soundscape. The sound output of the client devices were its own local sound output. Having sound emanating directly from the device situated it in the physical space. This acoustically placed a sound source in the space and differed markedly in effect compared to the virtual surround soundscape of the server output. We call this a *hybrid rendering* model where audio can be rendered remotely or locally to represent the personal and community levels of context.

6   In Use

By developing a system that enabled rich media interaction on mobile devices, we sought to create a live musical dynamic that could be executed by non-musicians. To test this system, The user group for the study consisted of 15 professional actors and actresses taking part in the theatre workshop. They would work in small groups to rehearse an improvised sketch. This corresponded well to the number of prototype devices on hand (3), and provided a good variation of combination of users running through the same scenario.

Fig. 6. Visceral mobile music in theatre test setting, with three actors holding a mobile terminal inside the set environment and listening to cues generated by the hybrid audio display

The use of actors and actresses was consistent with the use of the black box space as a controlled environment for location tracking. As actors, they were accustomed to abstracting an environment and constructing a temporary reality based on the set, and to

live out their part. Although they were professionals in their domain (theatre), these users can be considered neutral and uninformed with respect to the technology at hand, as well as the musical processes proposed. In this sense, the actors and actresses represented a neutral user base similar to calling upon colleagues in a research lab or students in a university to conduct a user study. The actors could follow indications and reproduce scenarios, and they were not biased as musicians might be about the musical possibilities of such a system. In this way, the choice of the theatre and actors provided the controlled environment to reduce unknown variables, while their neutral stance with respect to technology and music made them an impartial test subjects. We hoped to contain the potentially wide ranging variation of social systems and geographical localization, to focus on the individual/group dynamic and the music it could produce.

The black box theatre space was filled out by a sparse set that was a combination of physical objects and boundaries and video projection. The users worked in groups of five, with three holding a device, two without, to act out a short sketch. The text was written so as to be reproducible, but their choreography in space and their gestures were not notated. Instead it was left to the actors/actresses to act out the script, articulating and moving in the way that allowed them to best express the text. Interactive soundscapes were programmed to accompany the scene. Sound filled in the sparse physical set, sonically painting a virtual environment that described an imaginary space. The quadraphonic sound system projected the background decor establishing the ambiance. As the actors moved through the space, detecting community context by the camera tracking system modulated sounds in this environment. The personal context of each actor pick up by the sensors articulated sounds locally on the devices. This accompanied and sonified the sense of the actors picking up and playing with sonorous objects in the skit. At time a playful dialog could be set up as gestures producing sounds on an object could be tossed or passed from one actor to another. The distribution of music engines across the network of devices worked invisibly in the background to render audio locally on-device or stream to other peers. The actor did not have to be concerned with the technology, for them they were passing sound objects around in an imaginary space. Their gestures operated on these sounding objects while the space itself musically responded to their movements.

The information specific to a local user is rendered directly on his client and is not subject to network latency, giving the user a sense of the system responding in a snappy way to her own actions. This has a twofold effect, first of apparent responsiveness of the system and second of task specific audio localization. Community context, on the other hand, pass through the network and server, to be aggregated. Latency is less of an issue here as each individual's part contributes to a musical whole. The hybrid audio display technique parallels the locus of action, placing user-centric actions acoustically at the device, and community-centric actions in the public sound space.

7   Reflexive Translucence

The term *social translucence* is used in the field of Social Computing to describe information displays that reflect social dynamic [33]. These systems support coherent group behavior by making actors aware and accountable for their actions by making them visible through representation and abstraction. A system exhibiting translucence displays

faithful yet abstract representations of the state of a community. Here the public audio display can be considered to have the property of translucence. It sonically reflects and displays the group dynamic to its members, and fulfills the qualities fundamental to social translucence, those of visibility, awareness, and accountability. With the dual personal/community contexts, *Visceral Mobile Music* must not only give a global view of the situation also represent local action back to its originating user in a compelling way. The locally rendered audio needs to be responsive and satisfy an immediacy for the user to have a *sense of agency* connecting his intention or originating act to the resulting media displayed [34]. The whole system, then, exhibits social translucence and at the same time affords a sense of individual agency.

We introduce here the notion of *reflexive translucence*, the hybridization of group translucence and individual sense of agency, where the two are organically intertwined. The system has a view and is able to display the global state of the community. Within this community, each individual user must have a sense of her part in the whole. The community and its constituent individuals are forcibly related. The *reflexive translucence* of the proposed hybrid display system recognizes the two types of identities, individual and group, that emerge in the total environment.

8 Conclusions

We have described a second-generation mobile music system that captures both personal user context as well as group, community dynamic. While the system makes use of advanced mobile electronics technology, it has been conceived as an artists system, and in this way distinguishes itself from products created under marketing constraints. Similarly, the system has been evaluated by non-musicians in a creative context. This approach calls upon techniques and methodology from several disciplines, including interactive instrument design, human computer interaction, and social computing.

Inasmuch as we intended the system to be at the cutting edge of technology, we wished it to have a depth of musical expression. In order to explore the depth of musical interaction, we called upon the field of NIME and its predecessors to understand the richness of gestural sonic interaction. Musical instruments built with sensor interfaces, and performance practice on such instruments, including ensemble performance, and compositional notions of *idiomatic writing* help us to find the musical voice of digital technology. Retracing the history of network music, including precursors in radio art and telephone music, aid us to understand the potential of communications technologies. As temporal accuracy is difficult to attain, we looked at examples that explored the spatial, social potential of networks as a musical medium. One installation project by the author was presented as using both sensor and network technology, to create a long-distance instrument that could be performed by virtuosi or played by lay-visitors.

Artists have already begun to use geographic localization systems for creative practice. Locative media and mobile music exist today as vibrant areas of artistic output. By taking the lessons gleaned from interactive sensor music projects, we sought to inject a physical sense to extend upon prior work. Experience with network audio systems aided to flesh out the participative group dynamic of the new system. by combining these two qualities, we arrive at visceral mobile music, and the different musical and design implications it affords. First we observe that the system is capable of sensing two distinct

contexts: personal and community. On device sensors are suited to detect users' direct conscious and sub-conscious gestures, while location tracking capture the state of the community. We propose a novel *hybrid audio display* system that situates these two contexts sonically in space. Furthermore, the combined client/server and peer/peer architecture of the system affords an immediacy and responsiveness for personal context all while aggregating information from multiple users to project group dynamic.

The system satisfies the qualities of *social translucence*, and with the sensing of two contexts coupled with hybrid display techniques, extends this notion to be able to represent not only a view of the group, but provide for each participant a meaningful compelling sense of agency for his part in the whole. We coin the term *reflexive translucence* to describe this multilayered concurrent representation. Finally we describe a field trial where the system is put to use in a controlled black box theatre environment. This test case proves practical for several reasons, including the possibility to study location tracking on a smaller-than-urban scale. Actors constitute interesting test subjects as they are non-musicians yet are creative practitioners.

Through this approach we have sought to apply creative practice and technology development in parallel, each with the rigor of its respective field. By doing so, we hoped to create a system that pushed present day technology to its creative potential. We hoped that by drawing upon related fields we could gain some insight into expressive possibilities not otherwise explored. Calling upon methodologies from HCI and social computing helped to inform the design of the system to be not purely technical nor purely artistic. By conceiving of the system as a framework built on technical specifications that had expressive qualities, we hoped to arrive at a result that had a generality and pertinence beyond the singularity of an individual artwork. In this way, we situate the creative act in the process of research.

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