Approaches to creating interactivated spaces, from intimate to inhabited interfaces

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In contemporary music and arts practices the previously distinct roles of author, composer and performer have become increasingly conflated, catalysed by the use of computer technology. Newly combined *roles* of composer and performer that are assumed by one or more people or computer systems are identified and described, as well as *actions* including preparation, organisation and presentation. In this paper the interface is described as an 'interactivated space' to encompass both the intimate scale of a performer manipulating the materials through an on-body interface, and the larger in-space interface where the work is shared with the performers and audience. Two examples of projects the authors are involved in are described, which form the basis for further discussion. The two interfaces that manifest themselves in the processes, the *instrument* and the *score* are discussed in more detail with a focus on their changed appearance and role.

1. INTRODUCTION

Through the use of computer technology it has become increasingly feasible to create time-based live art works playing sound (music) and light (images, video) and placing them in real time in the architectural space. In order to enable people to access and manipulate the materials inside the computer, interfaces are needed and many artists have developed their own solutions. In this paper the interface is described as an 'interactivated space' to encompass both the intimate scale of a performer manipulating the materials through an on-body interface, and the larger in-space interface where the work is shared with the performers and audience.

In contemporary music and arts practices, the previously distinct roles of composer and performer have become increasingly conflated, catalysed by the use of computer technology. Based on our own experiences, we identify and describe the newly combined *roles* of composer and performer that are assumed by one or more people or computer systems, and *actions* including preparation, organisation and presentation that take place during the creative trajectory from the first gathering of material to the final presentation. In situations such as discussed in this paper, this is not a linear process, the roles and actions influence each other in a continuous 'plaited' development over time. People or other entities such as computer systems can take on roles and perform actions in various orders and combinations sequentially or simultaneously.

Throughout this development, the traditional idea of an instrument has evolved to become the interface between human and computer technology, a state that includes previously unconsidered actions, such as gathering, processing and placing sonic or visual material. This is paralleled by the conceptual change in the role of a score which, due to the mingling of composer/performer roles, is emerging as a dynamic interface capable of continuous communication. The scale of these two interfaces, instrument and notation, ranges from the intimate to the architectural.

To further elaborate on these issues we will first introduce two projects that helped us in our research, by allowing practice to inform theory and vice versa. This will be followed by sections that describe in more detail the elements of the proposed approach to creating interactivated spaces.

1.1. The Video-Organ project

Developed by the authors over a period of two years, the Video-Organ practically addresses questions of composing audio-visual combinations, the control over the progressions of sound and video material through specially designed interfaces called 'instrumentlets' and the dynamic placing of the material back into a specific architectural space. The authors take on the combined roles of composers, performers and instrument designers and builders, and are developing strategies to make a coherent approach to creating these environments made out of the diverse materials of sound, images and space. The instrument is described in more detail elsewhere (Bongers and Harris 2002).

1.2. The Meta-Orchestra

Starting as a European project, the Meta-Orchestra is a changing collective of about fifteen musicians, visual artists and dancers. All members of the orchestra are individual in their computer/instrument set-up and the material they choose to use, but collaborate to make performances where each member is networked allowing the sharing of material. A number of significant issues

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are brought up by such a situation. These include control, access to private work, sharing, and how to develop a coherent structure. This project is extensively documented elsewhere (Bongers, Impett and Harris 2001, Impett and Bongers 2001). Like the Video-Organ, it is an ongoing project and a large-scale Score-Space is being developed to add a layer of communication to the ensemble.

2. ROLES, ACTIONS AND INTERFACES

From the experience gained by the above projects it seems essential to understand changes in traditional terminology used to describe the creative process behind an art work. Instead of thinking of the composer or author as an exclusively specialised person, it is seen as a role that can be taken on by one or more members of a creative team. The same is true for performers. In this sense, the same person can be both performer and composer, or the roles are not necessarily mutually exclusive but rather extremes on a continuum. Improvising musicians have been taking positions throughout this whole continuum for decades, also increasingly influenced by the computer technology. This has unbalanced the reliance on scores to communicate between composer and performer, although these scores are taking on new qualities, as will be further discussed in section 4.

In either of these roles, the person can perform actions including *preparation*, gathering or synthesising material, the *organisation*, processing and development of the material and interfaces, and the *presentation*, which externalises these elements within a performance setting. In the case of the Video-Organ, these actions are usually the following. Preparation includes recording sounds and moving images from various real places; organisation includes the editing of these raw images and sounds into useful, manageable clips, and mapping these to gestural parameters that are then made into small instruments and used for further editing; presentation includes the analysis and placing of the video and sound within the specific space of the performance, a phase which can completely change the way the material comes across. All of these 'actions' happen throughout our process towards the final performance, and we may gather material as late as the day before or even during the performance, whilst we may have experimented for a considerable time during the early stages with placing the material in the specific space. These three actions are constantly present, 'fluidifying' what was previously segregated within the creative trajectory.

The materials that we work with must go through the computer. Corresponding with the actions above, in order to get the material in the computer, then manipulate it and then bring it out in a performance, *interfaces* are required. These interfaces between human and computer often have to be specially developed for a specific artistic purpose or to achieve a particular result. The instrumentlets developed for the Video-Organ are examples of this, where an interface is designed and built to match a certain human gesture or action to the manipulation of a piece of audio-visual material. These instrumentlets are often used not only in the presentation stage of the project but also in the organisation phase as editing tools. The design and development of these instrumentlets both influences and is influenced by the material, therefore becoming part of the artistic process. This is true not only for hardware development, but also for the software development involved where it seems a more widely accepted notion; see, for instance, 'The art of programming' (Evers, van der Velden and van der Wenden 2002).

It is helpful to expand the idea of an instrument as illustrated by the following examples. The digital camera is 'played' in time, somewhat like an instrument in the process of gathering material with a specific effect or image movement in mind. In a similar way, the architectural space exhibits specific qualities that become part of the instrument to be played. Aspects such as projection surfaces, dimensions and layouts are considered as parameters of the instrument, for instance in one case ornamented stucco walls were chosen to be used for projection, considerably influencing the moving images projected. Both of these 'instruments' are also described in section 5. In the Meta-Orchestra, not only are the roles of composer, performer and conductor continuously blurred, but also the members can (to a pre-defined extent) influence each other's performance set-ups. Some parameters of the processes that are used in the presentation can be influenced by others over the network, thus extending the notion of an instrument.

In the following section the design approach in the context of new instruments is elaborated, describing the interface between human and computer.

3. THE INSTRUMENT: THE HUMAN–COMPUTER(–HUMAN) INTERFACE

The instrument is a physical device that enables a communication between the human brain and the digital world inside a computer. The computer system needs input from the real world through input devices (which consists of *sensors*), and to address the senses of the users through output devices (displays that consists of *actuators*). Inside the computer system, sensor data has to be analysed, behaviours are programmed, materials are generated and manipulated so that a closed loop between the input of the system and the output is established, and the system can *interact* with the user(s) in a multimodal way.

Modalities are communication channels between humans or, as in this case, between humans and computer systems, or between humans through computer systems. These channels are usually described reflecting the human senses and actions, for instance there are

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visual modalities (text, colours, moving images), *auditory modalities* (speech, music) and *tactual modalities* (touch). Within each of these sensory modalities, separate communication channels can be described, for instance within the auditory modality we can discern speech and other sounds. Machine input modalities (through sensors) register human output modalities (actions), and machine output modalities (through displays) address the human senses (Schomaker *et al*. 1995, Bongers 2000). This description can provide the basis for both the instrument and notation interfaces that are discussed in this paper.

The Physical Interface Design Space is being developed in order to describe existing interfaces as well as to serve as a tool to guide the process of designing new instruments. The fundamental approach is, as it were, to *decompose* a complicated device into its actual sensors, and then to build it up again in human terms.

3.1. The physical instrument design space

In the HCI (Human–Computer Interaction) literature several interface taxonomies or design spaces can be found, each reflecting the state of the human interface technology of their time (Foley, Wallace and Chan 1984, Baecker and Buxton 1987, Card, Mackinlay and Robinson 1990). This is always a complicated exercise, with the risk of comparing apples and oranges. A recent and ongoing project to establish a new design space is included in this paper because of its perceived relevance to the issues of interactivating spaces on scales from the intimate to the architectural. A brief summary can be found in the Video-Organ paper (Bongers and Harris 2002) which analyses the range of instrumentlets in the terms of the design space.

The Physical Interface Design Space describes only the *physical* layer of the interaction between human and computer, on top of which the higher layers can be described which convey *meaning* and *intent* (semiotic, syntactic, semantic) and the *mapping* between content and action. The notion of the importance of mapping has been the topic of several papers in this field (Hunt *et al*. 2002).

Movements in the Physical Interface Design Space are described in **Degrees of Freedom**. The diagram below gives the definition of the six Degrees of Freedom that describe movements and orientations of objects in three-dimensional space. There are the three lateral movements along the X, Y and Z axes, respectively, and three rotational movements around those axes notated as rX, rY and rZ. For the rotational degrees of freedom, often the terms pitch (rX), yaw (rY) and roll (rZ) are used, as is common in the fields of robotics and aviation. Each DoF can be described in **range** (linear distance or angle), **precision** (resolution, speed and accuracy) and **feedback**.

In summary, the PIDS is based on:

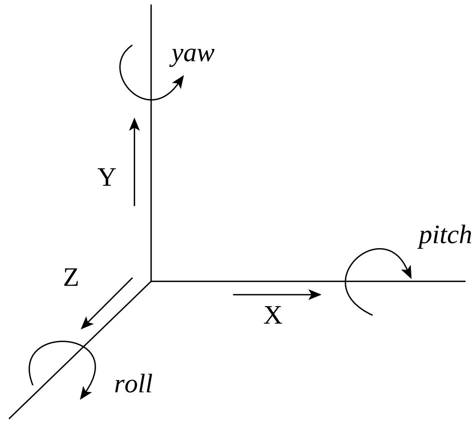

Figure 1. The degrees of freedom.

- description of both input (from human movement) and output (feedback addressing the human senses that guide the movement), the interface as a two-way device,
- breaking up the functions of the device into separate sensors and actuators, relating to individual Degrees of Freedom,
- describing each of these elements along the dimensions of the design space, and
- the design space consisting of Range, Precision and Feedback.

The next sections describe these dimensions of the design space in more detail.

3.1.1. Range

The range of a sensor is defined in distance for the lateral degrees of freedom and in angle for the rotational degrees of freedom. The range can be continuous, such as in the case of turning a potentiometer (typical range is 270°), or discontinuous, which means the user can jump between values such as on a drawing tablet. The range can be 0 (this is the case with a force or torque sensor, referred to as the isometric case), to a few millimetres, to several metres. We describe three spaces of the human scale: within the hand, within reach of the arms and within reach of the moving body:

- The *intimate* (isometric/0–10 cm) within the hand or mouth. Computer interfaces that use the extreme sensitivity and fine control of the human mouth are rare, but many musical instruments such as flute, trumpet and saxophone prove the value of this channel.
- The arm range or *bodysphere*, within the reach of the whole arm or feet (0–1 metre). Often involving desk-based devices such as the mouse or joystick, or foot pedals that are used to control the computer with the feet.

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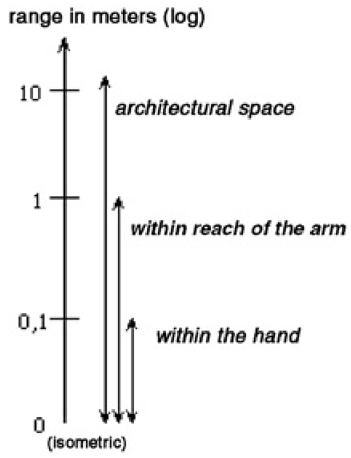

Figure 2. The Range parameter of the Design Space.

- The architectural, or *spatial*, body movement – locomotion and location in space (0–10 metre). This is the scale of interactive architectural spaces, where the system senses the presence of humans in space (Bongers 2002a, Oosterhuis 2002).

As is often the case with measuring quantities on human scales, it is best plotted against a logarithmic scale. In the Design Space the range of a sensor or (part of an) input device can be put on an axis as shown in figure 2.

3.1.2. Precision

To describe the precision of a measurement, a number of machine factors are involved, such as the resolution (number of bits used, from one for a switch to 12 bits or more for analogue sensors), speed (sampling frequency ranging from 200 Hz for normal analogue sensors to 48 kHz for audio), and accuracy. These factors are dependent on the hardware interface and driver software rather than on the actual sensor.

The simplest case is the switch, with two positions which can be read into the computer in one bit: on/off. Rotary encoders and some other sensors output pulse trains, the pulse width being proportional to the physical quantity measured. Analogue sensors are read through an A/D converter with a certain resolution (number of bits used to describe each sample) and sample rate. Depending on the application, there are several levels of software drivers involved, each with their own delays and round offs.

It is therefore almost impossible to consistently qualify this parameter in machine terms. In the context of the PIDS it is proposed to use a human movement based measured figure that gives the ratio between the measurements of the slowest and the fastest movement. This number then indicates the speed and precision of the whole chain from actual movement to effect in the computer, before it is mapped to a task. It is a measure of potential expressiveness of an input device.

3.1.3. Feedback

The information that is perceived by the user when manipulating the interface to obtain a certain effect or carry out a certain task is called feedback. In most cases, a physical device will give *passive* or inherent feedback, such as the normal force perceived from the weight of the device, the click felt when pressing a key, or the visually perceived movement of the hand. The system can also actively generate feedback information, and this *active* feedback can happen in two ways. One is by the content itself, for instance the sound played with the musical instrument or the video images scrubbed with an instrumentlet, and the other is explicitly built in the interface as information generated only for the user manipulating and is the most useful for the articulation of a movement. This articulatory feedback happens on the intimate scale of movement and a very suitable human input channel for this is the sense of touch.

Any manipulation upon or with an object or artefact in the real world is guided by touch, in other words any movement measured is influenced by the haptic feedback or articulatory feedback. The term tactual perception (Loomis and Lederman 1986) is used here because it encompasses the three main channels of the human sense of touch: the cutaneous sensitivity of the skin which informs our tactile sense, the internal mechanoreceptors in the body or proprioceptors which inform our kinaesthetic sense of the position and orientation of our body (parts), and the so-called efference copy of the signals from the brain that control the movement in the case of active exploration. This last channel is called haptic perception, which is involved in the case of the use of a computer input device. Haptic feedback can be roughly classified as *texture*, (normal) *force* and *shape*. Through actuators, which translate electrical signals from within the computer to physical quantities that can be perceived by humans, the computer can actively address the user's sense of touch (Bongers 1998). Using vibrotactile actuators, virtual textures can be generated (Bongers 2002b), and through motors, for instance, forces can be generated which address our kinaesthetic sense.

The tactual feedback in a Design Space has to do with how a device and the material manipulated feel. It also deals with the difference between free moving (a gesture tracker) and grounded (where the input device has a fixed connection or mechanical linkage). The values on the force axis range from 0 (no feedback, free moving) to ∞ (no movement, isometric force). The value can be negative, when the device actively guides the user by pulling rather then pushing against the movement. This case is called feed-forward.

Tactual feedback can be expressed on an axis, again logarithmically, from a range of 1 Newton for moving a light object such as a mouse of about 100 grammes (which, depending on the friction, would roughly translate to 1 Newton) to the range of, for instance, the index

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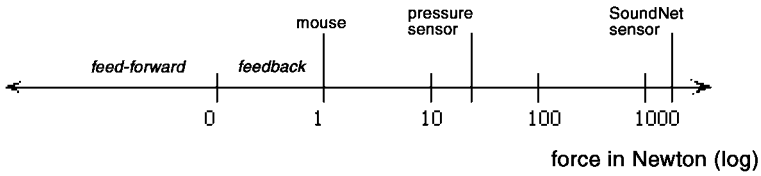

Figure 3. Forces displayed on a tactual feedback axis.

finger (< 20 N), the 'power grip' of the hand (< 150 N), arm force (< 250 N) or forces generated by the whole body (< 2,000 N), as shown in figure 3. Rotational DoFs would be expressed in torque, which is the product of the force and the arm length. To be able to compare input devices or sensors across DoFs, it may be necessary to define a uniform parameter for all DoFs that also includes form factor issues (at least the leverage arm, and friction) and texture.

In the next section the second important interface will be described, involving new forms of notation systems as a means of communication between composer and performer.

4. THE DYNAMIC SCORE: THE COMPOSER–PERFORMER INTERFACE

The musical score is an interface between composer and performer acting as a means of communication through an agreed notation system. It contains information about specific qualities of sounds as well as technical instrumental instructions and group coordination. The type of notation system chosen by the composer depends on what elements are most necessary to communicate, and what symbols or visual gestures are understandable for interpretation by the performers. Although notation is not a necessity for music to exist, it certainly influences the direction of musical development. In working with computer technology in a situation such as described in this paper, the use of notation is minimised, but it is still essential to make clear how the digital information is developing throughout a piece. To create a score in such a situation becomes a question of how to bring out only the most important information in a clear way, whether by visualising it, displaying it haptically, or by the sounds themselves. It is important to consider two points of view in such a notation system, that which allows the composer to add to the score, and that which allows the performer to read and be influenced by the score. As the roles of composer and performer can often be assumed by the same person and take place instantaneously, side by side, the score itself has to be constantly updatable and dynamic.

To expand on this it is helpful to take an example from the historical development of one musical notation system, that of Western staff notation. The most generally accepted theory for the emergence of neumic notation in the mediaeval period is that it aided memory, with the effect of encouraging repetition, non-oral preservation and subsequently compositional development. During this period, the musical score developed as an interface and communication medium between musicians across historical and geographical boundaries. It provides an example of the visualisation of certain parameters of music and it is probably no coincidence that this happened within a society literate in visual symbolism. The music, the image, the space, even the smells and the strict ritual of the mediaeval mass was the environment that the score manuscript 'inhabited' whilst containing within it the same intimate precision and decoration that was expressed in the greater scale of the mass. The role of the score was not only a form of communication between composer and performer, but an 'illuminated interface' between people, music, image and space.

The disintegration of the Western musical notation system occurred during the twentieth century, perhaps beginning with the Futurist dreams of Russolo in his attempts to visualise noises in a graphic score (Sinker 2002). The wide variety of graphical notation systems that arose throughout the century, ranging from precise symbols with specific interpretative instructions to freely interpreted visual scores, demonstrates the vast possibilities of the score as a communication medium and as a visual medium in its own right (Harris 2002). The extent to which the performers were given interpretative freedom again illustrates the conflation of the roles of composer, performer and improviser. Both the Video-Organ and the Meta-Orchestra projects take these issues as a central part of the approach and ask: If the process of creating a piece for the Video-Organ is so modular and evolutionary, how should it be structured by a score? The challenges of scores in the described projects of Video-Organ and Meta-Orchestra bring out the following suggestions and solutions.

It seems that in some ways the 'illuminated interface' found in the mediaeval score is relevant to the conceptual transformation occurring in the role of the score in today's technologically extended performances. Whilst fulfilling a similar task, the score expands to address the needs of this new performance situation and the technological context. As a communication medium it can be imagined to stretch from an intimate to an architectural scale, using various means such as sound, image and touch. It must become a spatial interface that surrounds the performance, allowing it to be immersed in the environment of the 'score-space'. Different ways of structuring, communicating, using, changing and influencing the

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information presented by such a physical, multi-modal and dynamic Score-Space need to be developed. It is suggested that notation can be based on the sensory modalities and theory of input–output interaction as put forward in the section on instruments in this paper involving gestural human movement. The Score-Space will be addressed in a future phase of the Meta-Orchestra project.

5. INSIDE OUT

We will now describe one of our public performances called *Inside Out* that relates to the matters discussed so far, informing the theoretical considerations. It took place in July 2002 in the artist residency Nau Côclea in Camallera, near Barcelona. The aim of the performance was to interactivate the building, from the inside where the performers were, to the outside, where the audience was. Sound was projected from inside the building, generated in real time using computers and the Rebellious Flute, and images were projected on three surfaces using the computer with a video projector and several slide projectors. The idea of interface was highlighted in the physical space by the placing of screens and sounds on the boundary between the private part of the house and the public. These surfaces were semi-transparent and constantly changing in their appearance. Sounds and images were used including some that were captured in this location during a working period preceding the concert, and dusk was chosen to maximumise the impact of environmental sounds and images: birds, crickets, frogs; sun setting, moon rising and trains passing. An inhabited house was revealed in its environmental context through the performance, during the transition from day to night.

A new instrumentlet was developed to control an array of six slide projectors displaying, for example, images of the nearby sunflower field by daylight on a long thin window. The instrumentlet consisted of an assembly of mercury switches which acted as tilt sensors, each designated directly (through a solid state relay) to an individual projector. By moving the instrumentlet in the hand through various inclinations and movements, projection patterns were generated, effectively animating the long window space. One slide projected through onto the trees behind the audience. The house was isolated in some woods on a hill and the effects were visible from a large distance, drawing the audience to the spot. The main gateway was filled with a projection screen, moving slightly in the wind like a sail, with high-quality video projections generated by the computer and manipulated by the performers through the instrumentlets. In some parts of the work, live images shot by the performers from inside the house, revealing the activity of the performance including the projections, were projected outside, effectively folding the space in time. The third projection in the doorway of the studio space used still images taken during the process of creating the piece, projected on three layers of semi-transparent gauze. This allowed a glimpse through the doorway to the performers in action, thus superimposing layers of time.

The work took the intimate scale from inside the house to the architectural and environmental scale outside the house.

6. DISCUSSION AND CONCLUSION

The extension of the idea of the creative trajectory leading to a work of art which includes instrument design and performance context is of course not new. It is however clear that, under the influence of the emerging new computer technologies, the traditional boundaries between the arts seem to be disappearing. A new kind of art has come about which freely uses elements from other disciplines, and although boundaries are disappearing, a lot of knowledge from traditional disciplines may still inform electronic arts practices. This movement calls for an approach which, by its multidisciplinary nature, must be both generalist and have specialist elements.

An issue that remains clear is that computer technology is still in its infancy. This is particularly true for user interfaces that give access to and control over the rich and increasingly powerful capabilities of the computer. The ever-increasing speed and capabilities of the computer, roughly following the prediction of Moore's Law which states that the density of logic circuits doubles every eighteen months, is out of step with the developments of its accessibility for the human. The developments of machine factors related to the human interface, such as screen size and resolution, number of degrees of freedom of the input devices, senses addressed such as the tactual, are not following Moore's Law. As a result, artists cannot rely on the standard software, hardware and interface technologies available, and so have to know how to use the technology and develop their own solutions for instruments and notation systems that enable control over diverse and complex elements.

In this paper we have tried to give some ideas about the multidisciplinary art form, and some demystification of the computer technology. The conflation of roles of composer/performer and the idiosyncratic relationships with computer-based instruments changes the nature of traditional interfaces such as the instrument and the score. As a result, it is not possible for an external composer to 'write a piece for' the Video-Organ or the Meta-Orchestra in the traditional sense. It is a collaborative process, interweaving roles and actions, and the result is directly related to the members of the group. These points have been illustrated with examples from practice, which are explicitly described as ongoing projects, suggesting directions rather than end goals.

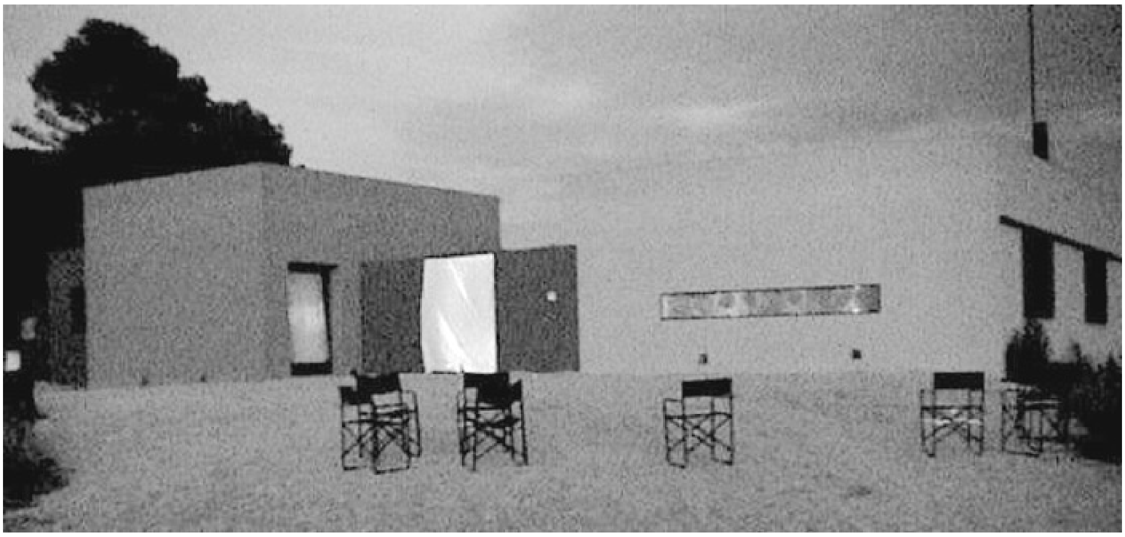

Figure 4. An image of *Inside Out.*

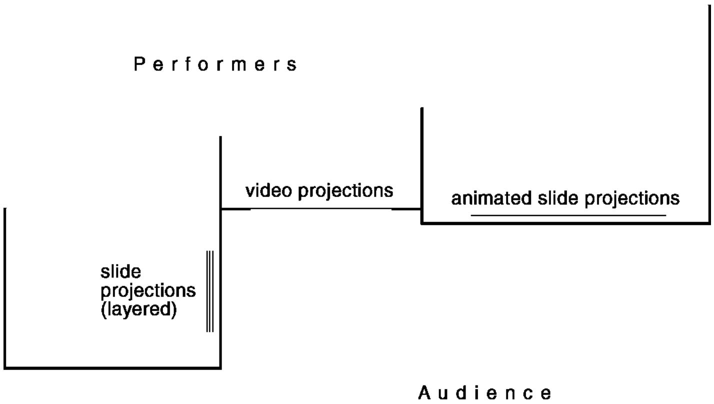

Figure 5. The layout of *Inside Out.*

REFERENCES

Baecker, R. M., and Buxton, W. A. S. 1987. The haptic channel. In *Readings in Human–Computer Interaction*, pp. 357–65. San Mateo, CA: Morgan Kaufman.

Bongers, A. J. 1998. Tactual display of sound properties in electronic musical instruments. *Displays Journal* **18**(3): 129–33.

Bongers, A. J. 2000. Physical interaction in the electronic arts, interaction theory and interfacing techniques for real-time performance. In M. M. Wanderley and M. Battier (eds.) *Trends in Gestural Control of Music*, pp. 41–70. Paris: IRCAM.

Bongers, A. J. 2002a. Palpable pixels, a method for the development of virtual textures. In *Proc. of the Touch, Blindness and Neuroscience Conf.*, Madrid.

Bongers, A. J. 2002b. Interactivated spaces. In *Proc. of the Symp. on Systems Research in the Arts 2002*, Baden-Baden, Germany.

Bongers, A. J., and Harris, Y. C. 2002. A structured instrument design approach: the video-organ. In *Proc. of the Conf. on New Instruments for Musical Expression 2002*, Dublin, Ireland.

Bongers, A. J., Impett, J., and Harris, Y. C. 2001. *HyperMusic and the Sighting of Sound*. Project report and CDs for the European Commission, available on line at www.Meta-Orchestra.net

Card, S. K., Mackinlay, J. D., and Robertson, G. G. 1990. The design space of input devices. In *Proc. of the CHI 1990*, pp. 117–24.

Evers, F., Van der Velden, L., and Van der Wenden, J. P. 2002. The art of programming. In *Sonic Arts 2001 Conf. on Digital Art, Music and Education*. Amsterdam: Paradiso.

Foley, J. D., Wallace, V. L., and Chan, P. 1984. The human factors of computer graphics interaction techniques. *IEEE Computer Graphics and Applications* **4**(11): 13–48.

Harris, Y. C. 2002. Architecture and motion: ideas on fluidity in sound, image and space. In *Proc. of the Symp. on Systems Research in the Arts 2002*, Baden-Baden, Germany.

Hunt, A., Wanderley, M. M., and Paradis, M. 2002. The importance of parameter mapping in electronic instrument design. In *Proc. of the Conf. on New Instruments for Musical Expression 2002*, Media Lab Europe, Dublin, Ireland.

Impett, J., and Bongers, A. J. 2001. Hypermusic and the sighting of sound, a nomadic studio report. In *Proc. of the Int. Computer Music Conf. 2001*, Havana, Cuba.

https://doi.org/10.1017/S1355771802003035 Published online by Cambridge University Press

Loomis, J. M. and Leederman, S. J. 1986. Tactual perception. In *Handbook of Perception and Human Performance*, Chapter 31.

Oosterhuis, K. 2002. *Architecture Goes Wild*. Rotterdam: 010 Publishers.

Sinker, M. 2002. Destroy all music: the futurists' art of noises. In R. Young (ed.) *Undercurrents, the Hidden Wiring of Modern Music*. London: Continuum.

Schomaker, L., Mnch, S., and Hartung, K. (eds.) 1995. *A Taxonomy of Multimodal Interaction in the Human Information Processing System*. Report of the ESPRIT project 8579: MIAMI.

https://doi.org/10.1017/S1355771802003035 Published online by Cambridge University Press