Digital Tools for Performance

A Methods Network Working Paper

The designation of this document as a 'working paper' is an acknowledgement that its content is not meant to be regarded as finalised or fixed. As part of the Methods Network remit to encourage discussion about the advanced use of ICT tools and methods for arts and humanities research, comments, annotations, corrections and recommendations relating to this paper are sought from all sections of the digital performance community. An online forum related to this subject area may become available to accommodate feedback of this type (as part of ongoing Methods Network community-building activities – please see website for details) but in the meantime, please feel free to send comments to: neil.grindley@kcl.ac.uk.

Introduction

The focus of this paper is to take a very selective look at some of the ways that practitioners have used digital tools in the course of planning, designing, 'doing', communicating and documenting performance-related works, a term that covers an enormous amount of territory and is intrinsically cross-disciplinary, connecting activities as diverse as design, music, drama, electrical engineering, human movement studies, communications theory, literary studies, and so forth. Perhaps the most straightforward method of defining what 'performance' involves is to consider the disciplinary areas which feature it as an activity. AHDS (Arts and Humanities Data Service) Performing Arts[1] define those categories as:

- Music
- Dance
- Theatre
- Radio
- Film
- Television
- Performance (Live Art)

In order to comply with the general aim of this series of working papers, which is targeted more towards individual academics or research groups who are looking to increase their knowledge of the types of tools that will complement and enhance their research, the focus will be geared towards identifying selected techniques and specific software solutions that could potentially empower individuals to broaden, add value and enrich their (practice-based) research. The technological complexity that underpins the capture and delivery of performance footage in the realm of radio, film and television often requires an institutional or commercial infrastructure and is therefore largely beyond the scope of this paper and will not be specifically addressed.

In many instances, the remaining four categories (music, dance, theatre and live art) are difficult to isolate from one another when determining the overall effect of particular performances. To take an arbitrary example, 'Allegro Molto Con Brio King Kong', a digital opera composed and conceived by Kenneth Doren[2] in collaboration with the choreographer Danielle McCulloch and the librettist, Doug DeRoche, uses an eclectic range of techniques and reference points to deliver its digital re-working of Beethoven's 'Creatures of Prometheus'. The web reference to the production states:

> The libretto and choreography for 3 dancers are based on television and movie culture juxtapose [sic] with the myth about the Greek god Prometheus. The dance, music and writings embody pop

[1] AHDS, http://www.ahds.ac.uk/performingarts/index.htm, (accessed 27 March 2007)
[2] Kenneth Doren, http://www.digitalopera.org/home.htm, (accessed 27 March 2007)

culture paralleling antiquity. This synthesis explores the genres of technology-based new music, opera and dance.[3]

With so many types of productions aspiring to present themselves as a technologically updated version of Richard Wagner's notion of 'Gesamtkunstwerk'[4] (total art), there is a possibility that any sectional division of tools that divides up technologies in relation to activity type, e.g. music, dance, etc., will result in references to seminal performance works having to be duplicated. The organising principle for this paper, therefore, will reflect the steps that might be taken in the course of organising and staging a generic theatrical production. Whilst this ostensibly forces an unwanted orthodoxy onto notions of performance, it should be noted that these categories are intentionally very loosely defined and are meant to serve merely as a subjective organisational principle that gives some structure to an otherwise arbitrarily ordered account of relevant tools. The sections are as follows:

1. Developing Ideas
2. The Performance Space
3. The Cast
4. Props, Costumes and Instruments
5. Stage and Scenery
6. Music, Audio, Graphics, Lights and Effects
7. Performance and Audience
8. Archiving and Representation

1. Developing Ideas

Of all the sections, the initial process of formulating creative ideas for delivering effective and interesting performance works should, in theory, be the least likely to benefit from the application of digital tools. If it is accepted that the initial intellectual creative process should be 'ideas-led' rather than 'technology-led', then the scope for using the capabilities of software or hardware as a basis for the dramatic or artistic impact of any given piece decreases. That having been said, knowledge of the up-to-date capabilities of systems may lead to a situation where an original idea is enhanced by the possibilities offered by technology, so there is a complex relationship between these two positions.

At a recent Methods Network workshop, 'Advanced Technologies for Collaborative Performance',[5] some of the participants were introduced to a range of sensor equipment that could be used in conjunction with *Max/MSP*[6] and *SuperCollider*[7] software, in order to experiment with new ways of generating sound signals. This workshop was an interesting example of the way that technology and imaginative thinking can become entwined to the point where it is difficult to discern if the outcome was technology or ideas-led. An account of a project undertaken by one of the workshop groups refers to the use of an obsolete upright piano which was resurrected by the introduction of sensors, microphones and speakers into the fabric of the piano, allowing the keyboard to once again function as a signal input device and the body of the piano to act as a resonating chamber.[8]

[3] King Kong Digital Opera, http://www.digitalopera.org/KingKong1.htm, (accessed 27 March 2007)
[4] Multimedia – From Wagner to Virtual Reality, ArtMuseum, http://www.artmuseum.net/w2vr/timeline/Wagner.html, (accessed 27 March 2007)
[5] Methods Network, http://www.methodsnetwork.ac.uk/activities/act13.html, (accessed 28 March 2007)
[6] Cycling 74, http://www.cycling74.com/products/maxmsp, (accessed 28 March 2007)
[7] Audiosynth, http://www.audiosynth.com/, (accessed 28 March 2007)
[8] 'The Prosthetic Piano Party', Chris Nash, http://www.cl.cam.ac.uk/conference/performancetechnology/, (accessed 28 March 2007)

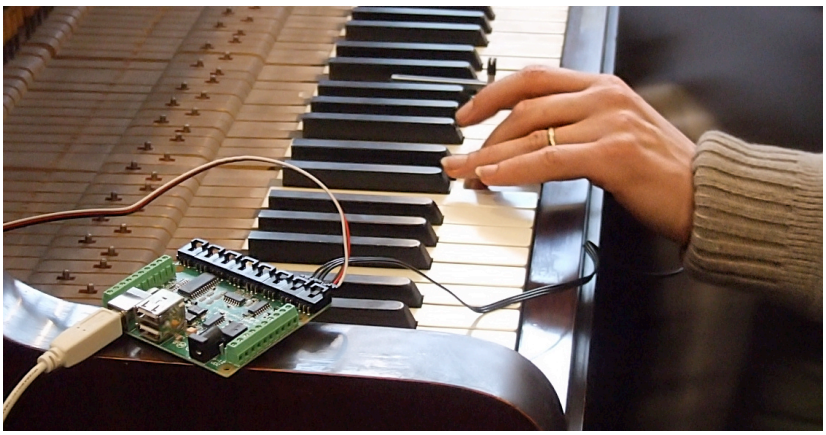

Fig. 1 Image from 'The Prosthetic Piano Party' project, Cambridge Anglia Ruskin University

2. The Performance Space

Of all the different ways of interpreting this concept, perhaps the most immediately practical application of digital tools is the widespread use of CAD (computer aided design) packages to assist designers with visualizing performance spaces prior to the costly task of purchasing materials and paying for construction costs. Borrowed originally from the engineering and architectural sectors, commercial packages such as *AutoCAD*,[9] *SolidWorks*[10] and *Vectorworks*[11] are all sophisticated fully featured 2D and 3D spatial and object design systems. *QCAD (Community Edition)* from Ribbonsoft[12] offers an open source software alternative for 2D design whilst *Google Sketchup*[13] is a user-friendly freeware option for producing quick and easy 3D representations with zoom, orbit and pan functions. The *Google Sketchup Pro* version provides export options that interface with other commercial CAD packages but this package incurs a purchase cost. Fig.2 represents an illustrative example of the type of scale model that could (after a short process of familiarisation with the online tutorials) be put together in a matter of minutes using the basic Google Sketchup toolset.

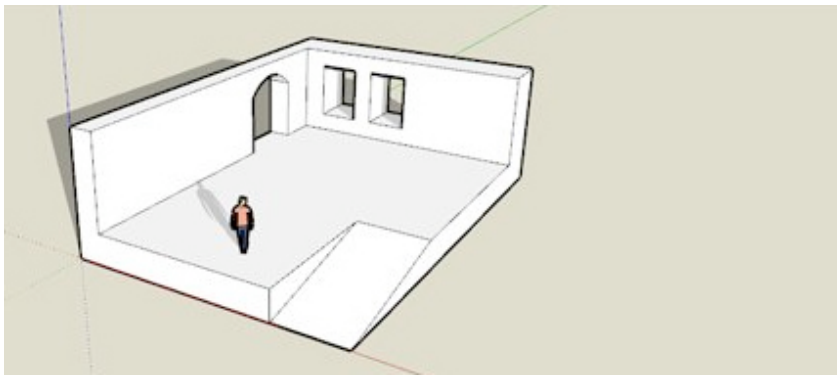

Fig. 2 Illustrative basic spatial design, taken from a Google Sketchup tutorial page14

[9] Autodesk, http://www.autodesk.com/autocad, (accessed 28 March 2007)
[10] SolidWorks, http://www.solidworks.com/, (accessed 28 March 2007)
[11] Vectorworks, http://www.nemetschek.net/, (accessed 28 March 2007)
[12] RibbonSoft, http://www.ribbonsoft.com/qcad.html, (accessed 28 March 2007)
[13] Google Sketchup 6 is a fully functional light version of Google Sketchup Pro 6 which is not freeware. Both can be downloaded from: Google. http://sketchup.google.com/index.html, (accessed 28 March 2007)
[14] Google, http://sketchup.google.com/index.html, (accessed 29 March 2007)

The principle of designing highly plausible three-dimensional spaces informs the research of groups who are interested in recreating historical performance venues. One of the principle centres of this kind of activity is the King's Visualization Lab who have worked on a number of theatre-related projects, notably the 'Pompey Project'[15] and more recently, a series of computer modelled 3D visualizations of the architectural interior of the Hellerau Festspeilhaus featuring the modular scenic designs of Adolphe Appia (1862–1928).[16] These reconstructions refer to data gleaned from historical documentation and the photographic record that still exists of performances dating from 1912. The 3D models are an attempt to represent and demonstrate the innovative use of "rhythmic spaces", a concept pioneered by Appia to explore the relationship between music, time, space and movement.

Other initiatives in this area include the 'Virtual Vaudeville Project'[17] developed by David S. Saltz at the University of Georgia and the collaborative EU funded 'THEATRON' project.[18] The type of tools used in the production of these computer models include commercial offerings such as *3ds Max* from Autodesk,[19] which currently retails at £2,695, for a single commercial use licence (source: Escape Studios[20]). Other high-end 3D software packages include *Softimage|XSI*[21] and *Cinema 4D*.[22] An open source software alternative is *Blender*,[23] which also features a powerful range of tools for a wide variety of 3D modelling processes. A comprehensive comparison chart for 3D tools is currently available at:

http://wiki.cgsociety.org/index.php/Comparison_of_3d_tools

Staying with the theme of historical representations of theatre, 'The Chamber of Demonstrations' is a multi-viewpoint representation of a Jacobean theatrical production involving the use of actors and a professional film crew.[24] The performance was captured using high definition digital cameras and is available as an interactive high definition DVD, featuring realistic candle-lit levels of illumination, a choice of position within the theatre to view the performance, and supporting material including still images, text and a computer-generated VR model of the theatre.

On a slightly different track but complementing the notion of virtual performance spaces, the *KeyWorx*[25] platform is an 'extensible application framework' that allows a wide range of synchronous and asynchronous interactions within defined virtual 'spaces', allowing an assortment of digital objects, including streamed multimedia, to be viewed and modified by multiple users. 'Channels' are made available through which client applications can interact with a *Keyworx* server

> A KeyWorx web application may start with a user session through a web browser (HTTP channel). By clicking a link in a page, a Flash application may be started that connects to another channel (TCP/IP connection) that attaches to the same user session. Other examples are the use of channels like email and mobile technologies like SMS.[26]

[15] King's Visualization Lab, http://www.kvl.cch.kcl.ac.uk/pompey.html, (accessed 28 March 2007)
[16] King's Visualization Lab, http://www.kvl.cch.kcl.ac.uk/appia2.html, (accessed 29 March 2007)
[17] University of Georgia, Virtual Vaudeville, http://www.virtualvaudeville.com/shows.htm, (accessed 29 March 2007)
[18] THEATRON, http://www.theatron.org/, (accessed 29 March 2007)
[19] Autodesk, 3D Studio Max, http://www.autodesk.co.uk/adsk/servlet/index?siteID=452932&id=7736447, (accessed 29 March 2007)
[20] Escape Studios, UK 3ds Max reseller, http://www.escapestudios.co.uk/?page=45, (accessed 29 March 2007)
[21] Softimage, http://www.softimage.com/products/xsi/, (accessed 29 March 2007)
[22] Maxon, Cinema 4D, http://www.maxon.net/pages/products/cinema4d/cinema4d_e.html, (accessed 29 March 2007)
[23] Blender, http://www.blender.org/, (accessed 29 March 2007)
[24] This was a collaboration between Martin White (University of Bristol) and Ignition Films, http://www.ignitionfilms.org/, (accessed 29 March 2007)
[25] Keyworx, http://www.keyworx.org/, (accessed 29 March 2007)
[26] Keyworx, http://www.keyworx.org/, (accessed 29 March 2007)

This software was originally called *KeyStroke* and was initially developed primarily for use by the performing arts community.

Allowing the concept of 'performance' to extend to an assortment of collaborative real-time interactions over TCP-IP connections, it is clear that a flexible virtual space of this type might accommodate interesting collaborative work. In a similar vein, Ruth Catlow from Furtherfield recently participated in a Methods Network seminar,[27] and demonstrated *Visitors Studio*, a networked performance and play tool which can accommodate 'real-time, multi-user mixing, collaborative creation [and] many-to-many dialogue'.[28] Like *Keyworx*, this usefully focuses attention away from the concept of 'performance' as only being able to take place in a physically constructible Euclidean space. The type of impossible floating object that one can construct in a virtual world such as *Second Life*[29] might easily become a venue for performance as might a distributed highly interactive *Access Grid*[30] session. This latter technology allows multiple sites and individuals (with the appropriate software and hardware) to all connect via video and audio links to a virtual venue where interaction can take place in real time and a record made of the collective contributions of all parties.[31] With the widespread use of webcams and the ubiquitous use of CCTV cameras - and even the video recording function on mobile phones - it becomes apparent that the nebulous concept of a 'performance space' (and when and how it is represented) can encompass a multitude of tools - too numerous to cover adequately in this paper.

3. The Cast

Starting with an early and influential piece of software, *LifeForms* from Credo Interactive[32] was used by Merce Cunningham in 1989 to choreograph dance movements prior to working with real dancers in a studio environment. The animated figures that were capable of being rendered at this early stage of development were built up using hooped lines to represent head trunk and limbs, but were nonetheless effective enough for Cunningham to visualize specific and complex actions, some of which (he was pleased to discover) were impossible for dancers to emulate.

In keeping with software developments throughout the field of 3D modelling, dance simulation packages are now capable of displaying highly sophisticated representations of human movement. *LifeForms* (version 4.0) is now branded as 'character motion software' whilst *DanceForms* (version 1.0) is labelled as software specifically aimed at choreographers. The *Mega MoCap* motion picture library, another in the stable of products on offer from Credo, states that the objects are available in eight different formats to ensure interoperability with all of the most popular 3D applications on the market. As well as *3ds Max* and *Cinema 4D*, these include: *Poser*;[33] *Lightwave 3D*;[34] and *Maya*[35] (which was acquired by Autodesk as of October 2005). At another level entirely, an interesting and freely available java-enabled web-based system that aims for the functionality of a desktop application is *Dance Simulation*,[36] a package which offers users a chance to position and animate a simple schematic figure.

[27] Methods Network, http://www.methodsnetwork.ac.uk/activities/act18.html, (accessed 29 March 2007)
[28] Furtherfield, http://www.visitorsstudio.org/?diff=-60, (accessed 29 March 2007)
[29] Second Life, http://secondlife.com/, (accessed 29 March 2007)
[30] Arts and Humanities e-Science Support Centre, Access Grid – Briefing Paper, http://www.ahessc.ac.uk/access-grid-briefing-paper, (accessed 29 March 2007)
[31] For an example see: Digital Worlds Institute, Dancing Beyond Boundaries, http://www.digitalworlds.ufl.edu/projects/dbb/default.asp, (accessed 3 April 2007)
[32] Credo Interaccessed, http://www.charactermotion.com/, (accessed 29 March 2007)
[33] E-Frontier, http://www.e-frontier.com/go/poser, (accessed 30 March 2007)
[34] Newtek, http://www.newtek.com/lightwave/, (accessed 30 March 2007)
[35] Autodesk, http://usa.autodesk.com/adsk/servlet/index?siteID=123112&id=7635018, (accessed 30 March 2007)
[36] Ron Eglash, Rensselaer Polytechnic Institute, http://www.ccd.rpi.edu/Eglash/csdt/subcult/brdance/software/dancer.html, (accessed 20 March 2007)

The casting of fictional animations in choreographed sequences is presumably at its most effective as a pre-performance design tool. Other systems advance that functionality to integrate animations with real-time movement and provide directors and producers of performance works with subtle and highly effective visualization devices to enhance and in some cases reiterate and manipulate the actions, movements and gestures of performers. One such influential piece, again directed by Merce Cunningham, was called BIPED and was premiered in 1999. The technology behind this piece was based on software called *Biped*[37](which lent its name to the performance work), which then became embedded into a commercial software package called *Character Studio* (now integrated into Autodesk 3ds Max).

Cunningham and long-term collaborators, Paul Kaiser and Shelley Eshkar, used *Character Studio* and another software module called *Physique*[38] - in conjunction with a motion tracking system - to record the movements of three dancers performing sequences choreographed by Cunningham (see fig.3).

Fig. 3 Still image from BIPED, by Merce Cunningham in collaboration with Riverbed

Reflective markers were attached to the joints and body parts of the dancers that allowed multiple cameras to capture movements as animations in 3D space. These sequences were then transferred into *Character Studio* for manipulation as hand drawn, mercurial, schematic representations of the original dancers, which were then projected during the performance to combine animation with live dancing. The spectral animated figures retained an eerie verisimilitude with their human counterparts and also changed in scale from life-size to thirty feet high during the course of the performance. Steve Dixon talks about the combination of live and animated figures being seen together for the first time (together with a score composed by Gavin Bryars),

> ...the overrall effect, when suddenly combined, appeared to many reviewers of the time as something approaching the supernatural, affording insights into the great unexplained.[39]

Of all the performance disciplines, dance has arguably the strongest interest in examining the 'corporeality' of the human form and might therefore be characterized as having the most use for animated visualizations that represent (or mis-represent) bodily movement. Beyond this territory, however, are practitioners who have used artificial intelligence (AI) and robotics to create entities that are programmed to demonstrate the appearance of acting in a performative manner. "It/I" is a two character play (1997) created by Claudio Pinhanez where the 'I' character is played by a real actor and the role of 'It' is taken by an autonomous computer character.[40] The forty minute play is essentially an interactive session between the computer and the performer where the computer controls the underlying narrative but is capable of responding to the

[37] Developed by Michael Girard and Susan Amkraut, Ohio State University
[38] Developed by John Chadwick, Unreal Pictures
[39] Dixon (2007) pg.190
[40] AHDS, Digital Performance Archive, http://channel.creative-capital.org/project_77.html, (accessed 30 March 2007)

actions of the performer in real time, using sensory apparatus and a communication language known as *ActScript*.[41]

In contrast to Pinhanez's virtual autonomous character, whose presence is manifest by the responsive nature of what appears on a screen and is emitted through speakers, the cacophonous and pyrotechnic productions of the Survival Research Laboratories (SRL)[42] are ritualized spectacles of robotic and mechanized interaction that create visceral environments filled with noise and smoke, redolent of conflict, warfare, destructive science and industrialization that has autonomously and irrationally gone beyond human control (see fig. 4). As pieces of cinematic-like spectacular drama, SRL's productions might be said to inhabit a space near the boundary of an artistic and dramatic territory that also encompasses less frenetic use of robotic 'characters'.

Fig. 4 Image of Inchworm taking a hit from the Tesla Coil, image by Garth Webb[43]

Examples include Amorphic Robot Works,[44] a collaborative group that endeavours to explore the 'primacy' of movement and sound using machines that enact and mimic the actions and appearance of organic entities. Another example is the artist Heidi Kumao[45] who favours using video screens and sensors installed into mechanized constructions of everyday objects, an approach reminiscent of some of the kinetic mechanical creations of the artist Rebecca Horn.

4. Props, Costumes and Instruments

After robotics, it is perhaps logical to look at areas of performance practice that make use of extensions or additions to the human body, a sort of 'augmented-reality' in contrast to the full-on 'virtual reality' of the robot as human surrogate. Neither prop, costume nor instrument (or perhaps all three at once), Stelarc's 'Extra Ear' project[46] is an attempt to graft a prosthetic ear made of soft tissue and cartilage onto his own forearm. Though staggering in terms of its audacious vision of anatomical transformation, it is the second phase of the process that is more relevant to the focus of this paper, dealing as it does with the embedding of technological devices into the prosthesis (and elsewhere in the body) to enable the artist to demonstrate

[41] Claudio Pinhanez, "It/I": A Theater Play Featuring an Autonomous Computer Character, http://www.research.ibm.com/people/p/pinhanez/publications/presence02.pdf, (accessed 30 March 2007)
[42] Survival Research Laboratories, http://srl.org/, (accessed 30 March 2007)
[43] Survival Research Laboratories, http://srl.org/shows/sanjose/show/, (accessed 30 march 2007)
[44] Amorphic Robot Works, http://www.cronos.net/~bk/amorphic/about.html, (accessed 30 March 2007)
[45] Creative Capital, Heidi Kumao, http://channel.creative-capital.org/project_77.html, (accessed 30 March 2007)
[46] Spatial Information Architecture, RMIT, Stelarc, http://www.sial.rmit.edu.au/Projects/Stelarc_Tissue_Culture_and_Art.php, (accessed 30 March 2007)

a unique new mode of channelling digital communication signals. When complete, the artist's new prosthetic ear and one of his teeth will contain equipment that will act in the manner of a distributed Bluetooth-enabled headset. The artist will be able to talk into the ear positioned on his forearm and will receive messages back via a speaker positioned in a tooth cavity. The expectation is that witnesses standing near the artist will be able to hear the voices of other people coming out of the artist's open mouth when he is engaged in dialogue using the equipment.

An organism enhanced by the addition of mechanical or electrical equipment is referred to as a cyborg, and as well as being a recurring theme in science-fiction writing, this has also been explored in the realm of art/science, an area of practice where it is arguably difficult on occasions to perceive the precise point where 'valid' science stops and 'art' and 'drama' begin. Kevin Warwick, professor of cybernetics at Warwick University, implanted an RFID (radio frequency identification) tag under his skin in 1998 which enabled him to influence mundane computer-controlled objects such as doors, lights and heaters by his mere proximity.[47] This was followed in 2002 with a more complex electronic device being inserted that interfaced with Warwick's nervous system, to the extent where a remote robotic arm could be made to mimic the movements of his own arm in real-time.[48]

Other figures that have adopted cyborg attributes, who are more explicitly related to the realm of performance art, include Eduardo Kac[49] and Marcel.lí Antúnez Roca, the latter known for a work entitled *Afasia* (1998) where he appears onstage wearing an exoskeleton of various body plates and arm and leg appendages which pass sensory signals to an offstage computer via an 'umbilical' cable.

Fig. 5 Marcel.li Antunez Roca performing Afasia (1998)[50]

Roca shares the stage with a group of robots and a 20' x 15' screen which respond to signals produced by each and every type of movement he performs, provoking kinetic responses from the robots and a dazzling variety of graphic and unnerving images on the screen positioned above and behind him.[51]

The use of sensors to gather and transmit movement is of central importance to the sort of wearable technology that enables participation in 3D virtual reality environments, including items such as datagloves

[47] Kevin Warwick, http://www.kevinwarwick.com/Cyborg1.htm, (accessed 1 April 2007)
[48] Kevin Warwick, http://www.kevinwarwick.com/Cyborg2.htm, (accessed 1 April 2007)
[49] Eduardo Kac, http://www.ekac.org/, (accessed 1 April 2007)
[50] Image taken from: Marcel.li Antunez Roca, Afasia, http://www.marceliantunez.com/tikiwiki/tiki-browse_gallery.php?galleryId=5, (accessed 4 April 2007)
[51] Marcel.lí Antúnez Roca, http://www.marceliantunez.com/tikiwiki/tiki-browse_gallery.php?galleryId=5, (accessed 1 April 2007)

and eye and head-tracking systems.[52] The force feedback systems available in items like electronic gloves are designed to provide a level of haptic interactivity that demands an active engagement on the part of the viewer of the work, thereby bringing a sense of performance to what might otherwise be defined as a purely passive process of viewing.

In the field of musical performance, the use of gesture alone to control the signal output of an instrument has been around for some considerable time in the form of the Theremin, an instrument created in 1919 by Lev Sergeivich Termen and introduced to Europe and America in the course of the 1920's. The sounds emitted by the fully electronic system depend on the distance of the performer's hands from an antenna which is connected to two radio frequency oscillators. Typically, the position of the right hand (in space) controls the pitch of the signal and the left hand similarly controls the volume, resulting in a uniquely expressive and microtonal instrument that is played without being touched.

More recent innovations in electronics-enabled musical performance include Laurie Anderson's *Talking Stick*[53] and the development of the *Hyperbow*[54] by Diana Young at MIT Media Lab. The first of these was used by Anderson in the 'Song of Moby Dick' (1999) and was (in the context of this work) consciously meant to represent a harpoon-like object as well as being an instrument in its own right. About six foot in length, the 'stick' is sensitive to movement and touch and sends MIDI (Musical Instrument Digital Interface) commands to an audio processing system, allowing the performer to produce a dynamic range of manipulated sounds using unorthodox performative gestures. The *Hyperbow* looks like a standard carbon fibre bow that one might use in conjunction with a violin or cello, but includes accelerometers, gyroscopes and force sensors integrated into the frog that measure spatial position, force, speed and bow-bridge distance. Designed originally as an expert analysis aid, its potential to augment techniques for playing traditional bowed instruments is in the process of being examined and exploited.

5. Stage and Scenery

Digital techniques associated with this section largely overlap with the types of tools mentioned in relation to 'The Performance Space', but it may be of use to briefly mention some specifically relevant techniques. Mark Reaney (University of Kansas and i.e.VR – the Institute for the Exploration of Virtual Realities) has extensively explored the use of virtual reality for designing stage sets, starting with a production of 'The Adding Machine' (1995).[55] Following this foray into integrating screen-based representations with live action, Reaney's next project (1996) was a version of Samuel Beckett's 'Play',[56] which required audience members to wear semi-translucent head-mounted displays (HMD's) in order to fully appreciate all aspects of the production. Pre-recorded 3D video footage of the actors was superimposed over a 3D navigable virtual environment with the audience's attention being directed by a live actor - visible through the non-opaque displays of the HMD's – who appeared as a ghostly figure amongst the digitally created imagery. The latest project featured on the ieVR website is a 2003 production of Mozart's 'The Magic Flute' which places great emphasis on the use of CGI enhanced characters and mobile projection equipment for dynamic placement of scenographic elements.

The use of stereoscopic glasses is another method for introducing a sense of depth to an image and derives from techniques that precede the invention of photography. Binocular images that were designed to be viewed separately by the left and right eyes existed in the sixteenth century[57] and the modern

[52] For an illustrative sample collection of such devices, see: VRLogic, http://www.vrlogic.com/html/datagloves.html, (accessed 1 April 2007)
[53] REM Design, http://www.remdesign.com/port7.html, (accessed 1 April 2007)
[54] MIT Media Lab, http://www.media.mit.edu/hyperins/papers/Young_NIME2002.pdf, (accessed 1 April 2007)
[55] University of Kansas, The Adding Machine – A Virtual reality Project, http://web.ku.edu/~mreaney/reaney/, (accessed 2 April 2007)
[56] University of Kansas, Play, http://web.ku.edu/~mreaney/reaney/, (accessed 2 April 2007)
[57] Robert Leggatt, http://www.rleggat.com/photohistory/history/stereosc.htm, (accessed 2 April 2007)

equivalents of the small hand-held wooden stereoscopes that isolated respective eye-views are called 3D Liquid Crystal Shutterglasses. This technique involves showing alternate left and right images onscreen at higher than normal refresh rates which are then viewed through shutterglasses with a liquid crystal blocking mechanism in both lenses that flickers on and off in synchronisation with the screen refresh rate, allowing each eye to only see the appropriate alternate image. This technology can be used very effectively in conjunction with wide rear-projected displays such as Fakespace Systems' Powerwall™ product,[58] or a CAVE (CAVE Automatic Virtual Environment)[59] immersive system where three walls and the floor of a designated space are capable of displaying stereoscopic images.

For early phases of projects where it is only necessary to block out movements within roughly designed sets, free or inexpensive software is available. *Visual Assistant*[60] is a freely downloadable tool that is aimed at creative rather than technical users and enables rapid visualization of stage settings using an intuitive toolset. Output is in VRML[61] (Virtual Reality Modelling Language) format rather than the more current iteration of that standard which is now maintained by the Web 3D consortium and is called X3D.[62] *VirtualStage*[63] from DakineWave is more recent software that provides users with a way of creating entire 3D animated plays and dramas involving characters that can be chosen or imported from model libraries along with sets and locations that can be similarly selected either from within the programme or from other appropriate systems. Another offering is o*penStages*[64] authored by Chris Dyer which offers the user options to build stages and then manipulate and light custom or generic pieces of scenery in very plausible looking theatrical spaces.

6. Music, Audio, Graphics, Lights and Effects

One of the most widely used tools across the performing arts is *Max/MSP* developed by Cycling '74[65] which is a graphical programming environment for music, audio and multimedia. It works on the principle that users manipulate 'objects' that represent actions and entities and that when these are moved around into different sequences, the embedded code moves with the objects. *Max* represents the basic environment and *MSP* features a set of audio processing objects that enable the user to carry out a wide range of specific signal manipulation tasks. Cycling '74 also produce *Jitter*[66] which extends the Max/MSP environment to support the real time manipulation of video and 3D graphics. Though optimized for very fast graphics handling, *Jitter* can in fact handle any kind of numerical data that it is possible to input into a computer and does so by abstracting all data as multidimensional matrices. Bundled together, the power and range of Max/MSP/Jitter is very significant and there is a large and active international community using this software for live music events and performance and installation artworks.

A recent interesting joint announcement by Cycling '74 and Ableton,[67] who are responsible for a powerful piece of software called Ableton Live,[68] states that the two companies have formed a strategic partnership and will be looking at ways to leverage their respective strengths to add value to future software releases. Ableton Live is a music creation, production and performance platform used by a roster of very prestigious international performers for all phases of musical creativity, from rough audio 'sketching' to complex

[58] Fakespace Systems, Powerwall, http://www.fakespace.com/powerWall.htm. (accessed 2 April 2007)
[59] University College London, http://www.cs.ucl.ac.uk/research/vr/Projects/Cave/, (accessed 2 April 2007)
[60] University of Waikato, Visual Assistant, http://www.cs.waikato.ac.nz/~cbeardon/VA/index.html, (accessed 2 April 2007)
[61] Floppy's VRML 97 Tutorial, http://web3d.vapourtech.com/, (accessed 2 April 2007)
[62] Web 3D Consortium, http://www.web3d.org/, (accessed 2 April 2007)
[63] Dakine Wave, http://dakinewave.com/, (accessed 2 April 2007)
[64] openStages, http://www.openstages.co.uk/, (accessed 3 April)
[65] Cycling '74, http://www.cycling74.com/, (accessed 2 April 2007)
[66] Cycling '74, Jitter, http://www.cycling74.com/products/jitter, (accessed 2 April 2007)
[67] Ableton, http://www.ableton.com/, (accessed 2 April 2007)
[68] Ableton Live Showcase, http://www.ableton.com/live6-showcase, (accessed 2 April 2007)

finished compositions. In contrast to these commercial offerings, the open source system SuperCollider,[69] authored by James McCartney,[70] is another object-oriented programming tool that potentially has a range of applications for audio and video but is particularly suited to the creation and manipulation of music. The adherents to this system also form an active and enthusiastic user-community.[71] (There is a Windows-compatible version called Psycollider.[72])

The use of MIDI show controllers (MSC's) for handling complex sequences of lighting, audio, pyrotechnics, scenery movements, atmospheric conditions, etc., has been commonplace in performance venues for many years. Like the MIDI music protocol, MSC's interface between devices that recognise commands to cue or end specific encoded instructions and as such, can potentially work with any piece of equipment that can accommodate MIDI input. Given their long history of use, it is perhaps more interesting in this context to focus on the use of lighting and special effects in *virtual* environments and the types of tools that designers can use to enhance these spaces. Radiance[73] is an example of an open source product that handles sophisticated virtual lighting schemes by calculating the amount of light passing through a specific point in a specific direction, a technique known as 'ray tracing'. Fig. 5 shows an example of the type of lighting simulation that can be produced and compares a corner of a room in the House of the Vettii in Pompeii as it might have appeared prior to 79 A.D. when it was highly likely that illumination would have been supplied by olive oil lamps. This is compared to lighting under modern conditions and the resultant effects on the visibility of the frescoes are discussed by Devlin et al in their report.[74]

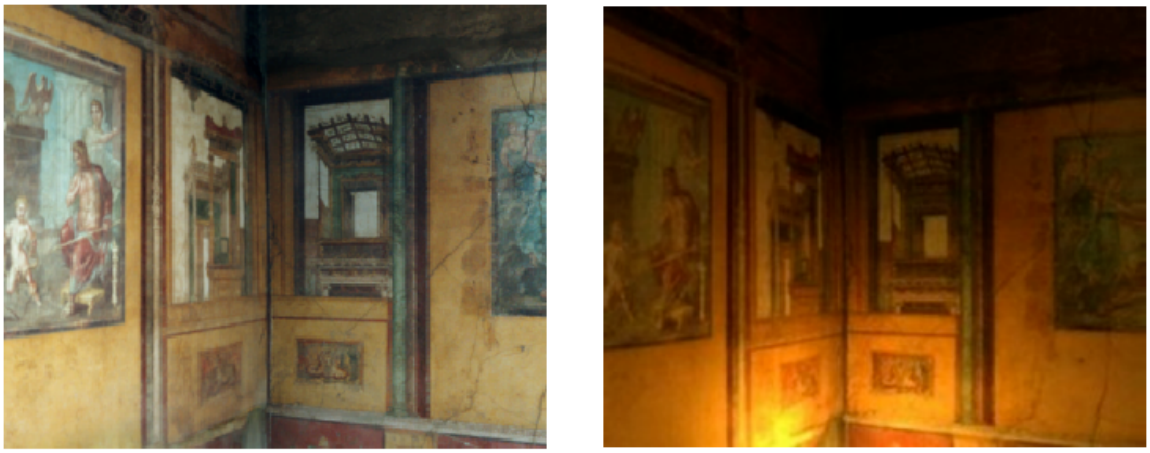

Fig. 6 House of the Vettii with simulated modern lighting (left) and olive oil lamp (right) – Kate Devlin et al

The software is complex and demands high levels of user knowledge but can produce stunning results. A commercial alternative comes in the form EIAS Animator developed by the Electric Image Technology Group.[75] In conjunction with EIAS Camera, these products claim to significantly reduce the time needed to render animations whilst still producing impeccable results. An interesting account of a project[76] from 2001 that produced a computer model of the Crystal Palace as it would have appeared in 1851 refers to both the

[69] SuperCollider Wiki, http://swiki.hfbk-hamburg.de:8888/MusicTechnology/13, (accessed 2 April 2007)
[70] James McCartney, SuperCollider Home page, http://www.audiosynth.com/, (accessed 2 April 2007)
[71] The Methods Network event 'Advanced Technologies for Collaborative Performance' brought together some of the practitioners, see: http://www.methodsnetwork.ac.uk/activities/act13.html, (accessed 2 April 2007)
[72] Psycollider, http://sonenvir.at/downloads/sc3/sc3-win/, (accessed 2 April 2007)
[73] Radiance, http://radsite.lbl.gov/radiance/framew.html, (accessed 2 April 2007)
[74] Kate Devlin, Alan Chalmers, Duncan Brown, http://doc.gold.ac.uk/~mas01kd/publications/unesco_paper.pdf, (accessed 2 April 2007)
[75] Electric Image Technology Group, http://eitechnologygroup.com/, (accessed 2 April 2007)
[76] Institute of Advanced Technology in the Humanities, Crystal Palace Project, http://www.iath.virginia.edu/london/model/notes.html, (accessed 2 April 2007)

use of *Radiance* and an Electric Image software product called *Universe*. This summary usefully highlights some of the challenges facing VR simulation projects and indicates the resources required to effectively illuminate and render complex 3D models.

7. Performance and Audience

Examples have already been cited where the movements of performers have been translated into digital signals and have been used to animate or actuate virtual dance partners, either in the form of digital representations of figures (BIPED by Merce Cunningham) or robotic devices (Afasia by Marcel.lí Antúnez Roca). The reason for separating these examples from those cited below is to allow a point to be made about the visibility of technology during performances and what effect this has on the perceptions of the audience. Particularly in the case of Roca's work, it is clear where the technology is situated in relation to the performer and it is also obvious that he is directly and dynamically choosing to interact with it.[77] BIPED also functions in an unambiguous way even though the appearance of the piece when staged can work at a slightly more enigmatic level. The live performers and the animated figures move independently of each other and any apparent interactions between them are serendipitous moments that the audience can perceive or not according to their level of engagement with (and their physical view of) the performance.

A number of other systems also allow the capture of movement and/or its translation into digital signals and they are interesting to consider in relation to the question of how explicit technology needs to be in order for an audience to appreciate the contribution it is making. *MidiDancer*[78] and *Isadora*[79] are systems that have been developed by Mark Coniglio who co-directs the dance company Troika Ranch.[80] *MidiDancer* is a wearable hardware movement sensing system that uses flex sensor strips over the dancer's joints (elbows, knees, hips etc.) which then connect by wire to a small microcomputer usually attached to the dancer's back. This box also features a radio transmitter which sends information from the sensors to a receiver offstage linked to a computer running the *Isadora* software, which then uses the data to control a range of media that is simultaneously seen or heard in conjunction with the performance.

Whilst this allows for seamless interaction between the performer and any media format that is configured to respond to that performance, there is a danger that the work will take on the appearance of having been created entirely in advance and therefore lack any sense of 'liveness', a concept and an issue that has been widely debated in digital performance circles for some years.[81] This same issue in relation to 'laptop music' is identified and countered by Marc Weidenbaum:

> During abstract sound-art shows by laptop musicians, it's not uncommon for someone to ponder whether the performer is just checking his email while the music plays by itself. Such skepticism fades with familiarity, as the rough contours of laptop music become understood and the listener can judge a performance on the basis of the music rather than the player's theatricality.[82]

Troika Ranch are just one of a number of dance companies over the last ten years that have continually developed and refined their use of technology to the point where the software and hardware systems they use now blend with live performance in much more subtle and nuanced ways. The mid to late 1990's seems to have witnessed something approaching a 'goldrush' of dance performers using digital tools such as *EyeCon*,[83] *BodyCoder*,[84] *Laserweb*[85] and *Very Nervous System* [86]*(VNS)*, all of which enable expressive

[77] Dixon (2007) pg. 326
[78] Troika Ranch, http://www.troikaranch.org/mididancer2.html, (accessed 3 April 2007)
[79] Troika Tronix, Isadora, http://www.troikatronix.com/isadora.html, (accessed 30 March 2007)
[80] Troika Ranch, http://www.troikaranch.org/, (accessed 30 March 2007)
[81] See: Modern Drama, a review of Philip Auslander's Book, 'Liveness: Performance in a Mediatized Culture', http://www.utpjournals.com/product/md/433/liveness15.html, (accessed 3 April 2007)
[82] Remix Theory, Marc Weidenbaum, http://remixtheory.net/?p=140, (accessed 3 April 2007)
[83] EyeCon, http://eyecon.palindrome.de/, (accessed 3 April 2007)

movement to be transferred to other formats. In such an environment of experimentation and methodological immaturity it is unsurprising that some works might now be assessed as being variably successful in their objective of using technology in artful and integrated ways. By contrast - and highlighting the value of just 3 or 4 years experience of using specific methods - Steve Dixon cites an example of a simple but beautifully devised piece from 2003 called 'Touching', created by Robert Wechsler and Sarah Rubidge (Palindrome[87]), where *EyeCon* is used to define the point where two dancers come slowly towards each other and then make contact, causing screen images of their figures to turn from positive to negative.[88]

Having considered passive audience reactions to the use of technology in the context of 'shows', there is also scope for considering the ways which technology can bring experiences and interactivity directly to the viewer. At a very accessible and technologically basic level, the use of webcams has enabled any space adjacent to a network connection to act as a site for performance, a format famously exploited by Jennifer Ringley who maintained a continuous netcast of her daily comings and goings for almost eight years at a website called 'Jennicam'.[89] The Telematic Art of figures such as Roy Ascott, Paul Sermon and Eduardo Kac is a more formal attempt to use computer-mediated communications technology to investigate ideas such as: presence/absence; the virtual and the physical; and the nature of human relations as defined through digital media.

As a brand of performance, a work such as Paul Sermon's 'Telematic Vision'[90] (1993) defines a slightly different paradigm where the differentiation between audience and performer breaks down. In this installation the participant is seated on a sofa facing a screen which initially appears to be a straightforward depiction of them taken from a camera positioned above the screen.

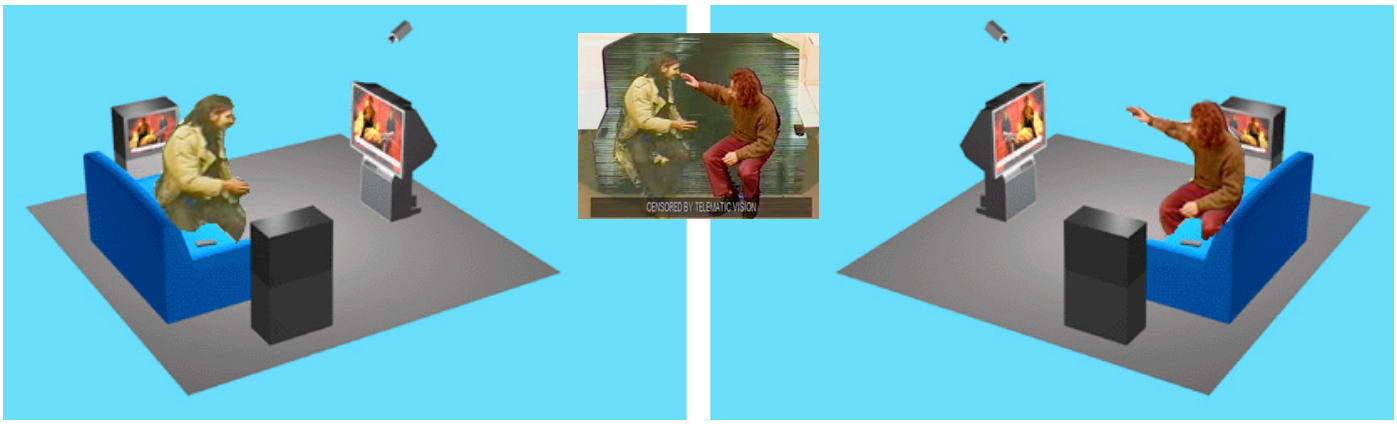

Fig. 7 Representation of the technique used for 'Telematic Vision' by Paul Sermon[91]

The unexpected occurs when someone at a remote location faced with an identical scenario also sits down on their sofa which results in both screens displaying both people sat on the sofa as if they were seated

[84] Julie Wilson, Mark Bromwich, Bodycoder, http://journals.cambridge.org/article_S1355771803000256, (accessed 3 April 2007)
[85] Troika Ranch, Laserweb, http://www.troikaranch.org/laserweb.html, (accessed 3 April 2007)
[86] David Rokeby, Very Nervous System, http://homepage.mac.com/davidrokeby/vns.html, (accessed 3 April 2007)
[87] Palindrome, http://www.palindrome.de/, (accessed 3 April 2007)
[88] Dixon (2007) pg. 205-206
[89] Paul J.R. Brown, http://www.arttech.ab.ca/pbrown/jenni/jenni.html, (accessed 3 April 2007)
[90] Paul Sermon, Salford University, http://creativetechnology.salford.ac.uk/paulsermon/vision/, (accessed 3 April 2007)
[91] Figure details from: Telematic Embrace, The Presence Project, http://presence.stanford.edu:3455/Collaboratory/595, sofa diagrams from: http://www.hgb-leipzig.de/~sermon/vision/, (accessed 4 April 2007)

together. Interplay between unfamiliar remote participants often begins uncertainly but soon develops into a playful investigation of the space they both inhabit, much in the same way as participants responded to his earlier work 'Telematic Dreaming' (1992) which used comparable methods in the context of remote bed-sharing. The tools that underpin this work include an ISDN connection, video-conferencing equipment and video cameras.

Many performance-related telematic art works are concerned with the presence, absence or extent of communications infrastructure, as well as the latency, effectiveness and veracity of the links that such networks provide. Installations that address themes of surveillance have been widely tackled and the spread of wireless networks have focused attention on increasingly discreet methods of telematic intervention. A presentation at the CHArt (Computers and History of Art) 2006 conference[92] featured a work by the LOCA (Location Oriented Critical Arts) group which involved the setting up of a wireless network node in a public space that allowed LOCA to send unsolicited text messages to the mobile phones of passers-by indicating that they were being observed and monitored by an unknown agency.[93]

8. Archiving and Representation

Archiving and preserving performance and installation art works is a challenging proposition which increases with the amount of technological complexity that is included in the original conception of the work. Furthermore, if that technology is proprietary, bespoke or fragile, it stands to reason that the chances of being able to recreate the work in its original form will decrease as time goes by. Accordingly, the sensible option is either to base works on technology solutions that have some claim to compliance with accepted international standards, or, to design works that can be reproduced using updated technology without losing any of the qualities that made the work unique and effective in the first place.

In some cases, particularly where destruction of materials is one of the stated aims or extreme physical performance is at the core of the work, it is clear that neither of these options are viable. In such cases documentary evidence is a key preservation issue and advice and information about the creation and long term sustainability of text, still image and video material is available from the AHDS[94] (Arts and Humanities Data service), TASI[95] (the Technical Advisory Service for Images) and a number of other agencies and web-based resources including INTUTE[96] and ICT Guides[97].

Postscript

This paper is a brief and highly selective look at a very broad and complex field. For an in-depth and very readable account of a wide number of issues relating to digital performance, readers are encouraged to refer to Steve Dixon's monumental new volume (with contributions from Barry Smith), *Digital Performance: A History of New Media in Theater, Dance, Performance Art and Installation* (see Reference section below). This paper draws extensively on this book and its index for references to software systems and information relating to performances.

[92] CHArt 2006, Fast Forward: Art History, Curation and Practice After Media, http://www.chart.ac.uk/chart2006/abstracts/index.html, (accessed 3 April 2007)
[93] LOCA, http://3eyes.co.uk/views/public/?doc=Loca, (accessed 3 April 2007)
[94] AHDS, http://ahds.ac.uk/, (accessed 4 April 2007)
[95] TASI, http://www.tasi.ac.uk/, (accessed 4 April 2007)
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Original Draft – March 2007
Version control – 3 July 2007

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http://psi-web.org/index.html
Promoting communication and exchange between scholars and practitioners

David Saltz article
http://muse.jhu.edu/journals/theatre_topics/toc/tt11.2.html
Live Media: Interactive Technology and Theatre

Organisations/Groups/Projects

The Presence Project
http://traumwerk.stanford.edu/presence/
Information relating to artists and groups connected to performance and installation art

Mixed Reality Laboratory
http://www.mrl.nott.ac.uk/
A cross-disciplinary studio facility exploring mixed reality technologies

STEIM

http://www.steim.org/steim/
Studio for Electro-Instrumental Music

NIP
http://newinterfaces.net/nip/
New Interfaces for Performance

PARIP
http://www.bris.ac.uk/parip/index.htm
Practice-as-Research in Performance

Univited Guests
http://www.uninvited-guests.net/index_m.htm
Performance and media company

Vincent Dance Theatre
http://www.vincentdt.com/digital.htm
Project looking at the interface between dance and digital technology

Marcel Network
http://www.mmmarcel.org/marcel.htm
Network of multimedia art research centres and electronic laboratories

Networked Performance
http://www.turbulence.org/blog/
A research blog about network-enabled performance

0100101110101101
http://www.0100101110101101.org/index.html
Eva and Franco Mattes – Net artists

SMARTLab
http://www.smartlab.uk.com/
Digital Media Institute based at University of East London

George Coates's Performance Works
http://www.georgecoates.org/
Influential theatre company founded in 1977

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