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Report from the start-up workshops

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Report from the start-up workshops

Deliverable 4.1

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Chapter 1: Introduction

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This document, the first Deliverable from the SHAPE consortium, documents, as required, the plans of the consortium partners, developed as a result of the three SHAPE start-up Workshops conducted in the first three months of the project, at Stockholm, London, and Limerick. As noted in our project workplan, the purpose of these initial Workshops was to ensure a thorough mutual understanding within the project of the perspectives, backgrounds, and contributions of all project partners, and to produce 'in-line' plans. This document, however, goes well beyond the planning document officially required as a deliverable, and includes substantive project work already conducted by the project partners within the initial three months of the project. Substantial progress has also been made in terms of Disappearing Computer inter-project collaboration, and further detailed planning with end-user development and testing sites concerning the timing and nature of SHAPE research activities.

1.1. Report Outline

This report, which comprises the first Deliverable from Workpackage 4 of the SHAPE project, is structured into several chapters. This introduction (Chapter 1) provides a brief overview of the SHAPE project and the structure and contents of the different chapters and appendices. Chapter 2 consists of a report on the experience of visitors with a novel interactive medium at an exhibition, focusing particularly on the way in which the exhibit crafted collaboration between participants, and is an example of one form of empirical study that will be pursued during the project. This form of detailed interaction analysis of human conduct with and through artifacts offers illuminating insights into human-machine interaction and human-mediated communication more generally. Chapter 3 provides an account of the development of a novel technical interaction platform, that integrates a variety of sensory modalities through an interactive surface that allows for multiple participant roles. This demonstrator was developed during one of the start-up Workshops, and exhibited at the

end of the Workshop to a number of interested end-user groups who provided feedback on the prototype, which will be fed into the on-going development work. Chapter 4 provides a brief overview of the technical development work underway on physical/digital boundaries, one of the core dimensions of the SHAPE research concerns. Chapter 5 provides an example of an evaluation study of certain interactive media within a museum, showing how visitor behaviour is influenced by the siting and location of the technology. This kind of study is another form of empirical study that will be utilised throughout the SHAPE project in order to investigate human experience of use of our assembled artefacts. Our focus is not simply on the interface to the systems, but also on the context within which these systems are deployed, thus arguing for the need to understand the ecologies of interaction and location within defined spaces and settings. Finally, the Appendix to this Deliverable outlines the plans from all consortium members concerning immediate followup project activities.

1.2. SHAPE Project Overview

SHAPE is devoted to understanding, developing and evaluating room-sized assemblies of hybrid, mixed reality artefacts in public places. The objectives of SHAPE are:

1. to explore hybrid artefacts and the various relationships that are possible between physical and digital manifestations, and create prototype demonstrators;
2. to examine and construct organised assemblies of hybrid artefacts within room-sized environments as a means for delivering a thematically integrated, yet rich, social experience;
3. using social scientific methods, to study and develop a detailed understanding of the activities of members of the public as they engage with exhibited artefacts in public places such as museums and exploratoriums;
4. to deploy such an understanding, combined with techniques of participatory design, to develop actual public exhibitions demonstrating the project's technologies (two living exhibitions);
5. to reflect on the project's design methods and evaluate its technical products.

This Deliverable, though a very early piece of reporting in the project, should be seen as making initial contributions to Objectives 1, 2 and 3.

1.3. SHAPE Progress

Within the first three months of the project, SHAPE has conducted the required background briefings on consortium competencies and experiences and put in place a variety of intra- and inter-project collaboration and coordination mechanisms. This work has been structured around three SHAPE Workshops, held at monthly intervals and each hosted by a different site.

Our *First SHAPE Workshop*, held in January 2001 at King's College, London involved each partner in presenting an overview of its activities, its proposed user sites for future SHAPE work, and its new research personnel who would be working on the project. The first Workshop was particularly concerned to have a pedagogical function in providing new research personnel with tutorial material on the past work of partners and their preferred research methods and emphases. Planning of immediate further work on the project was also

undertaken at this meeting. The outcome of this planning work is an extensive list of project activities which appears in the Appendix to this document and which will form the basis of explicit progress review at our next Workshop/plenary meeting at Nottingham in May 2001. The early stages of the SHAPE project are explicitly designated as *explorative* in the project's Workplan. For this reason, partners' lists of SHAPE activities are knowingly over-inclusive, the May meeting being the time for sober review.

We have also managed to initiate a variety of collaborative activities at a number of sites that are directly linked to our stated objectives. Specifically, we have developed novel mixed-modality interactive surfaces and obtained feedback on the prototype. This work was conducted before and, especially, during the *Second SHAPE Workshop* held in Stockholm in February (see Chapter 3). This Workshop contrasted with the first in its explicitly constructional emphasis. Over the course of one week, researchers from all partners contributed to the construction of an artefact of relevance to SHAPE's overall goals and requiring integrated work across many of the project activities which were proposed by partners at the First SHAPE Workshop. In this way, we were able to initiate on-topic, close collaborative work within the project at a very early stage. (Our good experiences with this Workshop format and its constructional emphasis have encouraged us to add a Fourth SHAPE Workshop to the series also with this flavour prefacing the May plenary in Nottingham.)

Finally, we have analysed human experience of use of existing interactive artefacts in a variety of settings and using a variety of analytic techniques. This work was presented and discussed at the *Third SHAPE Workshop*, in March, held at Limerick (see Chapters 2 and 5). The consortium stated that it would "establish an archive of empirical materials collected at a variety of public places such as museums and exploratoriums." As can be seen in the work reported herein in this initial Deliverable, this archive is already being constructed, and will be added to during the lifetime of the project, resulting in a significant body of new empirical material, demonstrating a range of different methodological perspectives, and involving a variety of galleries, museums, and exploratoria of very different ethos, catering to different audiences, located in several countries within Europe.

We have also been engaged in substantive communication with our end user sites, and have now confirmed, not simply participation, but detailed commitments from several institutions concerning the timing of our planned "living exhibitions" (where SHAPE personnel will engage in research work at a collaborating institution), and the allocation of space for SHAPE teams at the designated institutions. This will ensure that SHAPE is not simply another research laboratory exercise, but will deliver on its objective of ensuring extensive and deeply grounded work with our domain specialists and their institutions. Representatives of collaborating institutions were invited to a public presentation of the artefact constructed during the Second SHAPE Workshop. In this way, not only have we as project partners found out about working together on the basis of dedicated constructional work, so have some of our external collaborators found out about the kinds of artefacts SHAPE is interested in producing, and this at a very early stage. We hope having this practical focus will greatly enhance the effectiveness of communication between the project and its collaborating institutions. Furthermore, it testifies to our concern to engage in dissemination activities from the outset of the project.

Mention should also be made of the substantive Disappearing Computer (DC) inter-project collaboration that has also been conducted. During the three SHAPE Workshops to date, we have had active participation from colleagues that are involved in two other EU DC projects,

namely Paper++ and SOb. This participation has involved more than just researchers from other project acting as observers at our meetings. In both cases, personnel have actively contributed ideas to the project, while SHAPE has reciprocated with suggestions for developing the research agendas of those other projects. For example, as part of the hybrid artefact reported in Chapter 3, we extensively worked on the incorporation of sound into the environment. This gave a concrete focus to our intended inter-project collaboration with SOb and, indeed, a researcher from that project gave a number of design suggestions during the Workshop. Our programme of initial Workshops, then, has also helped us initiate substantive inter-project collaborations.

In the light of the, to our minds, excellent progress within the project so far, we have decided to take advantage of our commitment to this early Deliverable to report in detail on the outcomes of our Workshops. The Workshops have, in our view, yielded research results which go beyond what might normally be expected of a series of start-up Workshops. We feel we are reporting here on substantive research achievements, not just the opening out of topics and collaborative pathways internal to the project. For this reason, we have preferred a delivery format which goes beyond our basic workplan commitment.

Chapter 2:
Crafting Participation
Interaction with and around artistic, mixed media artefacts

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There is a growing concern in CSCW and cognate disciplines in designing artefacts which engender flexible forms of co-participation and collaboration within public arenas. In this Chapter of the Deliverable, we discuss an interdisciplinary project in which we designed, exhibited and assessed a mixed media, interactive installation at a major international crafts fair. Since the start of the SHAPE project, we have analysed video materials of people encountering the piece in order to explore how they collaboratively discover, use and experience the installation, and the ways in which they shape each other's participation. Following a description of the key findings from this analysis, we then draw out the implications of this 'naturalistic experiment' for design, and in particular for developing assemblies of artefacts to enhance collaboration within public arenas.

2.1. Introduction

There is a growing interest in CSCW and cognate disciplines in using new technologies to engender new forms of co-participation and collaboration. These initiatives are coupled in part with a move beyond the confines of the workspace to explore how we can facilitate and enhance more informal, flexible, and opportune contact and communication between people. An important part of these initiatives involves developing infrastructures and systems to enable distributed participants to become aware of each other and interact in virtual spaces, distinct from the locales in which they may be 'physically' located (see for example Ishida, 1998; Chalmers, 1999). Alongside these seemingly more complex initiatives, there is also a growing interest in developing technologies and artefacts to encourage and enhance communication and collaboration in more conventional, co-located environments - the home, the classroom, and increasingly public arenas such as museums, galleries, and urban spaces. Consider for example developments such as KidPad (Benford et al., 2000) and the magic carpet (Stanton et al., 2001); as well as new projects and programmes concerned with

interactive public displays (e.g. the U.K.'s EPSRC Dynamo project), and augmented reality (e.g. the EU's "Disappearing Computer" programme and the I^3 "HIPS" project). These innovations and developments pose important issues concerning the design and development of artefacts, their relationship to the local environment, and most fundamentally, how technologies can serve to encourage and engender flexible forms of collaboration and co-participation.

In this chapter we discuss our concern with developing mixed media interactive artworks designed to facilitate collaboration within public arenas such as galleries and museums. This involves collaboration between artists and social and computer scientists. In this reagrd, the chapter discusses the design, deployment and assessment of a mixed media 'interactive' installation at an international crafts fair and, in particular, examines the ways in which people, both alone and with others, discover, experience, and animate that exhibit. This naturalistic experiment throws light on the ways in which people collaboratively discover the affordances of artefacts, and the ways in which they configure each other's experience.

From this study we reflect on the implications for the design of novel technologies that seek to encourage and engender collaboration and participation, not only systems that draw upon visual presentation but also those that utilise tangible objects. More importantly, we will suggest that studies of interaction around artefacts in public spaces may have a more general interest for those concerned with developing systems to support collaborative work. It provides a domain to consider the ways in which individuals interact with complex objects along with companions and also in the presence of other participants. Such a focus can provide insights into how individuals become engaged for the first time with an interactive artefact, how they discover for themselves and then display to others how such an artefact 'works' and how their engagement is shaped by and for, the activities of others in the perceptual range of the object. We conclude that such issues are of concern to both social and computer scientists with an interest in 'the disappearing computer', and hence the study of interaction in a range of public spaces could provide an innovative way of informing our understanding of participation, interaction and collaboration.

2.2. Art, Design and Cooperative Technologies

Recently, there have been a number of system development project which have involved collaborations with poets, directors and artists to stage various 'events' in novel technologically-mediated settings, such as collaborative virtual environments (Benford et al., 1997, 1999). Such activities need not just be an additional domain for system designers to apply their technology and for ethnographers to study, but have provided novel insights to the development of systems and the design process more generally. Moreover, staging these events provides the opportunity for researchers to assess their technology with a number of 'real', 'novice' users outside of a laboratory environment. It also provides a rich domain to consider how to develop technologies that could support novel forms of interaction and collaboration.

These concerns resonate with a growing commitment amongst artists, designers, curators, and educationalists to enhance the ways in which people participate and collaborate with, and around, installations, exhibits and artworks. For example, within the area of museum studies, there is a growing body of work concerned with the behaviour and learning of visitors to

museums and galleries. One powerful and long-standing message from educational and visitor research is that interaction is critical to people's 'learning experience' in museums and galleries (e.g. Falk and Dierking, 2000). In consequence, we are witnessing a growing commitment amongst curators and educationalists to enhance the experience of visitors by designing exhibits which facilitate communication and collaboration (e.g. Crowley and Callanan, 1998). In this respect, there has been a growing interest in using digital technologies to enhance interaction with and around exhibits (e.g. Oberlander et al., 1997). Unfortunately, our own research suggests that in many cases although technologies serve to enhance an *individual's* experience of an exhibit, they often impoverish interaction between people. This is an increasing concern for designers and curators.

It is not surprising therefore to find that creative artists are also exploring ways in which they can use technology to create new forms of collaborative experience. There is not space here to review a range of the more technically innovative installations which have been exhibited but it is perhaps worthwhile mentioning one or two to enable us to position our own commitments and interests. For example, the EU I^3 project eRENA developed an art installation called *Desert Rain* which drew upon recent developments in CVEs and mixed-reality environments (Koleva et al., 2001). Our own studies of the installation revealed that whilst it served to engender dramatic experience for individuals, and lively discussions after the event, co-participation and collaboration within the event was relatively limited; indeed, the installation segregated participants and provided little possibility of collaboration. Moreover, the installation required significant real time management by the design team, to enable the participants to navigate the world and achieve the desired goal and experience. The artwork was very powerful indeed and enjoyed by participants, and yet did not encourage collaboration and communication between participants (vom Lehn and Heath, 1999).

One further issue: despite the burgeoning body of research in the computing sciences (e.g. in CSCW) concerned with social interaction, in particular in the workplace, we remain relatively ignorant of the organisation of communication and collaboration in less formal domains. In part this reflects the more traditional focus of CSCW, as well as the relative absence of research in the social sciences concerned with conduct and communication in public domains. We believe that this is unfortunate, since, as suggested earlier, increasingly CSCW and allied research areas are becoming concerned with developing systems to support more flexible and emergent forms of collaboration and interaction, with technologies for public arenas becoming a critical focus of many new projects. Whilst naturalistic studies of existing domains such as museums and galleries will provide important insights into more flexible forms of communication and collaboration, we believe, and increasingly find, that 'naturalistic experiments' through which we deploy artefacts into settings and analyse how people respond to and 'interact' with the object, provide fruitful, sometimes unique, insights into conduct and collaboration. To coin Garfinkel's (1967) phrase, they provide 'aids to a sluggish imagination'; a way of seeing and discovering social and interactional organisation which might otherwise remain hidden from view.

In the light of these and other considerations, we have initiated a programme of work to develop artworks, which are presented in galleries and exhibitions and to undertake detailed studies of how people react to and interact with and around the piece. The first work developed by the project is called *Deus Oculi* and was exhibited at the Chelsea International Crafts Fair in September 1999. Throughout the duration of this exhibition we gathered data (field observations and videorecordings) of how people interact with and around the

installation. This chapter discusses the rationale and the design of the installation and considers how people responded to and experienced it. In particular we consider how it did become a resource for interaction and participation and the particular properties that seemed to engender different forms of collaboration between visitors. As part of the SHAPE project we have begun to consider how this rather novel approach to examining collaborative artefacts can offer useful insights to the design and understanding of technologies more usually associated with CSCW. In particular, we conclude with a series of design issues that will inform SHAPE technical and social scientific work.

2.3. *Deus Oculi*

The artist in our team, Jason Cleverly, has a long-standing commitment to creating aesthetic automata from well-worn materials; automata which engender curiosity, surprise, and not infrequently laughter. Cleverly uses the concept of interaction to drive forward ideas; these include the production of sound activated sculpture, radios and figurative automata. Another strand to his work which is, in a sense more formally interactive, are the cupboards, mirrors, lights and other prosaic artefacts given a surreal or augmented treatment. The use of 'lo-tech' materials provides the possibility of creating artefacts which are designed to engender interaction and participation, whilst retaining a strong commitment to enhancing the aesthetic experience of those in the locale of the exhibit. We were particularly concerned with how we can interweave digital media and tangible objects and artefacts to enhance interaction with craftworks and engender interaction and collaboration around craftworks.

Through our collaboration we have adopted an approach, which differs from typical approaches in the digital arts. Rather than replace material objects with digital displays, we are keen to explore the ways in which we can 'augment reality' (cf. Weiser, 1991). In particular, we wish to consider the ways in which we can take 'lo-tech', tangible objects and refashion or augment them to engender interaction and co-participation.

Deus Oculi is based on the use of re-cycled imagery. It consists of three parts: a main picture which displays a tranquil Renaissance scene and two fake 'mirrors' (Figure 2.1).

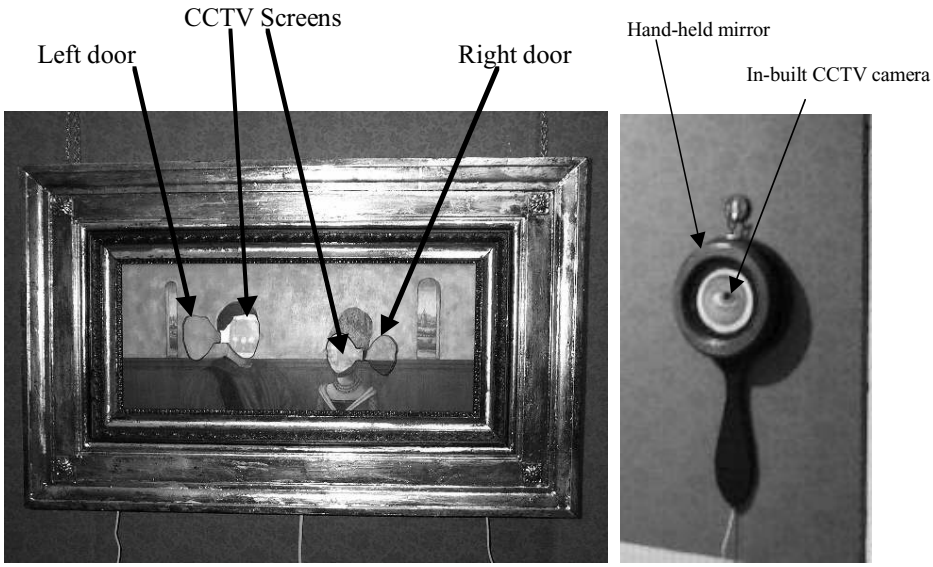


Figure 2.1: *Deus Oculi* (left), one of the 'mirrors' that are positioned either side of the picture, is on the right

The picture is devised by combining elements from three separate paintings and rendered in cold enamels and water-soluble pencil directly on wood. The picture, which is framed by a wooden box, includes the faces of two individuals, a man to the right and a woman to the left, each face is on a little door which can be opened up to reveal a small CCTV monitor. The hand-held mirrors to either side of the picture each contain a CCTV camera. Indeed, although they are designed to imitate the general form (if not scale) of a hand-mirror, they actually display a painting of an eye, behind which the hidden CCTV camera is located. The image from the left mirror appears on the right monitor behind the woman's face, and the image from the camera in the right mirror appears on the monitor behind the man's face. The three pieces are connected by wires.

Thus, if a door is opened and someone is standing next to the mirror or holding the mirror up to their face, their image will appear embedded in the picture (see Figure 2.2). The aim of the piece is to provoke curiosity, surprise and amusement, and it has certain similarities to cut-out pictures found at the seaside or at fairs. But in this case the one is momentarily immersed in the scene and thus become part of the work of some long-dead master.

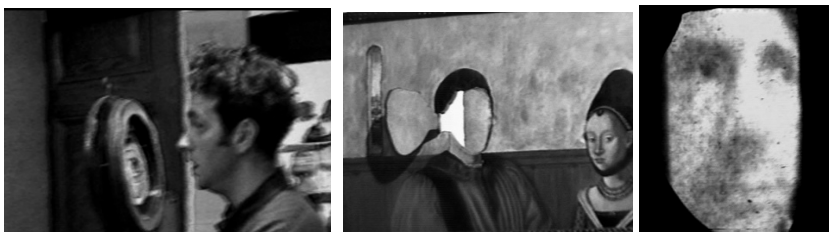


Figure 2.2: When someone looks at the hand-held 'mirror', their face appears in the central painting on the shoulders of one of the figures.

The design of the installation also reflects long-standing issues within the visual arts, in particular, with the ways in which the spectator can be brought into the artwork, and the artwork can resonate with the immediate environment. Shearman (1992) for example has powerfully argued how artists from early Renaissance onwards increasingly became concerned to establish a more engaged spectator, and in various ways to interweave figures and scenes in a painting with the settings in which they were placed. In the case at hand, our installation is designed to combine contemporary technology with period imagery, to include the spectator, and to interweave the painterly scene with the immediate environment. In this regard, the work proved surprisingly successful, and indeed in a naive yet curious way, transposed action within the installation to the surrounding ecology and *vice versa*.

Deus Oculi was exhibited at the Chelsea International Crafts Fair; a major event for displaying contemporary arts and crafts. The exhibition space enabled us to display the piece on the whole of one wall, bounded by a door opening and a passageway (see Figure 2.3). Therefore, the piece could stand alone, independently of surrounding work. The location of the space, towards a restaurant, also guaranteed passing traffic as well as visitors actually looking carefully at the various pieces in the exhibition space.

Figure 2.3: The setting for *Deus Oculi* in the Chelsea Crafts Fair.

When exhibiting the piece we decided not to give any written instructions, rather to let the participants discover for themselves, or others, the nature of the work. Occasionally, however, there was some verbal encouragement and demonstration.

We collected data for most of the period of the exhibition (a week). We undertook field observation, discussed the exhibit with visitors and with other artists and designers exhibiting at the fair and also undertook extensive video (and audio) recording. The video-camera was positioned to one side of the exhibit attached to a nearby doorframe so that we could record what people did with and around the exhibit.

2.4. Shaping Experience

The exhibit proves surprisingly successful in generating interaction and co-participation amongst visitors, both those who come ‘together’ and others who happen to meet in the same space. Indeed, in contrast to our studies of artworks and installations in more conventional galleries and museums (see vom Lehn et al., in press), including those showing more contemporary work, the exhibit serves to engender curiosity, surprise, appreciation, and aesthetic judgement and discrimination. It does so however, in ways that we had not imagined or designed for. Indeed inadvertent aspects of the installation’s shape and arrangement serve to engender interaction and collaboration. This section discusses the ways in which people who have examined the installation for a few moments shape each other’s use and experience of the artwork.

Fragment 1

S: Stand there

J: Oh I see::

In instructing Julia to remain in her position Susie configures her companion's conduct so that she herself can experience the exhibit, and through her exclamation, encourages Julia to see and share the joke. Their mutual enjoyment of the piece derives from their interaction with each other, both directly and mediated, through the installation. And in turn, this leads Susie and Julia to further discussion about the artwork, how it works and what it is about. In a sense therefore *Deus Oculi* successfully engenders co-participation, and in particular one positioning (literally in this case) another in an artwork, to engender a particular sensation and experience.

In examining our corpus of video-data, we find that visitors go to some trouble to use the installation to engender an experience for themselves and then for the person(s) they are with. For example, in the following instance (Fragment 2), after Simon and Vanessa have worked out the relation between the painting and the camera, Simon encourages his companion to stand in front of the camera to enable him to experience the piece for himself.

Vanessa then goes to some trouble to engender a similar experience for herself. As Simon briefly examines the mirror to the right of the painting she provides a series of instructions to position him so that his head and orientation maps precisely into the scale and position of the face in the painting.

Fragment 2

V: Stick your face so that you're that shape. I'll tell you how near to go (right).
V: Turn your face to the box
S: I'm going crossed eyed
V: Turn your face to the left a bit. O.kay come in a bit... Move, move your whole body to the oh that's it nearly. Yeh(ll) that's hah hah *hh perfect. hhhehheh thhheh heh

Even though Vanessa is able to anticipate the image that she will see when Simon appears precisely aligned within the painting, when the moment comes it still serves to engender surprise and laughter. It appears that an important part of the interest and enjoyment of the installation derives from the very trouble to which people have to go to align each other within its framework; the successive instructions and bodily rearrangements serving to escalate the moment of pleasure when it finally arrives.

Fragment 2 (detail)

V: Stick your face so…

V: Turn your face to the box

V: Perfect. hhhehheh

Curiously perhaps unlike many exhibits in galleries and museums the installation does not provide participants with the ability to view and experience its image and affect in unison; one party is put to the serve of the pleasure of the other, and in case after case, the participants exchange positions to enable the other to have a similar experience.

It should be added that an important aspect of the interaction and collaboration with, and around, the installation is the participants' ability to animate the image and give the other a surprise. So for example, when Susie places herself in front of the camera to enable Julia to experience the sensation, she sticks her tongue out. In other instances we find people playing with the image, raising their eyebrows, pulling faces and the like; the force of the animation deriving not simply from a person's image but that stands against the backdrop of a tranquil Renaissance scene. Splendidly, these animated displays, interweave, at that moment, conduct within the physical space with action within the painterly, mediated scene. The force and significance of the installation in part derives from its ability to incorporate actions and spaces, which are ordinarily distinct and unrelated. This achievement is produced in the collaboration of the participants. They shape their own and each other's experience in, and through. the installation.

2.5. Chance Discoveries

The previous section discussed two fragments in which participants shape each other's experiences of the artwork after they have worked out the relation between its parts. In system design there is a long-standing concern with how people encounter, use and learn about, novel artefacts that they have never seen before. There is, of course, an important body of research on the affordances and usability of technologies (e.g. Norman, 1990; Gaver, 1991). While those investigations often draw upon experimental research, naturalistic investigations into how encounters with and explorations of, novel artefacts are initiated and collaboratively accomplished, have rarely been conducted. The exhibition of *Deus Oculi* in a public domain provides us with the opportunity to explore in detail how people who do not have any knowledge about this particular artefact discover and learn about some of the object's features.

With regard to the design of the artefact it is noteworthy that the artist carved two notches in the painting, one to the side of each monitor, to hint at that there are doors embedded within the painting that can be opened. Also, he hung the two large hand-held mirrors loose

on a hook to each side of the painting to encourage people to take them off the wall. It was assumed that people would naturally pick up the mirrors from wall, open the doors in the painting, and then while standing in front of the painting would find out about the connection between the monitors and the mirrors.

However, as the following fragments reveal, participants rarely explored the exhibit in this way. Consider the following example (Fragment 3) that shows Susie and Julia (who also featured in Fragment 1) arrive and begin to explore the piece; the doors to the monitors are closed so that passing images on them are not visible. They, then, both turn to the mirror to the right of the painting, Julia standing very close to it and Susie a step behind observing Julia's actions.

Up to this moment the two companions have not noticed that mirror and painting are both parts of the same exhibit. While Julia closely inspects the mirror Susie stands behind observing her companion's actions. After a few moments, she makes a step backwards and looks to the ground below the mirror. There, Susie notices the cables that by chance we did not conceal, which connect the mirror with the main piece. She traces the cable from the mirror to the piece and then glances towards the corresponding image in the painting.

Shortly, after she has dwelled on the mirror for a few moments she again traces the wire as it comes out off the mirror, dangles down to the floor and leads up into the box. She, then, indicates to Julia that "`I know what it is`" and asks her companion to "`stand there`" while she moves over to the painting and opens the door to the monitor behind underneath which the cable leads into the painting. This is when Susie begins to shape her experience of the piece by instructing Julia's conduct.

Fragment 3

As developers of other artefacts have reported, people do not necessarily use them as intended by the designers. However, in the present case the fact that Susie and Julia do not pick up the mirror does not stop them from finding out about the relation between the different parts of the exhibit. Puzzled about the mirror's design Susie looks for hints in the local environment that may reveal its purpose. As she finds the cables linking the various parts of the installation, Susie uses them as a resource to discover the connection between the mirror and the painting. The installation, that we believed would intuitively be intelligible, poses a problem for the participants: discovering its function and the relationship between the various elements. Though people explore in some detail individual aspects of the artefact, such as the doors embedded within the painting or the mirrors at the wall, the functional relation between these objects is initially not intelligible to them. The affordances of individual parts of the exhibit do not suffice to reveal the functioning of the assemblage of objects. However, as it turns out in the present fragment and in numerous other instances the very process of having to investigate the piece, served in many instances to engender interaction and communication about the installation. Susie and Julia's enjoyment of the work,

for example, their surprise and laughter, derives in part from their having to spend time finding out what the artefact is about. Indeed, the very possibility of Susie giving a surprise to Julia derives from the fact that she has discovered how it works, whilst Julia remains ignorant.

In other cases, as people approached the piece, or even walked past it, one would suddenly notice something happening within the painting itself. Consider, for example, the following fragment, in which four visitors stroll by, when the last of their number suddenly notices an image appear on a monitor in the painting. The action begins however with the first visitor opening a window within the painting and in response to his wife's query as to what it is, utters "`don't know`". He then moves on and his companions follow.

Fragmen 4a

As they move past the exhibit, the last of their number, Chuck, suddenly cries out '`look look`' and points to one of the images inside the painting. His friends stop and turn back to the painting, and he explains what seems to be happening "`when he is over there and the camera is over here.....`".

Fragment 4b

Chuck Tim Mary

C: look look…

M: No:::: look

it's ma::::::d

As with the group in this fragment, many people discover the sense and significance of the piece by chance, noticing some changes within the painting and then working out what happened. This requires, of course, one of the installation's doors to be open so that the scene on the monitor is visible. It also requires more than one person to be located within the immediate environment, so that their conduct can be noticed, and the viewer can make a connection between action within physical space and changes within the painting. In other words, noticing the workings of the exhibit and making sense of its operation, requires people to interrelate the exhibit, the images it momentarily provides with the local ecology and

people's conduct.

The conduct and observations of people engaged with the installation also serves to generate curiosity and participation from those who just happen to be in the same space. For example, in the case above as one of the group, Chuck, asks "`what's that`", Tim who is looking at exhibits on the opposite wall turns round and begins to watch what is happening. A moment later his friend Mary also reorients, and as Chuck points to the piece, she exclaims "`No::::: look it's ma::::::d`".

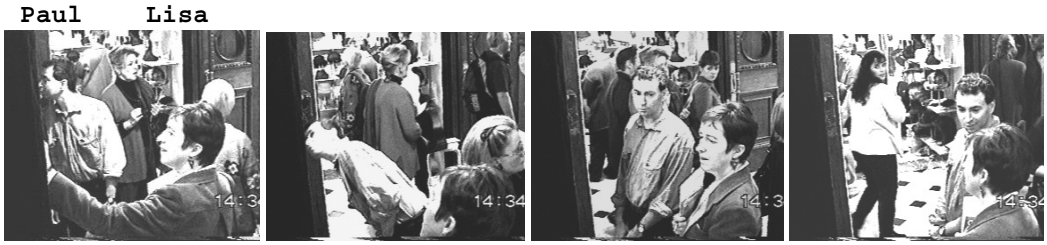
Tim and Mary, then, turn around and examine the exhibits on their own wall to see if they too are in some way connected to the installation. Their observation of the piece, therefore, derives from their sensitivity of the actions of others within the scene, both overhearing what is said and then looking at what others have noticed. Moreover, they then inspect other features of the local ecology, in particular exhibits, which are similar to the installation to see whether they too are tied to the scene of action and the other exhibits. We can begin to discern therefore how conduct and interaction around the exhibits provides resources to others to enable them to see, inspect and investigate features of the local ecology. As it turns out, then, the functioning of the interactive artefact is not discovered in the planned manner but is often understood by-chance.

2.6. Passing Encounters and Peripheral Participation

In public environments usually people are not only with their companions but also share the local domain with others. As we began to see in the last fragment they are sensitive to the actions and orientations of those others and, moreover, can use their actions as a resource to make sense of the objects around them. However, although there is a long-standing interest amongst designers of exhibits and other complex technological artefacts in exploring how exhibits can serve to engender collaboration, rarely do they succeed in generating explicit interaction between such 'strangers' within an exhibition.

In the case at hand, however, we find numerous instances in which people, who have not been introduced to one another, use *Deus Oculi* to engage in interaction with each other. Consider Fragment 5 in which two people, one we will call Lisa, the other Paul, arrive at the exhibit at different moments. They independently begin to look at the picture and the mirrors either side of the main piece and become increasingly sensitive to each other's actions, as they both independently try to discover how the piece works and what it is about. When Lisa discovers the faces in the picture open to reveal a monitor, she turns to the left hand mirror. Paul, subsequently steps towards the centre of the painting to examine the same monitor that Lisa has just examined. Then, for a few moments, Lisa and Paul stand there seemingly puzzled about the exhibit, and look at the painting. Without establishing face-to-face contact the two begin to talk when Paul utters "`There is something here`" and Lisa replies with "`it's very deep isn't it`". As the fragment continues, they then proceed to examine and discuss the piece together and soon discover how it works and together display surprise and curiosity. However, the interaction between Paul and Lisa remains visibly delicate, as the two participants rarely look at each other while exploring the exhibit.

Fragment 5



It seems that the design of *Deus Oculi* inadvertently serves to engender interaction and discussion between participants who happen to meet in its locale. Participants discover, almost by chance the enjoyment and curiosity of the piece, and the ways in which it provides an opportunity for them to see and respond to each other. The design of the piece gives participants opportunity to engage in talk that leads to collaborative exploration of its features. While in the present case the participants initiate and conduct their interaction rather delicately, in other instances interaction amongst strangers emerges with, and around, the installation more directly.

For example in the following instance (Fragment 6), a couple, Beatrice and Paul, approach the exhibit, and before they actually know what it does, Beatrice excitedly exclaims "`it's visual art`". She then notices that the woman to her left, Jo, who is actually depicted within the scene, turns to her and utters, "`Oh I see it's you:::`". Paul looks on as she then configures the scene to enable Jo, whom she has seen within the painting, have a similar experience. She tells Jo to stand in front of the painting and then goes over to the hand-held mirror.

Fragment 6

B: Oh I see it's you:::

J: Oooo^oooooh

Beatrice then has Jo experience the installation for herself and delightfully responds with "`Oooo^oooooh`" as she suddenly sees Beatrice appear in the scene. After discussing how it works Paul is then invited to join the action and experience the thing for himself.

In this as in other instances, the installation serves to engender interaction between people who happen to be in the same space. More importantly, the scale of the piece, coupled with the ways in which it incorporates and represents conduct and scenes within its surrounding area, provides the possibility for people to see and witness the behaviour of others, and in so doing, encourages people to remark and interact with each other. Many years ago, Sacks (1992) observed how particular objects and actions could serve as 'tickets for talk' amongst strangers (dogs, late running buses, unusual weather, bad driving, tripping over and the like). The installation, and the curious ways in which it made people appear within its scene,

provided an occasion for passing conversations and encounters, and serve to engender the sorts of inquiries and remarks that curators and others are keen to encourage within museums and galleries. Even the very fact that participants had to go to some trouble to discover how the installation operated, provided the social circumstances under which people could talk, experience and enjoy the installation together.

2.7. Discussion

It is increasingly recognised amongst curators and museum managers that exhibits and exhibitions frequently fail to encourage the patterns of conduct, interaction and experience that they are designed to achieve. Our own studies of conventional art galleries reveal how little explicit interaction arises between visitors, including those who are with each other. Little time is spent at particular exhibits, and whilst labels may receive a passing glance, they rarely provide resources for discussion and debate. Science centres and museums fare little better; discussion does arise around particular exhibits, but even there, curators are surprised by their inability to engender the desired forms of interaction and have people draw the correct conclusions. As we suggested earlier, these difficulties have not necessarily been solved by the introduction of new technology.

In contrast *Deus Oculi* proved surprisingly successful; serving to engender the conduct, collaboration and experience from visitors that curators and museum managers are often seeking to generate in exhibitions and galleries. In the first place, the installation facilitated dramatic aesthetic response occasioning outbursts, shock and surprise; exclamations such as 'look it's mad', 'ahhh', 'how brilliant', 'ooh', 'that's really funny', and of course laughter were not infrequent. Secondly, the installation served to engender curiosity and interaction with and around the piece. People inspected and manipulated the piece, and took time in assembling the sense and significance of the various parts. Thirdly, and for us perhaps, most importantly, the installation served to engender collaboration and co-participation, not only amongst people who came together, but also amongst people who just happened to be in the same space. How it achieved its success arose both by design and accident.

An important element of the installation in generating interaction and collaboration is the ways in which it renders both the response and appearance of others visible, both to people they are with and others who happen to be 'within perceptual range of the event'. One of the problems with many interactive exhibits on PCs in science museums, is that whilst individuals can witness the conduct of someone operating the exhibit, they cannot see the details of what that person is responding to; they can be seen laughing, but the joke cannot be seen. With traditional exhibits such as paintings, there is an opposite problem. Whilst the painting can usually be seen, people huddle around the piece and often whisper, such that their actions or 'responses' are not visible to others. So, in many cases, the 'user's' conduct and experience is not seen by others together with the very events and phenomena with which they are 'interacting'.

In this regard it is interesting, for example, how machines in amusement arcades are often designed to enable others to witness both the 'event' and the user's conduct. Similarly, with *Deus Oculi*, people notice another's reaction and can immediately turn to discover what it is that they were laughing at. The availability of the image in the painting to those within a wide range of the installation, enables others to see for themselves the very event which is creating

the response. The response and its source are rendered visible within the immediate ecology, and this serves, as we see in a number of the fragments, to engender interaction and collaboration amongst both, those within the event and others who happened to be near it.

The juxtaposition of seemingly related objects, coupled with opening doors, and dangling cables within the immediate domain, served to pose a puzzle. Many people began to investigate the function and operation of elements of the installation in isolation before they had any sense of the relationship between parts of the whole. Moreover, discovering the solution to the puzzle often required interaction or discussion with others. So for example people would simultaneously investigate different elements of the piece and then inadvertently discover the relationship between the parts and their function. The scale of the piece meant that a person inspecting a hand-mirror could be found a few feet away by another viewing the painting. In part, therefore, the scale of the piece as well as its distribution across the wall, occasioned talk between individuals, even strangers. The 'broadcast' of action from a few feet away was enough to encourage interaction. Whereas we often share public spaces with others, we are rarely given a monitor to see what those others are doing a few feet away. Connecting and displaying action in this curious way from different parts of even this small space encouraged co-participation and collaboration.

There is a problem however. For those who came across the installation alone they sometimes failed to discover what it did or how it worked. Because people largely failed to realise that the mirrors and cameras could be moved, enabling a visitor to see themselves in the painting, the success of the piece often relied upon collaboration. In part, its success derived from its failure to make recognisable certain aspects of its 'functionality'.

There is a counter-intuitive aspect to the installation's ability to engender collaboration. The design originally allowed people to have symmetrical access and experience of the piece. If two people each take hold of the cameras and stand in front of the central painting, they are able to simultaneously see themselves and each other within the Renaissance scene. This did not happen. Rather people took turns to position themselves as either a viewer or viewed. This involved people going to some trouble to instruct other people where to stand to get or give the viewing experience. They rarely experience the piece simultaneously, as you might when you are looking at a picture in a museum. Interestingly, this facilitated rather than hindered interaction and led to highly flexible forms of co-participation not ordinarily found around gallery exhibits.

A further and perhaps more important element of the installation is the ways in which it facilitates animation of the scene and event. In our studies of museums and galleries, we have found that occasions of more heightened engagement, often involves one person 'animating' elements of the exhibit for the other(s) through talk and gesture. So for example, one person will use gesture to exaggerate the lines of a painting, or dramatically manipulate a mechanism to give a friend a shock. Part of the success of *Deus Oculi* derived from the ability of one person to animate or transform the scene for others. So for example it was not unusual for the person looking into the camera, to pull a face, stick their tongue out or whatever, at the precise moment their co-participant turned towards the painting. These animated displays achieved their success by virtue of their appearance within the tranquil Renaissance scene and provided a charming contrast to the stillness and formality of the original painted faces. The ability for people to animate exhibits for others is a critical aspect of interaction in museums and galleries.

It is increasingly recognised that conventional approaches to design, found in HCI and

elsewhere, have primarily focused on 'interaction' with single artefacts, and paid less attention to the environment or ecologies in which they are located. This is somewhat surprising given the arguments of Gibson (1979) which have been extensively discussed in HCI and CSCW (e.g. Norman, 1990; Gaver, 1991). In the case at hand, a public setting, we can see how the affordances and characteristics of artefacts are discovered in and through the interaction of people within the same space, not only those who are together and discuss the exhibit, but also others who peripherally participate in their conduct. Indeed, as in other public settings, noticing, discovering and using objects and artefacts, powerfully emerges through the conduct and social interaction of those within the ecology.

There is a second issue in this regard. In the case at hand, as in others we have examined, the discovery, use and experience of particular exhibits, emerges through the ways in which participant 'interrelate' objects within the local ecology. The sense, significance and functionality of an object is actively explored in relation to the assembly of potentially related objects, so that the one is viewed in the light of the others and vice versa. Note, however, that in the case at hand people, like the couple in Fragment 4, turned to examine objects which were 'similar' to the installation to see if they discern a connection. Other artefacts within the same space, such as the radios and automata, were disregarded in this practical exploration. As far as we are aware, how individuals in public environments and in interaction with others assemble the characteristics of objects and discover their sense and functionality remains largely unaddressed in the social and cognitive sciences. For those of us with an interest in collaboration through innovative technologies it would seem to be an issue of critical importance for how we understand, design and create ecologies of objects and artefacts. As Shearman (1992) suggests, it is also an issue that has preoccupied artists at least since the early Renaissance and forms a major problem for those concerning with assembling spaces such as exhibitions.

One of the key concerns for SHAPE will be to design publicly displayed artefacts that encourage co-participation and collaboration, amongst companions, but also others who happen to be exploring the same space at the same time. In the design of artefacts and assemblies we could then consider different 'levels' of response or engagement that could be facilitated by different numbers or combinations of individuals exploring the space. In the first instace, then, we could think about building in more complex responses when collections of indidividuals collaborate.

In this regard, we suggest that our investigation of the use of *Deus Oculi* point towards three design issues that may prove useful in the deployment of artefacts that aim to encourage or stimulate collaboration and co-participation between groups and individuals in co-present, public or even remote arenas.

1. Rather counter-intuitively, the success of the exhibit as a 'puzzle' to be explored through collaboration between 'novice' users, in part, rested on the *asymmetrical* nature of the resources distributed across the local ecology. Images of individuals in different spaces were displayed a few feet away, thereby connecting activities. This also enabled individuals to discover how the exhibit worked, and then animate the exhibit for others. The asymmetrical access to information thereby encouraged co-participation (cf. Benford et al., 2001). This could even be of use to exhibit designers thinking of how to design labels, not for individuals but for individuals instructing others how to appreciate an exhibit.
2. The design of collaborative exhibits or technologies in public arenas should consider the

various relationships between individuals navigating and exploring a space. Rather than simply designing for the individual or even the group, artefacts can be designed to encourage interaction and collaboration between people who happen to be close by. *Deus Oculi* enables individuals to see both the details on the exhibit and the response of those using it 'at a glance', thus enhancing overseers' ability to participate. So for public arenas the design of an artefacts could include a consideration of how to provide strangers with a 'ticket to talk' (Sacks 1992) and interact; an occasion to engage in conversation with others. This, of course, is an aim for community-ware systems that could be brought into public arenas.

3. The notion of 'affordance' commonly adopted in CSCW and HCI should be fully embraced in terms of its relationship to ecologies of people and objects in interaction. The term is often used merely in relation to the design of individual artefacts, but should encourage the broader consideration of how objects will 'sit' together and the impact of juxtaposing different artefacts. This is critical not only in museums and galleries but also in the design and configuration of other public arenas and even complex work settings. Indeed, *Deus Oculi* powerfully demonstrates the relevance of considering the positioning of artefacts in social and material ecologies. Moreover, it suggests ways of designing ecologies to enrich the sense and significance of individual objects or collections of objects within the assembly. This demands a sensitivity not only to the design of individual artefacts and the placement of those with regard to one another, but also the ways in which such placements may help to order individuals and their activities within the ecology. Of course, it will be a critical to our understanding of the ways in which we can artfully manage participation in SHAPE assemblies that the social scientific work continues to explore how individuals in public arenas routinely constitute connections between objects and activities in their ecologies of action.

These issues will be considered as starting points for the design of exhibits and the social scientific analyses and assessment of interaction with artefacts in public places. Thus, they provide a foundation to the longer term project goals concerned with the design of novel assemblies of artefacts in public arenas. We will continue to explore the impact of situating various material and digital devices in ecologies of action. For instance, Chapter 3 of this Deliverable reports on some early attempts to engage with some of these 'design sensitivities' in the course of exploring novel combinations of sound and graphics. Whilst the design work will initially continue to focus on exhibits for museums and galleries, it is envisaged that the findings from our studies of interaction with and around these exhibits will have more wide-ranging contributions to make to the design of collaborative technologies in public places. Moreover, the use of 'naturalistic experiments' will continue to inform our understanding of how to 'encourage participation'; how to embrace and enhance our understanding of 'affordances' for design; and how to interconnect local and distributed ecologies of action.

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Chapter 3: ToneTable

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This Chapter describes events at the Second SHAPE Workshop held in Stockholm, February 2001. During the course of five concentrated working days, an interactive table top projection surface and associated multi-loudspeaker sound environment were designed, constructed and publically exhibited. The research background, design concepts, technical realisation and use-experience of this assembly of artefacts (ToneTable) is described. This leads to a series of proposals for future work in SHAPE. We also describe how the Workshop was conducted, the principles it was intended to follow, and appraise the potential value for projects like SHAPE in conducting such activities at an early stage.

3.1 Introduction: The Second SHAPE Workshop

The SHAPE project is concerned with the development of hybrid assemblies of artefacts embedded in real world physical environments at a room-sized level of architectural scale. Under the auspices of the Disappearing Computer, our intention is to realise a number of demonstrations of these concepts through collaborating with external institutions, in particular with musuems and exploratoria. To give a more concrete sense to these general research intentions, the project staged a Workshop (the Second SHAPE Workshop) in Stockholm between the 12th and 16th of February 2001. This Workshop had a *constructional* emphasis. That is, a major goal of the Workshop was to, during its five working days, create an artefact or an assembly of artefacts which, to the satisfaction of project members, manifested some of the key features the project is interested in. Thus, rather than exclusively engage in preliminary conceptual work deliberating on the definition of such key notions as 'hybrid assembly', we sought to inform such discussions through co-working on the development of a prototype instance.

The constructional format for the Workshop was intended to have other benefits too. Most notably, it provided an early opportunity for project workers, several of whom had not worked together before, to find out about each others skills and work-styles in an immediate

way. The Workshop was conducted so as to encourage the working-participation of project personnel at all levels of seniority. We wished to avoid a model of senior people outlining a design which was then delegated to junior researchers to implement, in favour of fuller collaborative relations. To give added motivation to the Workshop, we committed several weeks in advance to a public presentation at noon on its final day. We publicised that a demonstration of technologies of interest to the SHAPE project would take place on that day and invited several guests in addition to generally informing personnel at the host department (NADA, KTH). These guests in particular included representatives from the museums we intend to collaborate with in the Stockholm area during the first SHAPE Living Exhibition scheduled to be initiated later in Year 1. The public presentation, then, was not merely a means to give motivation to the Workshop, it was also to be a means for initiating concrete collaborative discussions with external collaborative institutions. In this way, such discussions would be informed by a demonstration of what the project was interested in and, provided all went well, what the project was competent in building.

Finally, an important goal of the Workshop was to give technical development a head start. Commonly, a project might engage in constructional workshops with the goal of facilitating intra-project collaboration and team-building but without the expectation that the artefacts produced would be of much worth. However, we saw no reason why we couldn't produce interesting technology of research value under such circumstances, provided that we worked within an advance framework which was motivated in terms of larger research contexts. Accordingly, under the guidance of researchers from KTH, we committed to taking earlier work this partner was involved with as a starting point.

3.2 Research Background: Mixed Reality Interaction Surfaces

In the ESPRIT I^3 eRENA project, KTH developed a number of interaction surfaces based around a table on which visualisations could be projected. Let us give a short review of this research and its background literature. A number of researchers have worked on interaction surfaces which combine the manipulation of physical objects on the surface with a projection of a computer graphical world onto the surface. These combinations of media (or, loosely speaking, 'realities') are of core interest to the SHAPE project. Let us give some examples. DigitalDesk (Wellner, 1991), Bricks (Fitzmaurice, Ishii and Buxton, 1995) and phicons (Ishii and Ullmer, 1997) are all concerned with the combination of computational media with a physical device or display surface. Several applications have been shown to successfully integrate physical interaction handlers and virtual environments or tasks, as in the system BUILD-IT (Rauterberg et al., 1998), where engineers are supported in designing assembly lines and building plants, or in URP (Underkoffler and Ishii, 1999) where a physical interface is used for urban planning, or the concept of 'Embodied User Interfaces' (Fishkin, Moran and Harrison, 1998) where the user physically manipulates a computational device.

In the table environment of Rauterberg et al. a menu area is proposed for object selection that, thereafter, can be placed on the virtual floor plan by moving the interaction handler. This approach uses the physical object as a general interaction device. The physical objects that are used in Underkoffler and Ishii for the urban planning example are mostly used in a less generic but more specific way which lowers the chances of errors due to user input, e.g. a building phicon would less likely be used as something else than a generic brick object.

Another approach is reported in Ullmer, Ishii and Glas (1998) where physical objects, the so called 'mediaBlocks', are used as digital containers that allow for physical manipulation outside of the original interaction area.

Work involving KTH in the eRENA project extended these approaches in a number of ways. First, we introduced a context sensitive functionality to the physical objects a user interacts with. That is, the exact significance of an action on a physical object can change in relation to the context in which the action is performed. This enabled us to support several different kinds of user action without proliferating the number of phicons which needed to be used and identified. Second, we propose a setup that combined physical interaction with abstract visualisation in an application that is not concerned with the off-line design of an environment, but real-time intervention in an environment. Finally, we emphasised the overall working ecology in which the physical interface we prototyped was designed to fit. We imagined a room-sized cooperative environment where physical interfaces might enhance and add to traditional interfaces and work activity. This concern for realistic cooperative working environments is rarely emphasised in the design-led demonstrations of physical interfaces and tangible bits which are commonly reported.

Hoch, Jää-Aro and Bowers (1999) describe The RoundTable in which a visualisation is projected up onto a table surface. On the table surface, a small number of phicons can be placed, which can have a variety of effects on the visualisation. The phicon positions, orientations and identities are extracted from video which is captured by a camera positioned above the table. Hoch et al. (1999) describe an application in which movements of the phicons control, amongst other things, the deployment and movements of virtual cameras in an on-line collaborative virtual environment, the table top visualisation providing a map-view of the overall environment (see also Benford et al., 2001). In an extension of this work, John Bowers, Jää-Aro, Hellström, Hoch and Witfield (2000) describe an application of The RoundTable in which the positioning of objects on the table surface mixes sound sources, a kind of mixed reality mixer desk. The position, orientation and identity of objects in the visualisation denote sound sources, while the position et cetera of phicons placed on the surface denote virtual microphones with the mix at a selected virtual microphone being computed and rendered on a stereo loudspeaker system.

This work was taken as a starting point for the Second SHAPE Workshop. KTH initially sketched the idea of building a physical environment with a multi-speaker array around its perimeter and an interactive table centrally placed. The proposal was for activities at the table to influence both computer graphical projections onto the table surface and the mixing and spatialisation of sound to the enveloping multi-speaker sound system. In a preliminary way, such an environment would instantiate a number of the features of interest to the SHAPE project. By combining interactive computer graphics with sound control, we would be examining a combination of media and sensory modalities. By enabling physical interaction in relationship to graphical displays, we would be ‘mixing realities’. We envisaged this construction as at a room-sized level of scale. We were proposing that a display surface and sound environment would be the main ways in which participants or users would encounter our artefacts: supporting conventional computing technology and interfaces would be hidden. In this way, a participant’s encounter with the environment would not be one based around a computer screen and its conventional peripherals. In all these respects, we regarded the proposal to build a graphics/sound environment of this sort to be grounded in the interests of the SHAPE project and on-topic for the Disappearing Computer programme.

3.3. Emergent Workshop Themes

This sketch of an interactive table within a sound environment, and a commitment to technically realise it, was all that was provided in advance of the the five working days of the Workshop itself. All of the detail was to be added by Workshop participants as they arrived and could contribute. A number of design themes of interest emerged in the early days of the Workshop which we shall discuss in this section.

3.3.1. Abstract, Yet Suggestive Content

We agreed to develop an artefact with abstract content. That is, we did not wish the computer graphical display to contain crudely recognisable objects, nor did we wish for the sounds to be so legible that their nature would dominate people's interpretations of what they were hearing. This enabled us to produce a demonstration without having to engage in a lengthy programme of 'content design'. We were also concerned not to overly prejudice the perceptions of what we were producing (or could produce) that our external collaborators might develop. If we were to have adopted the content from, say, a recent or proposed exhibition at a Stockholm museum, then this content, rather than issues of core SHAPE research interest, might have dominated discussions.

We agreed upon a set of computer graphical options based around visualisations of a fluid surface with virtual objects floating upon it. This was projected from above onto the table top, creating an image approximately one meter square in the middle of a table with side-length of approximately one and a half meters. A participant's activity at the table was to be visualised in terms of perturbations on this surface (ripples, radiating wavefronts). A number of graphical techniques were explored early in the Workshop which suggested a fluid surface without literal realism. Figure 3.1 gives an impression of the kinds of images we were working with. We describe in more detail how the graphics were computed below. Sounds were selected with a similar emphasis on avoiding excessively literal content.

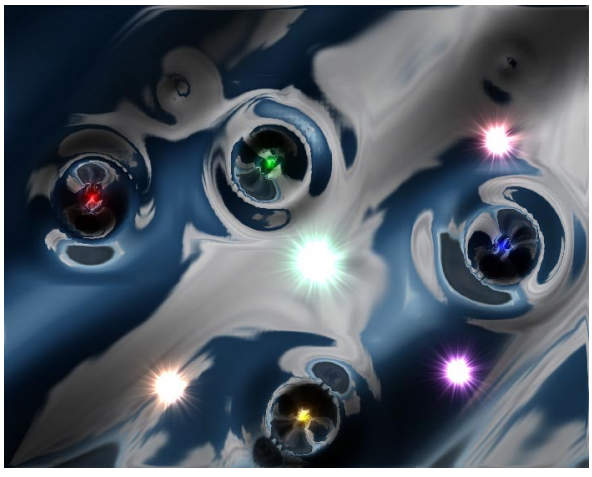

Figure 3.1: Four virtual objects floating on a computer graphical surface, together with four sets of ripples.

3.3.2. Sonification of Virtual Objects and Participant Activity

Sound was to be generated in the environment in two main ways. First, the virtual objects floating on the computer graphically rendered surface were to have a sound each associated with them. The position of the virtual object in the graphical display was to relate in some way to the position of a sound source in the set of speakers around the perimeter of the environment. We engaged in a number of informal experiments and listening tests as to how this could best be done.

A four loud speaker arrangment was explored, with each speaker at the 'corner' of the environment, approximately four meters apart. Two different methods of sound localisation were explored. First, VBAP (Pulkki, 1997) computes the mix coefficients for sound sources given a representation of their virtual position in terms of their angle from a reference orientation. For a three dimensional array of speakers (e.g. with speakers above head-level as well as at ear-level), two angles are required: an anti-clockwise angle in the groundplane and an angle of elevation. For a two dimensional array, such as the one we were using, a single anti-clockwise angle is required. After initialising VBAP with loudspeaker positions, the angle of a source can be input as a real-time control signal, with mix coefficients being computed in response. We experimented with a pulsing white noise burst as a test signal. When this source moved around the speaker array, a compelling rendering of a moving sound source could be heard. A stationary source was less impressive in that different listeners tended to hear the test signal as originating from the nearest speaker to them that was carrying a portion of the signal. While VBAP has a larger 'sweet spot' (the region where an optimal spatialisation is heard) than many techniques, with our speaker array, the table in the middle of the space seemed to occupy most of the sweet spot!

A further issue with VBAP prompted us to investigate another spatialisation technique, one based on that used in Bowers et al.'s (2000) mixed reality mixer desk. Here we regarded the graphical display has having four loci within it at which virtual microphones could be regarded as positioned. The proximity of a graphical object to each microphone was used to compute a mix coefficient, with each loudspeaker associated with a virtual microphone rendering the summed mix at that point. In this way, full coordinate information concerning a virtual object could enter into the computation of the sound mix, and not just its angle from a reference direction as in VBAP. However, listening tests produced similar results. Moving objects were convincingly rendered while stationary ones were not. We also conducted tests involving the movement of an object along a given radius. With Bowers et al.'s techniques this changes the mix coefficients, while with VBAP the coefficients remain constant (as VBAP is only parameterised by radial angle, not position along the radius). We found that Bowers et al.'s techniques did not give a convincing impression of a sound moving along a radius. Accordingly, we decided to use VBAP in this application as the computation of a single control parameter for each object (its angle) would be a useful simplification. That is, virtual objects floating on the graphical surface would have a sound source associated with them, with the angle of the position of the object in the display being mimicked by the angle of the sound in the four speaker mix. For example, an object in the top-left of the display would be heard as coming from a speaker in the nearest room-corner.

In addition to sonifying virtual objects in the display, we decided to sonify participants' activity at the table. This was done in two ways. First, each individual interacting with the table had a simple tone associated with them. The more they perturbed the surface, the louder this tone was and the greater its overtone content. In addition, the summed activity of the

participants at the table was computed and this was separately sonified. A sound synthesis algorithm was designed which gave a suggestion of water splashing. To clearly associate these sounds with the activity of participants at the table, and to discriminate this from the sonification of the virtual objects, we introduced a group of four speakers underneath the table, each speaker radiating outwards. The simple tones sonifying each individual were projected from the loudspeaker in this group nearest that individual. The collective activity sonification was mixed primarily across all four, though a small portion of the signal was mixed to the outer four which otherwise carried the sonification of the virtual objects. Finally, a subwoofer was introduced under the table, at the very centre of the environment, to emphasise bass frequencies and give the sounds a greater sense of physical presence in the environment.

With design decisions taken about loudspeaker deployment, we were able to settle on a plan for the environment. This is shown schematically in Figure 3.2.

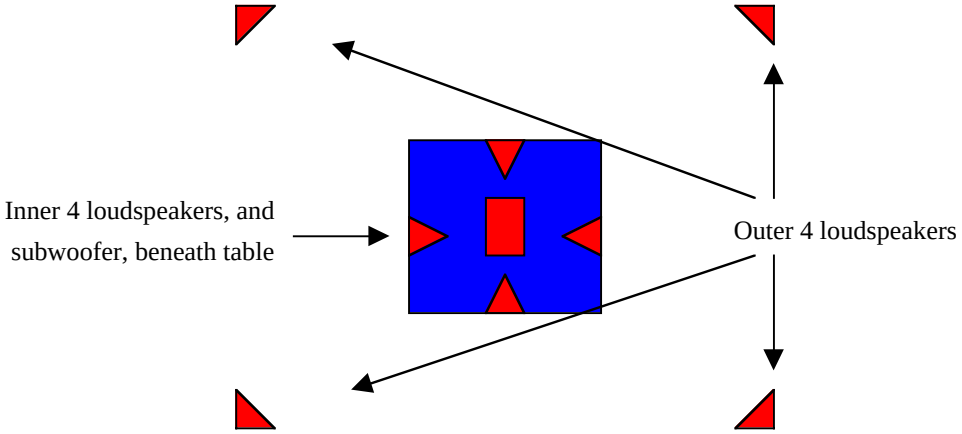

Figure 3.2: Schematic drawing of loudspeakers in relationship to the table.

3.3.3. Technically Robust, Simplified Input Devices

To realise a public demonstrator within a working week, we needed to compromise on some details of design. It would seem natural, following from our earlier work with The RoundTable, that we would prefer a tangible interface with, perhaps, phicons being used to influence the water surface and interact with virtual objects or, alternatively, a touch sensitive display. However, here we made a deliberate simplification and employed four standard trackball devices. As described below, we used an extension of Windows 95 to enable the 'mouse event' data (including coordinates) for these four devices to be simultaneously captured. This had a number of consequences. First, it more or less limited the number of people who could directly influence matters to four. Secondly, it compromises on the mixture of sensory modalities we would like to explore in SHAPE assemblies. A more tactile interface would be more idiomatic for us. Thirdly, a divergence exists with mouse devices and their derivatives between the locus of physical gesture (the device itself, ball, button et cetera) and the locus of effects (motion on screen, influence on a dynamic animation). As we shall see, this may have influenced people's abilities to interact at the table. However, these compromises meant that we did not have to devote time into calibrating novel sensor devices or controlling lighting conditions (cf. Hoch et al., 1999).

3.3.4. Collaborative Added Value, Collaboration Through a Virtual Medium

Chapter 2 of this Deliverable presents a number of examples of people collaborating around a publically exhibited artwork. Interestingly, many of the examples in that analysis show people engaging with one another in ways which were not intended in advance and, rather, are devoted to collaboratively working out how to engage with the work in the first place. Mindful of these results, we wished to design a benefit to collaboration into the environment we were developing. That is, while recognising that people would be likely to make of our design things other than we intend and collaborate around it in unforeseen ways, we wanted to explicitly design collaborative opportunities within it. To structure our thinking, we coined the phrase 'collaborative added value'. That is, we wished for individuals acting alone to gain some benefit from activity at the table. But we wished for the combined concerted efforts of two or more individuals to enable benefits to come into existence that those individuals working alone could not readily obtain.

The idea of activity at the table being a matter of perturbing a fluid surface suggested a design idea in this regard. We conceived that an individual, by moving within the virtual medium, would produce ripples radiating out from a position given by their trackball. The close proximity of another individual's ripples would yield ripples with a summed magnitude. Following classical wave mechanics, sometimes these ripples would cancel and sometimes they would reinforce, producing a combined wave of greater magnitude than either participant alone could produce. Our conception then was to make certain behaviours of the floating objects contingent upon them experiencing a virtual force or displacement which could only be achieved by the coordination of two or more sets of ripples. In this way, we hoped that new object-behaviours would be visible and audible with collaborative activity and provide added value and hence motivation to collaboration. The change in behaviour that coordinated activity yields is described below.

Our design idea brings out another feature worth noting. Our intention was to support *collaboration through a virtual medium*. That is, participants interact with the virtual environment rendered on the table's display by manipulating a virtual medium (the fluid surface). Collaborative activity is supported by carefully designing the dynamics of this medium to respond in variable ways, giving different behaviours when one supposes that collaboration is occurring. Importantly, there is no switch of interaction medium or mode to support collaboration. Participants do not have to do new things, with new technical features, in order to collaborate. In this way, it was hoped to support collaboration without an interaction 'mode switch' or a shift to new interaction techniques (for an alternative approach, see Benford et al., 2000).

3.3.5. Exploring the Legibility of Associations and Variable Intersubjective Agreement

The work reported in Chapter 2 of this Deliverable sensitised us to a further matter. This concerns how participants' interaction with respect to an artwork is often a matter of comparing each other's perception of it, and configuring each other's activities so that certain perceptual effects are likely to be experienced. We routinely noticed during the Workshop that we (as co-designers) were engaging in this in our presentation of design ideas to each other. The trials with different sound mixing techniques described above were often accompanied by one of us pointing to a virtual sound source as it moved around the

environment. Additionally, we would often compare our different experiences of where a sound was heard to be coming from. This was particularly topical with stationary sounds, which tended to 'collapse' into the nearest speaker to a listener leading to differences in perception as to the source.

These observations suggested to us that we should make the comparison of experience a designed for, thematic feature of what we were building. We noticed that our design already had different ways of associating activity with graphical objects and sound. By combining a number of different strategies, we could observe whether any one kind of association was more perspicuous than another. In addition, we had a design emerging in which whether participants were likely to agree on what they were hearing might also be made variable. Accordingly, we designed behaviours for the floating objects so that they noticeably orbited the display when they experienced an above threshold displacement. This was combined with an orbiting motion of the sound associated with them in the outer four speakers. As we noted above, the degree of agreement as to a sound source's location between participants varied in our set-up depending upon whether the sound was moving or not. Moving sound elicited some agreement as to momentary locations. Stationary sounds collapsed into the nearest speaker to the listener. Far from this being a weakness in design, we felt that we could, in principle, explore this variability as a thematic feature of our environment.

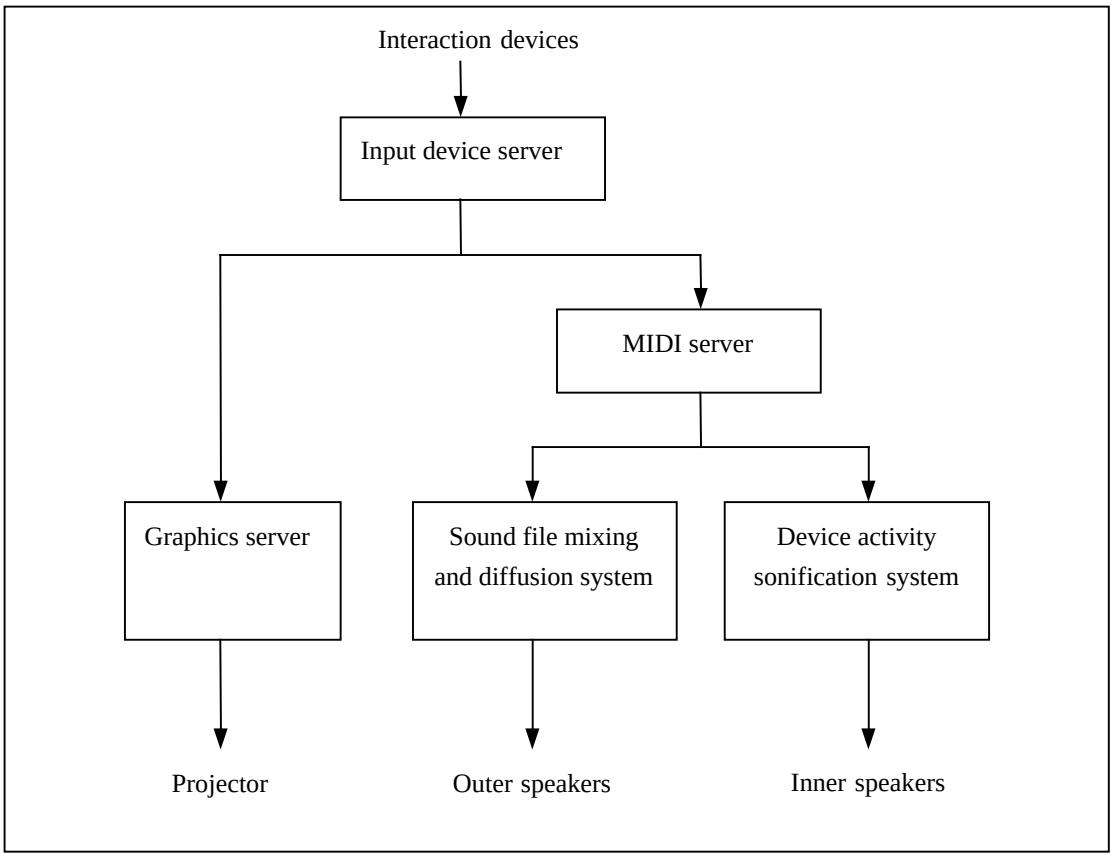

Figure 3.3: Schematic diagram of the technical components to ToneTable.

3.4. ToneTable: Technical Description

Having described some of the design ideas which emerged during the course of the Workshop, let us now give an account of the finalised technical set-up which realised ToneTable in the form that was publically presented at the end of the Workshop.

The ToneTable setup consists of five main parts: a graphics server, an input device server, a MIDI server and two sound generation systems. The setup is illustrated schematically in Figure 3.3. The interaction devices generate mouse events that are translated into positional data by the input device server. The positional data is sent to the graphics server and the MIDI server. The MIDI server translates the positional data into MIDI messages and sends them to the sound generation systems.

3.4.1. Input from Trackballs

Four people can interact with the ToneTable simultaneously using trackballs connected to a PC through a USB hub. In order to identify the trackball that originated a certain mouse event, the Multiple Input Devices (MID) package (Hourcade & Bederson, 1999) is used. The location of each trackball cursor is then sent to the graphics server through a TCP/IP socket.

3.4.2. MIDI Server

The MIDI server receives positional information from the input device server through a TCP/IP socket and converts it into MIDI (Musical Instrument Digital Interface) messages. The conversion is done using the publicly available NoSuch MIDI java package.

3.4.3. Graphics Server

The graphics server creates the visualisation that is projected onto the table. The visualisation consists of two overlaid parts: a watery surface layer and sound object layer.

The watery surface consists of a lattice of 3D points that are connected to form triangle strips. These strips are then projected orthogonally onto the image plane. The distance z_{ij} from the image plane for a lattice point $p_{ij} = (x_{ij}, y_{ij}, z_{ij})$ is defined as the sum of a wave function f and a "puddle" function c, i.e.

$$z = f(x, y, t) = w(x, y, t) + c(x, y, t)$$

where t denotes time. The wave function w is defined as the sum

$$w(x, y, t) = \sum_k A_k \sin(\varphi(t) + \omega_k d_k \langle (x, y))$$

where A_k is the amplitude, $d_k = (dx_k, dy_k)$ is a propagation direction vector, ω_k is a constant defining the period of the wave, and $\varphi(t)$ is a phase offset that is updated linearly with the time t. Each trackball cursor location is visualized as a "puddle" containing a set of concentric ripples.

$$c(x, y, t) = \sum_n d_n \sin(\phi_n(t) + kr_n)$$

where k is a constant, r_n denotes the distance between the cursor location and the point (x, y) and d_n is defined as

$$d_n = k'(1 - r_n)^m$$

clamped to the interval [0, 1] and k' and m are constants. Since each puddle has a pre-determined fixed radius, it is only necessary to evaluate the function c for points on the lattice that fall within this radius.

As an option, a set of "rain drops" can be added to the water surface layer. These are smaller versions of the "puddles" whose amplitude deteriorates with time. The water surface is lit by a directional light source and modulated by an environment texture map through cube mapping (Greene, 1986).

The sound object layer is rendered on top of the water surface layer. Each sound object is rendered as a combination of three textured and rotated quadrilaterals. The textures are combined using additive alpha blending (McReynolds, 1997). The quadrilaterals are given a size that is proportional to f(x, y) at the center of the sound object.

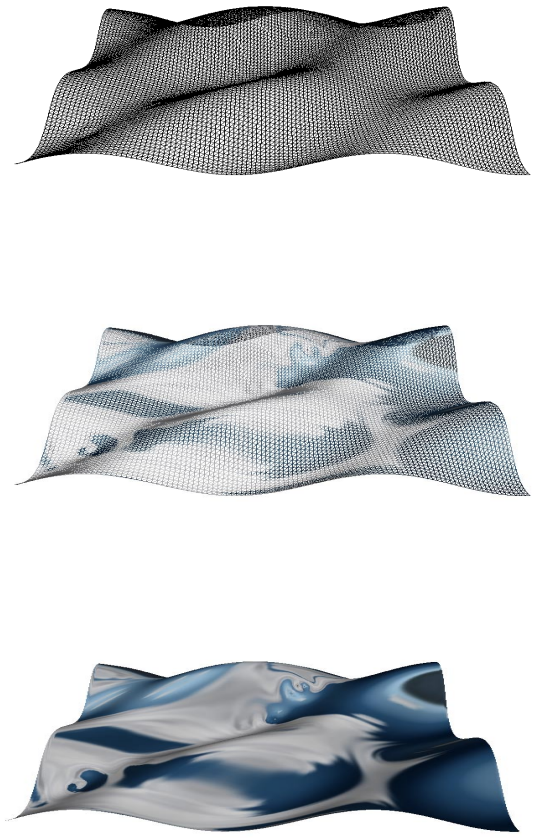

Figure 3.4: The triangular mesh underlying the animation of the watery surface in ToneTable (top), with a suitable texture projected onto it (middle), and with only the shaped texture rendered (bottom).

3.4.4. Animation of the Sound Objects

Each sound object can be in one of two states: floating or orbiting. When floating, the sound objects move with the water surface. At the same time, they attempt to avoid each other, the trackball cursor locations and the window edges. This is accomplished through numerical integration of the Newtonian equations of motion (Reynolds, 1987, Witkin and Baraff, 1997). The total force F acting on a sound object is a sum of the forces

$$F(x,y) = \sum_s F_s(x,y) + \sum_c F_c(x,y) + F_d(x,y) + F_e(x,y) + F_w(x,y)$$

where F_s is the force due to sound object s, F_c is the force due to trackball c, F_d is the force due to viscous drag, F_e is an window edge avoidance force and F_w is the force due to the water surface. The force due to a sound object is defined as

$$D = (x_s - x, y_s - y)$$

$$F_s = \begin{cases} \frac{1}{\|D\|^2} D & \|D\| > k \\ 0 & otherwise \end{cases}$$

where k is a constant. The force due to trackballs and the edge avoidance force are defined similarly. The force due to viscous drag is defined as

$$F_d = -k_d V$$

where V is the current velocity of the sound object and k_d is a constant. The force due to the water surface is

$$F_w(x,y) = k_w N(x,y)$$

where N(x,y) is the normal of the water surface at (x, y) and k_w is a constant.

If the magnitude of the total force acting on a sound object exceeds a certain value, the sound object state is set to orbiting. When orbiting, a decelerating circular motion around the center of the screen replaces the numerical integration of the equations of motion. When the circular orbit is complete the sound object state is reset to floating.

3.4.5. Sound Object Mixing and Diffusion

A sound file was selected to correspond to each sound object in the display. After some experimentation, it was decided to limit the number of such objects to five, and five contrasting sound files were selected. The files varied in length between 10 and 15 seconds.

Sounds which were sustained (so that a sound object did not 'disappear' from the environment) and which had their energy in a focused yet discriminable part of the spectrum (so that the sounds did not mask each other) were preferred. A number of the selected sounds were made by recording objects rubbing against or rolling on top of each other. The suggestion of intrinsic movement in the sound file worked well in this environment. We were, in many cases, able to maintain a suggestion of an object rolling around the outer speakers even though the sound files were all monophonic at source.

As already mentioned, the VBAP method of diffusion (Pulkki, 1997) was used to mix these sound to the outer four speakers. VBAP code-objects were embedded within a mixing application specially written for ToneTable in the Max/MSP audio programming environment. The application received the momentary angle of each sound in the display and computed the mix coefficients to each speaker accordingly. A further amplitude boost was given to a sound object whenever it came within one of the puddles or was engaged in the orbiting behaviour.

3.4.6. Device Activity Sonification

As outlined above each individual participant's trackball activity was sonified. This was accomplished by sampling the trackball position periodically (approximately every 50 milliseconds) and calculating a normalised magnitude of trackball movement since the last time the position was sampled. This value was then smoothed and scaled and further normalised to be sent as a MIDI controller value to a sound synthesis algorithm running on a Clavia Nord Modular synthesiser. The synthesis algorithm produced tones for each trackball which varied in amplitude and spectral colour depending upon activity. The summed trackball activity measures across the four devices was similarly scaled and normalised and used to control another synthesis algorithm running on a second Nord Modular synthesiser. This algorithm produced splashing of increasing intensity and impression of agitation as the combined activity measure increased.

3.5. Public Presentation and Evaluation

At noon on the final day of the Workshop, ToneTable was presented to the public. About thirty people were in attendance. One of us started by giving a welcome and a brief account of the SHAPE project and the Workshop, as well as the broader Disappearing Computer research context. The in-development status of our demonstrator was emphasised, as was the intention to create something 'abstract yet suggestive'. Suggestions at any level were welcomed. Following this, people were invited into a separate room to see and explore ToneTable. A number of images from the public presentation are shown overleaf.

Figure 3.5: Various images from the public presentation of ToneTable during the Second SHAPE Workshop

Let us now evaluate ToneTable in the light of our experience at this public presentation. First, from a technical perspective, it can be noted that setup for the ToneTable worked very well. Using Java for managing multiple input devices and conversion between positional data and MIDI was very straightforward. In addition, the MID package made it unnecessary to use one computer for each input device. One drawback of using TCP/IP sockets and Java, however, were that random stalls that originated within the Java virtual machine and/or

network packages would cause occasional drops in frame rate.

The graphical visualisation was effective in the sense that multiple users perceived it as a watery surface (as intended). The projection onto the table seemed to reinforce this illusion. However, the relatively low resolution of the water surface lattice caused some aliasing artifacts. These did not appear to interfere with the total experience, though.

Feedback from participants at the public demonstration was generally very positive. Indeed, some of it was extremely complimentary. A commonly praised point was that people experienced the ToneTable as having several different behaviour types and relationships between activity, sound and graphics and that these unfolded over time with increasing engagement and prolonged periods of observation.

The sonification of activity at the table was also well received and clearly several participants took some delight in making loud noises with vigorous trackball movements. The fact that a sound could be heard in an immediately responsive way to one's individual activity through the presence of a tone emanating from under the table gave a clear indication that one was having an effect. The synthesised splashing sound was also appreciated.

Good feedback was received about the high quality of the computer graphics and the sound, a quality far exceeding that ever experienced before in a computer-related installation by some of the attendees.

Our public demonstration raised a number of interesting critical points and these are worth discussion.

- *Crowding the space.* The environment could not 'carry' a large number of people. While space exists between the table and the outer set of speakers, this can only be comfortably occupied by the four principal participants and a small number of on-lookers. When the environment become crowded, people might find themselves right next to a single loudspeaker and very far from any audio 'sweet spot'. Indeed, from such a position, they would absorb some of the sound themselves! Generally, we had not allowed for large enough viewing and listening positions, except to support a small number of users and onlookers. Furthermore, we hadn't specifically designed ToneTable to give a listening position for onlookers. While they might be within the outer set of speakers, their impression of both stationary and moving sounds would have been compromised.
- *Object-sound associations.* While it was clear to participants that their activity was being sonified and that objects while orbiting moved around the sound space, it was not clear exactly which object related to which sound or whether, indeed, there was a fixed 'standing-for' relationship. It is possible that five sound objects is too many to individuate in such a setting and that future experiments should be conducted with very few, perhaps with just one initially.
- *Collaborative added value gained too cheaply.* While we designed in a mechanism to allow new behaviours (specifically the orbiting animation) to emerge as a result of combined activity from participants, this outcome could be gained rather too cheaply. If two users just thrashed around with their trackballs, there would be a good chance that sooner or later their ripples would coincide in such a way as to push an object into orbit. Accordingly, we observed few examples of the careful concerted coordination to move objects and yield new behaviours that we were hoping to provide for.
- *Gestural legibility.* As remarked above a feature of trackballs (and mice) as devices is that they disassociate the locus of gestural engagement from the locus of display

effects. This made it hard for participants to see which trackball was associated with which set of ripples. In turn, this made it hard to concertedly coordinate trackball activity with another as it would not be clear which other person was producing which effects on the surface. Trackball gestures then were not readily legible to other parties.

- *The ease of interaction.* There was a sense in which interaction with the ToneTable was too easy. Unthinking trackball movements would produce dramatic effects. We did not have time to experiment with various ways of damping or scaling trackball movements so that, for example, a user would have to push in a given direction for an extended time to get to a desired location. This gave the impression of the fluid as being a medium without any viscosity!

The above issues tended to 'screen out' an investigation of some of the other ideas we had designed into ToneTable and wished to explore.

- *Interaction through a virtual medium.* The intention to support collaborative activity through providing a shared virtual medium remains, for us, an interesting one. However, as we did not observe many instances of concerted collaboration at the ToneTable, we are not able to assess the quality of this proposal. In addition, the fact that unthinking trackball 'thrashing' could yield effects didn't give the virtual surface the 'phenomenology' of a medium, i.e. as something to work through. It is possible that an illusion of viscosity provided by more considered device calibrations would help in this regard.
- *Collaborative added value.* Similarly, our strategy for supporting collaboration in terms of this concept remains promising but untested.
- *Different kinds of shareability.* Finally, our proposals to explore different degrees of shareability of experience remain uninvestigated. We did not observe instances of people comparing their experience of ToneTable in the manner we hoped would take place.

3.6 Conclusions and Future Directions

Although a number of features of ToneTable could not be evaluated in the way we intended, and others seemed to not adequately implement our design intentions, it must be remembered that the experience of ToneTable of participants at the Workshop, both project members and visitors, was generally positive. We believe therefore that our work is a strong enough basis for future explorations. We believe that ToneTable demonstrates the consortium's ability to produce artefacts which integrate high quality computer graphics and sound in novel ways. We believe that ToneTable, when considered in its multi-speaker enveloping environment, gives a glimpse of what a 'hybrid assembly' of artefacts might look like at room-sized level of architectural scale. This has importantly been gained at a very early stage of the project and as a product of project-wide collaborative work. We also, at this very early stage, were able to present ToneTable publically in a coherent and enjoyable form, and use it as the basis of substantive discussions with external collaborators. In that respect, ToneTable and the concept of the constructional workshop in which it was developed have, in our view, been validated.

We also see a number of key immediate research directions being opened up.

- *Gesture and its legibility*. We remarked about the difficulties there were using trackball devices in ToneTable. It is clear that better uses of such devices, and of alternatives, are required if the gestures of participants are to be interpretable by each other in such a way as to enable collaborative activity. This will probably cause us to return to investigating physical interaction techniques of the sort present in earlier KTH work (Hoch et al., 1999) but which could not be pursued in the current Workshop.
- *Participation forms and associated regions*. There were various ways in which one could participate in ToneTable: as an on-looker within the sound environment, as an on-looker awaiting the next turn at the table, as a lurker by the door to the room that contained ToneTable, as well as being a fully fledged participant with a hand on a trackball. We further emphasise the remarks made in Chapter 2 (and this issue is taken up also in Chapter 5) that recognition of these different 'footings' with respect to the action has to be made and, where possible, influence design. This raises fascinating challenges for both visual and sound design.
- *Coordination and collaboration, added values and supportive virtual media.* ToneTable embodied the elements of a characteristic approach to designing collaborative systems. Participant activity is through a virtual medium which can have different emergent behaviours in a fashion which is sensitive to the social patterning of behaviour between individuals. This is an orientation which we seek to further explore, elaborate and demonstrate.
- *Mixing media*. ToneTable was an interesting experiment in combining sound and vision in a coherent fashion. To realise it we developed a technical infrastructure which worked effectively with very few noticeable delays in responsivity or drops in rendering rates. Both sound and graphics were smooth and responsive. Some parts of this infrastructure would be transferable to other assemblies of artefacts, some are ToneTable-specific. An important challenge is to use specific experiments like ToneTable as a source of requirements for more generic systems. To this end, collaborations have been initiated within the project to explore how installations like ToneTable might impact upon virtual environment platforms like MASSIVE-3 discussed in the next Chapter. More generic and less application specific techniques are required for integrating media in SHAPE. To give one specific example, experience with ToneTable has prompted researchers at KTH to think more generally about novel approaches for mixing and sound rendering in virtual and mixed reality environments in ways which, for example, could add detail and high quality sound reproduction to the 'fragmented boundary' demonstrators discussed in Chapter 4. In addition, for future developments, it would be convenient to build from a generalised set of graphical rendering and animation modules. These could include methods for data distribution, advanced rendering and projection methods onto surfaces of different shapes.

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Chapter 4:
Fragmented Boundaries
Mixing realities by replaying virtual worlds in real spaces

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This Chapter describes a series of techniques for creating hybrid, mixed reality environments based on a principle of 'fragmented boundaries'. This concept extends previous work on mixed reality boundaries (where some 'window' or 'portal' between a virtual and a physical world is provided to 'join' worlds) to cases where the worlds can be thought of as 'overlaid' by making partial information about a virtual world available in a physical environment. This could take the form of, for example, rendering the sound from a virtual environment using a multi-speaker sound system in the physical environment, or using an assembly of graphical display devices to give 'glimpses' onto activity in the virtual environment. It is suggested that techniques for recording and replaying activity from a virtual world will be particularly useful in supporting applications which contain fragment boundaries. This brief Chapter outlines the initial form of the concept of 'fragmented boundaries', describes a first demonstration of it, and raises the question of how fragmented boundaries might be realised in the public places which are of interest to SHAPE both at room sized levels of architectural scale and beyond.

4.1. Fragmented Boundaries

The technique of fragmented boundaries is a recent development, linking and overlaying a physical environment with its equivalent virtual world. We present the concept, and describe an early demonstration of using multiple fragmented mixed reality boundaries. This technique highlights the hybrid approach of SHAPE for mixing realities, and complements the mixing of modalities described in the previous Chapter.

The concept of fragmented boundaries extends our own work on mixed reality. A mixed reality boundary is a kind of interface that joins a physical space to a virtual space such that the two appear to become adjacent. The first mixed reality boundaries were simple windows between the two so that the occupants of each could see into the other (those in the physical would see a projection of the virtual and those in the virtual would see an embedded live video image of the physical). Later boundaries refined this through the idea of boundaries

having different properties – permeability, situation, dynamics, symmetry and representation (Benford et al., 1998) – leading to new kinds of boundaries such as traversable interfaces that create the illusion of participants crossing between virtual and physical (Koleva et al., 2000).

Rather than solely concatenating physical and virtual spaces, this document describes how several different fragments of a mixed reality boundary can be used to connect a physical space to a virtual space at several locations so as to create the illusion that the two spaces are overlaid one on the other. The core idea can be summarised as follows.

- Choose a physical space
- Build its virtual equivalent as a Collaborative Virtual Environment (CVE)
- Connect the two at various locations using: speakers in the physical world driven by virtual microphones at appropriate positions in the virtual world; virtual speakers driven by their equivalent physical microphones; physical projectors driven by virtual cameras; and video textures driven by physical cameras. The net effect is to create multiple points of contact where the action in the virtual world can be seen or heard from within the physical world and vice versa.
- Get some avatars to act out scenes in the virtual environment.
- Participants in the real space then see and hear these scenes being played out around them.

If we use the MASSIVE-3 CVE's record and replay technique (described below), it becomes relatively easy to improvise tours, dialogues, performances and stories in the virtual and directly play them back into the physical without having to program them. This approach to hybrid spaces should thus allow us to explore the potential for realising and investigating public exhibitions in museums, as well as outdoor public spaces.

4.2. A First Demonstration of Fragmented Boundaries

We have created a first demonstration in the Mixed Reality Laboratory (MRL) at Nottingham. Figure 4.1 shows the configuration of a part of our lab space alongside the configuration of a virtual equivalent created within the MASSIVE-3 system (Greenhalgh et al., 2000b). The two environments are connected via the following boundaries.

- Three virtual microphones linked to three pairs of physical speakers.
- A vertical window – this appears as a projection of the virtual world onto a vertical screen in the physical. At the same time a video image taken from a camera that is attached to the top of the projection screen is texture mapped back into the virtual world. The net effect is that avatars in the virtual MRL can position themselves so as to be seen through, and at the same time see out of, this window.
- A horizontal floor projection – this shows a shadow-like image of any avatar that passes over its equivalent position in the virtual world. The shadow effect is achieved by distorting the 3D graphics that are projected from a virtual camera in the MASSIVE-3 system. This distortion involves shearing the avatar geometry onto the ground plane and removing its colour.
- A periscope – a rotating display that has been created by attaching a flat-panel display, small 'lipstick' video camera and Polhemus™ 3D sensor to a rotating wooden frame,

suspended by a pole from the ceiling. Participants in the physical MRL can grasp and turn this display in order to follow avatars as they move around the virtual MRL. An avatar will appear on the display so long as it is pointing in their direction. At the same time, the avatars see a rotating video texture that offers them various views back into the physical.

- Finally, one of the participants in the physical MRL can sit down at a PC in order to drive the avatar in the virtual MRL.

The net result is that participants in the physical MRL hear the audio (speech) of avatars as they move through the virtual MRL. This audio appears to move around the physical MRL, following the avatars' virtual movements. Participants in the physical MRL also see occasional glimpses of these avatars as they pass by the various displays of the virtual that are located at different places in the physical.

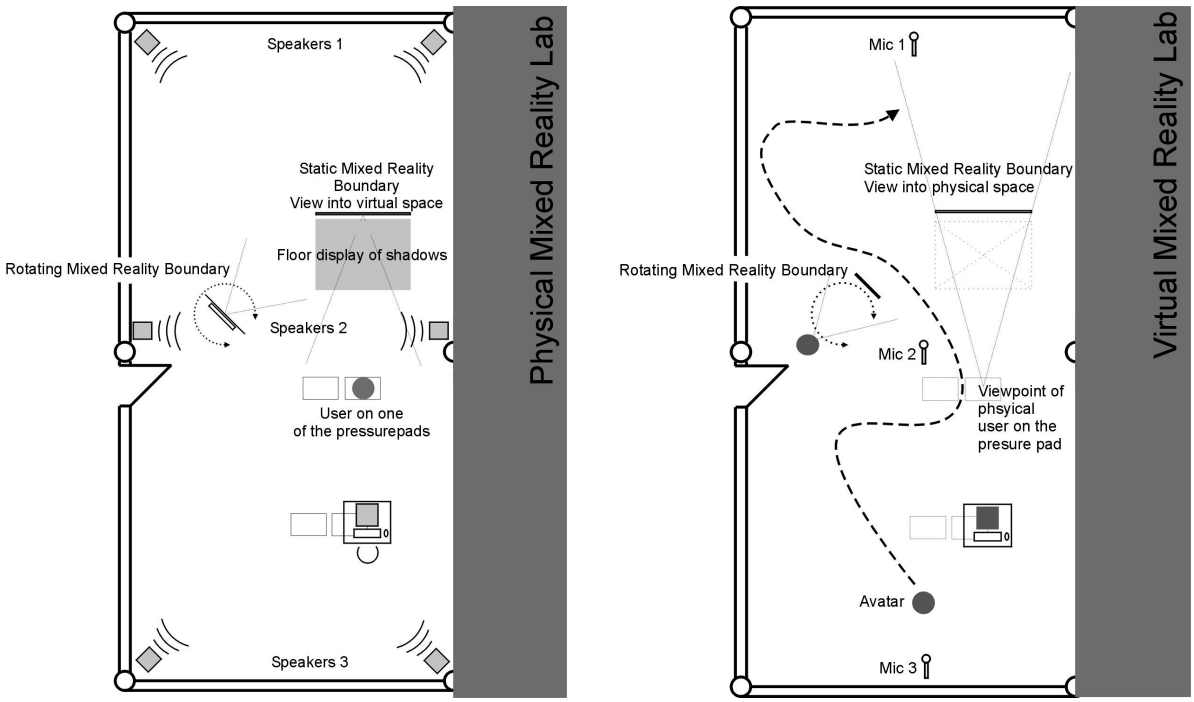

Figure 4.1: Configuration of the physical and virtual MRL

Figure 4.2 shows the vertical window and the horizontal shadow projection as they appear in the physical MRL. In the image on the left, the avatar is positioned in the virtual MRL so that it appears on the vertical projection. In the image on the right, this avatar has stepped forward 'out of' this screen. It is now effectively standing in front of it and so appears as a shadow on the floor projection. Figure 4.3 shows a close-up shot of the shadow effect.

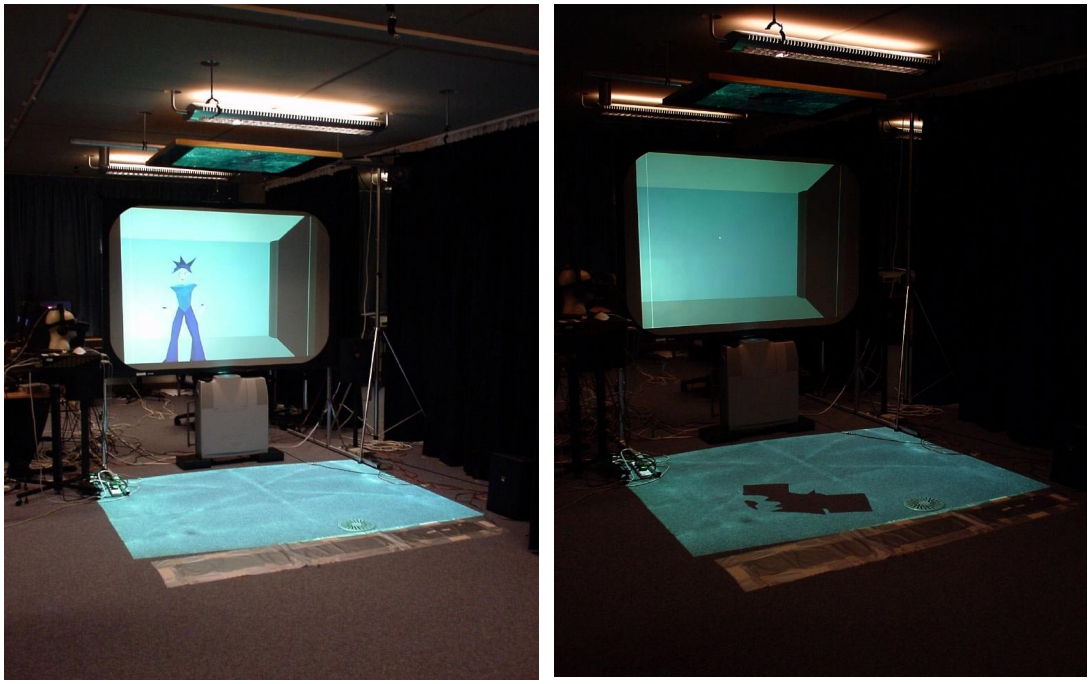

Figure 4.2: The vertical window and the horizontal shadow projections

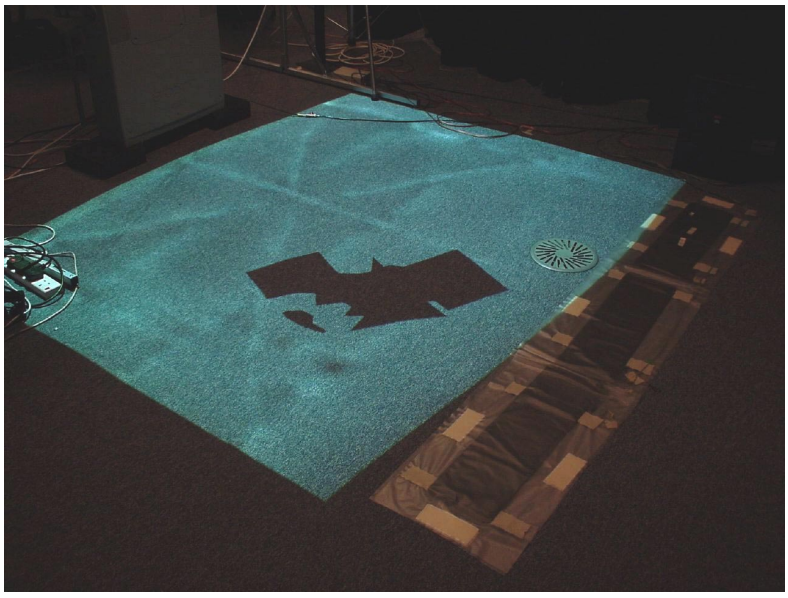

Figure 4.3: A close-up shot of an avatar's shadow cast on the floor

Figure 4.4 shows the physical appearance of the rotating periscope display in the physical MRL. The virtual MRL is displayed on the screen, including the video-textured view sent by the camera on the far side of the periscope.

Figure 4.4: The rotating periscope display

Figure 4.5 shows a view inside the virtual MRL, including the two video textures that define the virtual sides of the two mixed reality boundaries (vertical window and rotating periscope). The white rectangle bounds the volume inside which a shadow is projected. Two circles shown at the far end of the virtual MRL indicate the volume at which a particular virtual microphone picks up audio from the avatar (whose view of the virtual world this figure is).

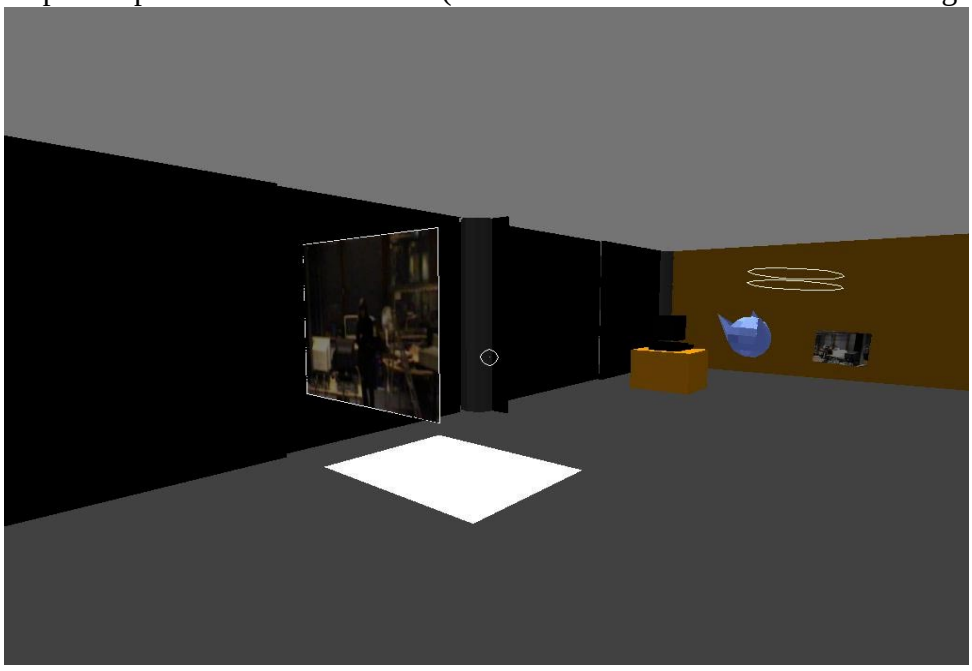

Figure 4.5: Inside the virtual MRL

4.3. Recording and Replaying 3D Worlds

Our demonstration builds on a technique for recording and replaying virtual worlds that has been realised within the MASSIVE-3 system. MASSIVE-3 includes a mechanism called 'temporal links' that can log every action within a locale (a region of a virtual world) (Greenhalgh et al., 2000a). This includes every movement, object interaction, and speech of every avatar within that locale. A log file can then be linked back into a live locale at a later time so that the recorded action appears to be recreated within the live world. Participants can fly around the recording, viewing it from any angle or following any character. The resulting mixture of live and recorded action can itself be logged as a new 3D recording. There are many potential uses for this 3D record and replay technique.

- Creating 'flashbacks' in virtual worlds;
- Post-hoc analysis of events in virtual worlds, for example on-line debriefing after a training session in a VR simulator, or social scientific evaluation;
- VR email and bulletin boards, where people leave recordings of their avatar in a world for others to find;
- Post production of material from virtual worlds – recorded data can be fed into animation packages for off-line high-quality rendering.

4.4. Appropriating Public Displays and Surfaces

This approach might potentially be applied to the creation of various public experiences in galleries, museums and exploratoria. Avatars could give guided tours or could act out historical dramas. Actors and museum staff could monitor activities in the physical museum (through various embedded audio and video views in the virtual world) and choose to make live interventions, mixing these with pre-recorded material at appropriate moments. Alternatively, members of the public visiting the virtual museum as an on-line shared virtual world could interact with physical museum visitors, either live, or through recorded 3D messages. Again, the important innovation here is the speed with which material can be created and replayed so that it appears to move through a potentially large physical space – in the most extreme case being improvised live. An interesting challenge would be to move onto the street, involving people in dramatic scenes as they move around a city, perhaps 'overlaid' on sites of historical interest in outdoor public spaces.

A key problem to be resolved when replaying virtual worlds within existing public spaces is the ready availability of display technologies. One option is to appropriate existing displays that are being used for another purpose. A journey through a modern building or city will reveal even to a casual observer a variety of existing computer controlled displays or potentially interesting surfaces for projecting graphics.

For example, Figure 4.6 summarises a journey through a city, in this case a short journey from London's Paddington station to Kensington High Street.

Figure 4.6: Some examples of public surfaces and displays encountered on a short journey in London

The sequence shows a number of public displays and surfaces that might be appropriated in order to overlay a virtual city on a physical city. These are, from top-left to bottom-right, flat-screen monitors in the Heathrow Express, information displays at Paddington station, shadows on the floor at Paddington, a text display on the London Underground, an ATM in Kensington High Street, and several televisions in a shop window on Kensington High Street. Would the owners of these displays allow us to borrow them? Might it be interesting for the owners of a television show to have some material to display in their window at night? We should not forget that we would also need to project sound from the virtual world into the physical environment, perhaps by appropriating public address systems.

An alternative to appropriating existing displays is to design new public information displays from scratch. These could be new kinds of public signpost, information screen, or even art installation that can double up to provide glimpses of a hidden virtual world. For example, one can imagine using the water projection system from the mixed reality artwork *Desert Rain* (Koleva et al., 2001) to create a public water feature that could also display images of a hidden virtual world.

4.5. Impressionistic Renderings and Ambient Displays

Whether we build them or appropriate them, visual displays of virtual worlds in public physical spaces are likely to be highly constrained in terms of their size and location. The boundary between the virtual and the physical may become highly fragmented. As a result, it may be difficult to convey with a high degree of visual realism or accuracy the idea that the virtual is overlaid on the physical. Indeed, if this kind of more conventional augmented reality is the goal, then it may make sense to use an augmented reality technology such as a see-through head-mounted display. A better approach may be to give a general impression that the virtual is overlaid on the physical through a series of fleeting glimpses of graphics that complement the projection of sound from the virtual world. Participants would see occasional shadowy glimpses of avatars that would cue them in to where dialogue could be heard.

Providing such fleeting glimpses might best utilise more impressionistic renderings such as the distorted avatar shadows that are projected onto the floor in the early demonstration. It may even be possible to create effective moving shadow effects on text displays.

A further option is to exploit the idea of ambient media (Dahley et al., 1998), to give peripheral indications of activity in the virtual world, for example, showing the presence of avatars as changes in airflow (possibly appropriate for conveying a sense of ghostlike presence). Could the table described in the previous chapter be used to display virtual activity, rendering it 'visible' as both waveforms and spatialised audio? There are certainly numerous opportunities where mixed realities and mixed modalities can be assembled together in hybrid public spaces.

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Chapter 5:
Designing Interactive Installations
A case study

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The successful introduction of technology into museums and exhibitions is a complex and difficult process. It requires detailed study of both visitor expectations and experiences and a sensitivity to curator and exhibition designer concerns, together with the concerns of architects and interior designers, in the case of newly built spaces. It also requires an understanding of the ergonomics of the spatial environment and the way that objects are located within the exhibition area, as these features affect the users' behaviour, and their communication and collaboration strategies. This Chapter provides some information on the process of introducing certain new multimedia artefacts into a new decorative arts museum - the National Museum of Ireland at Collins Barracks, Dublin. It notes some of the difficulties involved in the management of multi-disciplinary groups, each of whom have particular, and at times conflicting, interests. It also includes a brief discussion of a usability evaluation of the resultant interactive media installations, noting several difficulties with the implemented solutions.

5.1. Introduction

In this Chapter we present some reflections on the process of developing the specifications for interactive multimedia installations at a new museum – The National Museum of Ireland at Collins Barracks, Dublin, and examine the final implementation, noting certain problematic features of the achieved result. Our major goal here is not to criticise specific stakeholders or parties, as to the process or result, but to learn both from the process, and from our subsequent final evaluation of the achieved result.

The National Museum of Ireland was established by the Science and Art Museums Act, 1877. The collections are displayed at a number of locations[1]. The National Museum at Collins Barracks, which opened in 1997, includes exhibitions of decorative arts, history and folklore.

The museum is separated into several sections, including one set of areas reflecting the

[1] The archaeological and historical collections are displayed at the National Museum in Kildare Street. The Natural History Museum in Merrion Street holds an extensive collection of Irish and world zoology.

work of the Museum itself – e.g. "Curator's Choice", "Out of Storage", "The Museum at Work" and "Museum Development". Other displays trace the development of the country through the ages. The various collections chronicle the development of a vast range of arts and crafts including ceramics, silver, glassware, period furniture and weaponry. The Collins Barracks building has been chosen as the venue for the collections as it offers good accommodation for the collections in its large rooms, and it is an interesting historical building in itself, being a part of the longest continually-occupied military barracks in the world.

Figure 5.1: The Collins Barracks.

The new Museum area was a chance for the staff to make available for exhibit many items that have previously been held in storage, as the National Museum has had only a fraction of the Museum's holdings on show at any one time, as is the case in many Museums.

Consequently, another intention of the curators was to provide the visitors with the possibility to access a large body of additional information related to the displayed collections, by means of introducing computer-based interactive applications in the exhibition rooms.

The documentation of the way the technological installations were designed and then located within the museum space, and, subsequently, the analysis of the outcomes of the assessment survey we performed in the museum, can provide a valuable contribution to SHAPE. As stated in the Research Challenge 3 "Public Places and Physical Scale", presented in the SHAPE project Annex 1, one of the major aims of SHAPE is "to uncover principles for the design of assemblies of embedded devices which are appropriate for interaction in public places (…)", and in particular to achieve a "deeper understanding of people's interaction with technology in the presence of others in circumstances where a conventional computer does not provide such a clear locus of attention and point of engagement" (Bowers, 2000).

Our concern in carrying out the usability survey at Collins Barracks was understanding the visitors' experience of the space endowed with interactive installations: in particular how people approach, perceive and use the physical space, and how they relate to the artefacts on display and shape their behaviour according to the affordances of this context. The space the study refers to is very interesting as it is designed to encourage discovery of the objects on display and to develop an own path or sequence during the visit. The visitors are supposed to be immersed in the space, surrounded by objects and closets they can actively explore: in this perspective they should be provided with adequate tools that encourage sharing, collaboration and communication. It is clear that conventional 'desktop' applications cannot achieve the purpose of involving the visitors in an engaging and rewarding museum experience (Falk and Dierking, 1992).

5.2. Designing Technology for the Museum: the IDC work at Collins Barracks

In 1996 the Interaction Design Centre at the University of Limerick was appointed by the museum's curators to conduct consultancy work on the specifications for audio-visual and multimedia support, user requirements and design solutions for the multimedia installation to be introduced in the entire exhibition area at Collins Barracks, and in the assessment of tenders for the work (Fernström and Bannon, 1997).

From the IDC's perspective, the major design issue in this case was how to provide an engaging visitor experience of the quantity of material in the collection, and information on these items using new technologies, without overloading the visitor at a sensorial or cognitive level with too much physical detail about the items.

The IDC was included, with a certain reluctance, in the Design Group for the project, which consisted principally of architects and planners. Surprisingly, this group did not contain any curators, and so, in effect, the IDC became a spokesperson for the concerns of the curators at these design meetings. As our own work is based on the importance of user involvement in the whole design process, this arrangment was very problematic for us, and one which, in hindsight, we would not accept under any cirsumstances. However, at the time, we were keen to assist the curators in getting their concerns across to the design group, and given our involvement with the curators and the design team, we felt that perhaps we could act as agents for change. The authors conducted an initial survey of the site, where physical renovations were underway, and had numerous contacts with the Office for Public Works, architects, specialists in lighting and A/V equipment in order to explore the availability and/or feasibility (in terms of costs and requirements) of different design solutions. We also engaged in extensive discussions with the curators, concerning the Museum material available, and the major narratives being developed for the artefacts. The curators were then involved in discussions and focus groups and they were encouraged to express clearly any ideas they had about the possible uses of interactive multimedia in the galleries. There were other management committees overseeing the work on the new Museum, representing Government Departments, external Museum experts inter alia that handled overall financial matters and the public side of the development. However, one notable exception among the various interest groups represented on these various committees was the absence of the visitor constituency itself, who after all, were the ultimate recipients of this whole process! While we again did attempt to surface this concern, our relatively late arrival on the scene, and relatively lightweight political "clout" meant that this concern was never adequately addressed during the course of the project. The IDC group felt that this decision has greatly affected the design process and its outcome, as it is vitally important to proceed to a detailed study on the groups of end-users in the design of a certain system, analyse their features, preferences and behaviour in order to adapt the artefacts to the users and their activities (Preece, 1993; Hix and Hartson, 1993). The design solutions must be assessed on their effectiveness in encountering to the people's needs and behaviour strategies; in other words, in responding to the real *situation of use* (Bannon & Bødker, 1991).

Despite these practical limitations, we proceeded with the development of scenarios focused on a series of spaces within the museum, envisioning possible situations of use involving different artefacts and interaction styles (Carroll, 1995). One area was of particular interest in this regard: the "Out of Storage" gallery.

5.3. The "Out of Storage" Space: supporting discovery and learning

The "Out of Storage" gallery provides an extensive view (two storeys) of museum artefacts from storage, not arranged in a structured exhibit, but rather exhibited as being exemplars of vast collections of material still in storage. The intention behind the room was also to chronicle certain major historical events in the life of the Museum, particularly those that affected its collections policy over its lifetime.

According to the ideas expressed by the curators, the room needed to give an impression to the visitor of both a warehouse and a treasure trove, without being cluttered or indecipherable. Large window cabinets and open drawers encourage the exploration of the materials stored in the room: the users have to open up drawers to discover what they contain and to approach the cabinets at two different levels of the room. This allows the visitors to comfortably observe the objects displayed both in the lower and in the upper shelves of the cabinets.

The large variety of objects on display, their different sizes, origin and historical period make the "Out of Storage" very different from a traditional museum gallery, where the principles of disposition and the sequence of display are strongly structured to guide the visitor's experience within the space. On the contrary, this particular space encourages the visitors to develop their own paths and discovery strategies during the visit. The disposition of the room itself supports the sense of involvement and immersion, as the visitors find themselves surrounded by the glass cabinets and the open drawers that contain the art pieces. The conception is a striking one, and its realisation visually arresting. The challenge was then how to support visitors in understanding this physical space and array of exhibits without affecting the overall experience of the space as a "cornucopia of delights" (Fernström & Bannon, 1997).

Technology in museums should support the comprehension and enjoyment of complex and meaningful artefacts (the artworks), and to adapt itself to a structured environment (museum or exhibition), that is extremely rich in information resources and perceptible clues. Media applications should overlap in a seamless way with the objects they provide information about, and involve the visitors in a pleasant and rewarding experience by means of flexibility and personalisation of information. Our goal was thus to ensure that the technology was not seen as an end in itself, in terms of some form of stand-alone multimedia kiosk, but rather should be transparent in use, providing support to users in interpreting specific items in the displays when required. Thus the technology must be seamless, at-hand, and easy to use.

It is clear that the technology to be introduced into the "Out of Storage" space must respond to its very particular nature and it must support adequately the activities that can be performed by the visitors within the space. In particular, the educational potential of the room has to be supported and amplified; in fact, the process of learning in museums seems to be more likely related to the possibility of directly interacting with objects, instead of, for example, reading labels or guides (Caulton, 1998). It is unlikely to be found in traditional museums (differently from hands-on exhibitions or exploratoria), spaces where direct interaction and exploration by the visitors with the objects on display is allowed (Hooper-Greenhill, 1992). Through the active exploration of cabinets and drawers the "Out of Storage" allows the users to experience - in a limited form - discovery and freedom to structure a unique path in the visit.

The visitors' direct engagement with the exhibit favours the development of their curiosity

and interest towards what they are observing, and this leads the way to the experience of a condition of *flow*: the involvement happens at the sensory, intellectual and emotional levels and the visitor is highly motivated and consequently stimulated to further exploration (Csikszentmihalyi and Hermanson, 1994).

Our approach to interaction design is committed to the support of visitors' experience in this respect, particularly, envisioning possible devices (input-output) and systems architectures that could suit the museum context and allow the users to be rewarded by an optimal condition and engagement while visiting the environment as a whole.

We envisioned proposals of possible interactive applications (prototypes) based on different devices, but all focused on the main goal to enrich the visit experience and to highlight the value of artistic heritage, without distracting the users and interfering with their comprehension and enjoyment of artworks.

Our proposed solution for the "Out of Storage" gallery was essentially driven by the requirement of supporting human perception and physical response within the context, as the space's physical and perceptible features, or *affordances* (Gibson, 1979; Norman, 1993, 1999), naturally call for behavioural responses by the visitors. The style for interaction should be designed to be flexible, without physical constraints and responsive to the visitors behaviour. Our initial recommendations were for a wireless tool to ensure the visitors were free to move in the room as they preferred, and the use of a "pointing" interaction style: just pointing at the object of interest would have allowed the users to listen to a 3D auditory comment. This tool would support unobtrusively the exploration and enjoyment of the space and would allow the users to be close to the objects, and to observe them carefully while being provided with a comment or a description. The development of multisensory interfaces, wireless or 'invisible' appliances, grounded on the physical space and unobtrusively supporting human physical behaviour are core issues of this perspective.

Our suggestions for the use of interactive media focussed on the nature and amount of documentation on the artefacts available (in many cases documentation was quite sparse), the possibilities for interactivity, and the general ecology of the museum space where the artefacts would be located. In a number of cases, we recommended that simple still images or audio/film strips would be sufficient. Only in a relatively small number of cases could we make powerful arguments for computer-based media. (One such example concerned the silver collection, were many visitors had a strong interest in determining the provenance of specific items, and so there was an obvious need for a databse of information, and an image collection.) Our approach created some problems within the design group - at the level of policy concerning procurement of audio-visual and interactive multimedia installations, as others wished to allocate the technology budget *en bloc* as a single specific budget allocation for 'multimedia'. In our view, this separation of the technology provision at an early stage was problematic.

Ultimately, interactive media were installed in the the "Out of Storage" gallery, but the implementation differed in fundamental ways from the outline scenarios we had devised. While the original plan was for the IDC to be involved in evaluating the implementation by the contractor, this did not happen, for complex organizational reasons, and our consultancy ended at this point. Nevertheless, we were keen to discover what was ultimately provided, and over a year later, with the addition of new staff, we were able to carry out a brief evaluation on the interactive multimedia that had been installed, concentrating on two areas, including the "Out of Storage" gallery.

5.4. Brief Evaluation

An informal evaluation of the new technology in the Museum had been conducted by the IDC researchers involved in the original specification work described above, which noted some difficulties. Subsequently, a more extensive evaluation was conducted by a new member of the IDC staff that was not involved in the earlier work. Certain problems were noted and a further review of the site was conducted by the new researcher. It is principally the report of the latter researcher that is provided below as this was also specifically occasioned by her participation in the SHAPE project. In the later phases, all the researchers involved spent some time in assessing the relation between the original design concepts and the final implementation.

Initially we performed a survey of the museum in order to clarify the exhibition's structure and organisation, conducting a preliminary heuristic evaluation of the main multimedia installations and collecting some data on their effectiveness (Preece, 1993; Nielsen and Mack, 1994). The main goals of the survey were to focus on the organisation of the museum, the intended and the actual role of the several multimedia applications and, in particular, the way these installations fit the exhibition's physical space.

Consideration of the findings coming from the first survey at the Museum and the discussion of data followed at one of the IDC research meetings. From that several evaluation issues have emerged. In particular:

1. the problem of the integration between the technological installations and the museum's physical environment: need for observations of how users interact with the applications and the way they behave towards them;
2. the problem of the exploration and enjoyment of the space itself in order to design more effective information resources: need for observation of how the visitors move through the space and how they behave towards the objects that are exhibited.

Consequently, we planned and performed two observation sessions, conducted during different days of the week, so that we could include different groups of visitors (e.g. art students, school classes, foreign tourists during weekdays; art *amateurs*, tourists from Ireland and Dubliners and families during the weekend).

The observational study focused on specific aspects of the visitors' behaviour within the space, as well as their interaction with the computers and, specifically, the graphical user interfaces. A number of visitor behaviours were noted:

- physical path in the room
- pauses in front of the cabinets
- use of the free space (windows, benches, aisles, etc.)
- use of the information resources (labels, panels, descriptions, guards or guides, books, multimedia[2])
- possible breakdowns and/or problems
- total time of the visit and time of stops.

We applied various evaluation methodologies such as observation, usability analysis, heuristic evaluation and cognitive walkthrough (Preece, 1993; Nielsen and Mack, 1994; Hix and Hartson,1993). We observed 30 visitors during the first observation session (weekday), and 70 visitors during the second session (weekend). In the following section we present in

[2] We then proceeded to further specific observations regarding the interaction with multimedia applications.

detail the outcome of the sessions conducted in two specific galleries of the museum, where there is a significant use of computer-based installations.

5.5. Technology in the Galleries: some relevant cases

5.5.1. The Cloyne Harp

The "Exhibition Development" gallery (located on the 2nd floor, West block) is intended to present the development of the Collins Barracks collection and its forthcoming acquisitions and rearrangements.

In the gallery, there are two multimedia installations. By means of the first one, the users have the possibility to consult other museums' websites offline.

The second application focuses on a single object, the ancient "Cloyne Harp". As the main purpose of our survey was analysing how the technical appliances and installations fit the physical space and the artworks' locations, this specific part of the "Exhibition Development" room is particularly interesting, because the A/V presentation is related to a specific artefact and its display, and it is located in the immediate surroundings of the object itself (see Figure 5.2 below).

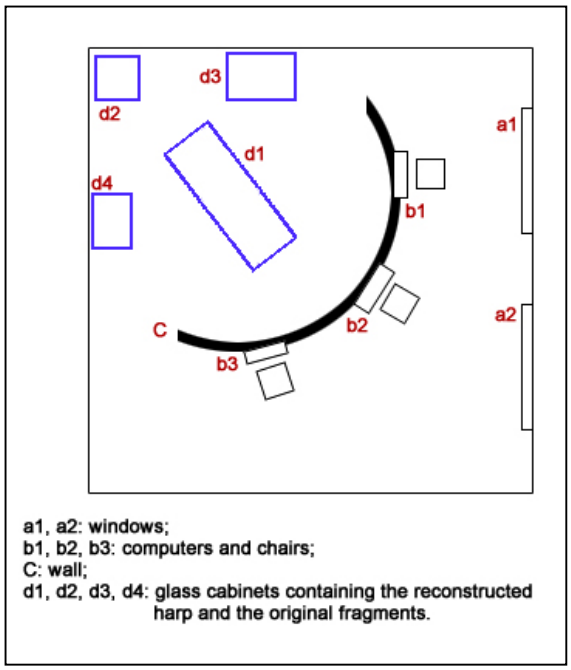

Figure 5.2. Outline of the "Cloyne Harp" exhibit.

The PCs' screens lean out of an upright wall that surrounds the cabinets where the reconstructed Cloyne Harp and the fragments of the original instrument are located. This round wall is placed in between the harp's cabinet and the aisle along the windows.

The PCs' stations are equipped with headphones and chairs. The screens are placed at different heights to allow for the physical features of different users. The monitors are placed inside metal frames that are intended to protect them from interference but we noted that it was possible to insert one's hand between the computer screen and the frame, and manipulate the screen controls, even turning the screen off, without any great difficulty. Unless there is

extensive custodial supervision, one would expect that certain visitors would indeed enagage in such behaviour over the lifetime of the exhibit.

The natural light entering the room by two windows might have been used to good effect in lighting the harp exhibit, but the upright wall covers the light as well as the objects on display. Problems in the physical location of the installation and of the harp itself are noticeable: the users cannot see the harp while sitting in front of the PCs. The wall has some openings between every two screens, but they are too far from the user's location to allow the visitor to look at the harp. Moreover, given the location of the wall, people who are sitting on the benches under the windows cannot see the harp either (see figure below).

Figure 5.3. The installations in the "Cloyne Harp" exhibition space.

Almost all the visitors we observed sat down in front of the computers, but, as soon as they started reading information about the harp, they realised they couldn't look at it, and they abandoned the interaction with the machine to move back to the surroundings of the artwork. The installation thus prevents the visitors observing the art piece and simultaneously accessing relevant information. The structure of the informative medium does not support the affordances of the space and the behaviour of the visitors within the specific physical environment.

As well as analysing these aspects of the physical and contextual relations between the presentation and the harp, we conducted a thorough heuristic evaluation of the interface by means of an extensive walkthrough of the system as well as focused observations of the users, with a view to assessing the effectiveness of:

- user interface and interaction styles
- role of sound
- information organisation and delivery.

The devices consist of touch screens and headphones. After 30 seconds without any interaction, the system returns to the first page. A set of basic commands is available on the interface:

- touch anywhere to continue
- touch a button to choose a section
- click on a word to learn more.

A general problem users encountered was that there is no way to go back while browsing the presentation (it is possible just to touch the screen to go forward): in order to browse another section the user has to exit the current one, then to choose another. The use of sound is limited to the "Hear the Harp" section, while it could be effectively used for providing other information, such as brief description, comments, music clips. Also, all the icons that introduce the sections are graphically represented by the same picture and this did not help the

users to have an immediate idea of the different topics available.

In the case of the "Cloyne Harp" exhibit, even though the software system itself is well designed and the interface simple and quite straightforward, the choice of a kiosk as interaction device and its placement in the room do not fit the space and do not respond to the visitors' behavioural strategies within the space.

Even if the presentation is relatively good, the design choice is not effective because the context structure and the patterns of action within it are not taken into account to develop the solution. The users tend to interact with the system only for a few minutes, then they prefer to move back to the surroundings of the object to observe it.

A shortcoming of the information provided was also pointed out by means of the observation of users interacting with the system. There are some other ancient harps in the Museum and this gives the possibility to create cross-references between similar pieces of the exhibition, located in different sections or rooms. The verbal account from the observations revealed that a good number of visitors were able to remember some of the other harps displayed at Collins Barrack; they mentioned similarities with the Cloyne Harp and expressed their interest in learning more about this topic. Unfortunately, the information available on the interactive presentation does not cover this subject, missing the opportunity to create links with other objects of the collection and stimulate correlations and further reflections in the visitors.

5.5.2. Out of Storage

As said in advance, the "Out of Storage" gallery (1st and 2nd floor, West block) is a very impressive physical space: the lighting is excellent, and the double entrance at two levels gives the posssibility to have two different views on the exhibit.

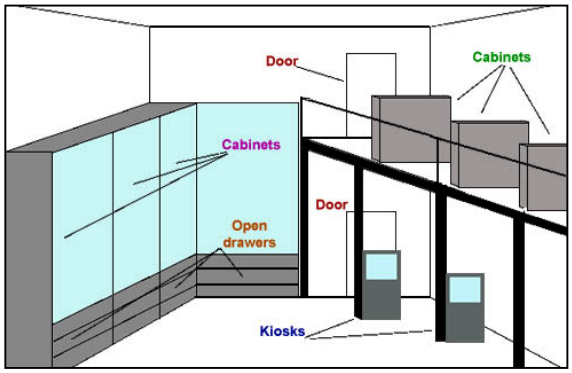

Fig. 5.4: Outline of the exhibit in the "Out of Storage" Gallery.

The underlying idea of object "storage" is extremely interesting and it can be an effective way of displaying a series of pieces that otherwise would not been on display due to limited space and resources. In particular, the possibility for "discovery" of the drawers' contents is potentially very interesting and involving for the visitors, and the visibility of the objects in the glass cabinets is very good.

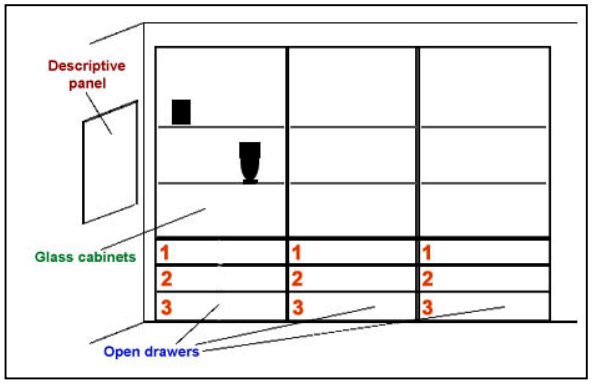

Fig. 5.5: Outline of the main exhibition cabinets in the "Out of Storage" Gallery.

A first problem in the room's organisation is the poor mapping and unclear correspondence between the cabinets and the related descriptive labels put on the walls, and this affects consequently the effectiveness of the same informative function in the interactive presentation. In fact, sometimes the label on the wall is not corresponing to the nearest cabinet and the user can easily mismatch the object and its description. The users we observed had lots of difficulties in understanding what description was related to a certain shelf, drawer and object. They complained that there were a lot of interesting objects to observe but they could not find out what they were. Moreover, the series of numbers used to identify the objects in the cabinet's shelves is repeated very similarly for any cabinet in the hall, which can cause confusion as well. The layout of the objects beside their descriptions in the label does not help, as there are a lot of similar pieces in the shelves (vases, glasses, containers) and they can be easily confused.

Concerning the multimedia presentation, we previously described the IDC recommendations for this room that included the encouragement of the user to remain in the surroundings of the objects and to explore the drawers, as the browsing and understanding of information is supposed to overlap the activity of discovery and observation of the pieces (Shuh, 1994).

The computers are located beside the windows, along the only wall where no objects are displayed: they are endowed with a touch-screen and installed into kiosks at different heights. They are very distant from the glass cabinets, and some of the visitors we observed did not even notice them, as they were attracted by the variety of objects in the room and by the drawers. The users who approached the computers interacted with them only briefly, then moved away. From the data collected during our observations, it emerges that the average duration of the users' interaction with the system is very low: out of 100 visitors observed, over half of them used the system for a time between 5 and 10 minutes; only a small number of visitors (around 7%) spent less than 5 minutes on the system.

If we consider that accessing and reading the description of a single object can take up to several minutes, these data make clear that the presentation is not being used appropriately by the majority of visitors. In other words, it does not achieve its purposes.

A first and evident problem in the presentation structure is that it requires as many as 8 clicks to reach a single description, and it is not easy for the user (being at the deepest level in the menu structure) to be aware of the current location and to return quickly back either to the main menu or to the upper level. In this respect, there is a lack of an effective "home" button,

as the back button works as “history” and it keeps trace of all the pages previously displayed, rather than of the different levels of information structure. The main introduction page of the presentation is problematic in terms of the graphics used, and it presents a very large blank space that might be better used for a “welcome” or a more appealing introduction to the system. Indeed, the presentation is rich in information resources, even if badly arranged. Some other specific problems can be identified: first of all, in the interactive system there are no indications about the cabinets’ and drawers’ identification numbers. For this reason, the references to the real locations of the objects are not clear. The mapping between the information space and the real space is not effective and this doesn’t help the users in associating an object to the related information and vice versa. As the interaction style is based on a touch screen, another problem that the users cannot easily operate on some interactive portions of the device: in fact, some of the “hot spots” are located near the edge of the screen and the user does not have enough room to touch the surface. Numerous visitors were frustrated by this feature of the interface. In the case of this gallery, the interactive presentation itself has problems in its structure and interface. More importantly, as we saw for the Cloyne Harp, the technology does not respond to the environmental conditions in which it is located and the visitors prefer not to use the tool as this distracts them from observing the objects and exploring the exhibition space.

5.6. Conclusions

Collins Barracks is a very interesting museum in a number of respects. The building itself is architecturally impressive, and the renovation work has not taken anything away from the imposing façade of the building. Inside, the development work has been done with the utmost sensitivity, creating a number of superb exhibition spaces within the confines of the orginal physical structure. Also, the Museum exhibits have been thoughfully displayed within the spaces. Our focus here has been to examine some of the successes and failures of the new technology being used within the museum. We have noted how visitors do not engage with a number of the interactive media installations – a common finding in many museums and exploratoria around the world. Our analysis has attempted to show how an understanding of the physical setting, together with an understanding of visitor behaviours can allow us to understand why certain of the technological installations were problematic in terms of user acceptance and use. The kind of appliances that have been introduced are not suitable in supporting the users’ behaviour. In certain instances the kiosks interpose themselves between the visitors and the objects, preventing the visitors from maintaining their physical proximity to the exhibit. Approaching the computers means, rather, breaking a condition of flow (Csikszentmihalyi, 1990) and engagement they are experiencing during the visit. In other cases the computers are not interposed, but then they suffer from too distant a linkage with the actual exhibit, both physically and semantically, and users are unable to make the link between the artefacts and the installations.

This study shows how important it is that in the design process of SHAPE we incorporate important topics such as visitor studies, analysis of human interaction within public places, analysis of the physical space that accommodates the exhibit together with the objects on display, and the way they are perceived and experienced by the visitors. The process of technology exploration must also take into account these aspects. With regards to the SHAPE

Research Challenge 3 and specifically the Workpackages 2 and 3, we plan a series of participatory sessions with potential users and museum personnel, and field studies in order to develop a deep understanding of interaction in public places, in particular focusing on the way people behave and interact with the objects present within the physical enviroment. The entire consortium will collaborate in analysis of the outcomes to inform the design process both on the socio-scientific and technological side, and to ensure that the resulting artefacts and infrastructures we create will integrate seamlessly with the existing physical exhibits.

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Appendix: SHAPE Activity Listing In-Line Plans

At the First SHAPE Workshop at King's College, London, January 2001, the project's partners assembled a list of research activities which would engage them over the course of (at least) the first six months of the project. The SHAPE workplan emphasises the importance of 'in-line' planning. That is, the workplan itself is given detail by concerted planning which involves all researchers on the project. This kind of planning is closely associated in our workplan with activities of consolidation and reflection. That is, we plan alongside reflecting on and consolidating achievements to date. The intention of this approach to workplanning is to make the workplan 'collective property', involving all researchers in its interpretation and detailing. We do not regard workplanning as part of the management function of the project solely, as if members of the project's PMC would do the planning, while other researchers enact those plans. We also wish to support a dynamic and flexible approach to workplanning and project organisation, allowing us to be quickly reactive to developments in our own work or the general research context in which we operate.

This Appendix presents the project's in-line plans in schematic form. We individuate a list of activities and associate with each (at least) a principal partner, give an indication of the timing of the activity (in particular when the project at large can expect an outcome), and note the Workpackage(s) to which the activity is relevant. It is to be noted that the SHAPE project is organised around cycles of creative design and exploration alternating with reflection and consolidation. Out intention is to offer consortium members times of creative, speculative research in which to pursue insights and hunches, while also having key moments when the results of these periods are carefully reviewed. This Deliverable is written at the close of our start-up activities and at the beginning of our first phase of creative exploration. Accordingly, at the First SHAPE Workshop, partners were encouraged to err on the side of over-inclusion in the list of activities they intend to explore in the first six months of the project. Activities could be included of a speculative and schematic nature. It was not expected that all activities listed would be successful or, even, that their contents could be envisaged in advance. At this explorative stage, we are tolerant of the fact that the activities as listed below might not be all realised. What is, of course, required is that enough of them be realised so that the project is confident that its overall goals will be met. To ensure that, progress on these activities will be reviewed as part of the project's next Workshop/Plenary to be held in May 2001 in Nottingham. This will involve the revision of the listing and the creation of a new set of activities, which will see us through the production of Deliverables for review at the end of Year 1, as well as establishing a strong basis for the work devoted to the First Living Exhibition which is also to be initiated at about the same time.

Animated Spatial Mixing
KTH, Nottingham, Limerick
February Workshop, replan thereafter, partially reported in D4.1
WP 4 -> WP 1 (generic sound infrastructure)

MASSIVE Sound, MIDI interfaces, Distributed Mixing Concepts
KTH, Nottingham
February Workshop to initiate discussions
WP 4 -> WP 1 (generic sound infrastructure)

Technology Audit
General
Lead by Nottingham, All partners
End February

Initial Specification for Video Record Replay Tool Building on VR Record-Replay
Notts, King's
Month 6, document of tool
WP 1 and WP 2

Field Study
(Stockholm Technical Museum, Courthauld, V&A, Design Museum, Science Museum, and other science centres, interactive arts, inter alia)
King's
Month 6 internal report
WP 2

Field Study Workshop (Limerick, March)
All partners
Reported in D4.1
WP 4

Review on Research on Learning in Museums
Notts
End April
WP 2

Specialised Field Studies
(sharing viewing/tactile properties)
King's
Preliminary report month 6
WP 2

Installations: Rationales and Plans
King's
Short report month 6
WP 2

Exhibiting Anthropology
King's, All partners
Sorting out local context at science museum in 2 months, installation by month 6 in science museum, planning for more major work year 2
WP 1/2

Design Sensitivities
King's, Limerick
Initial reports as part of D4.1, more mature versions by end month 6
WP 2

Local Small Empirical Studies
Limerick
Initial report as part of D4.1, end month 6 fuller version
WP 2

Museum Linkage
(Hunt and Green's Mill)
Limerick and Nottingham, King's
TBD by end April
WP 3/2

Museum Field Studies
(Green's Mill)
Nottingham, King’s
Report due mid-June
WP2

Preliminary Design Work on a Mathematics Exhibit (Green's Mill)
Nottingham, KTH
Report due mid-July
Preparation for the second Living Exhibition

Museum Linkage
(Stockholm Museums)
KTH
TBD by end April
WP 3/2

Preliminary Design Work on an Exhibit based on GPS Technology and 'fragmented boundaries'
(Stockholm Technical Museum)
All partners
Report to be scheduled for the second half of Year 1
Preparation for the first Living Exhibition

Understanding the Museum Organisational Context
Limerick, KTH
Short report by end April
WP 2

Understanding Professions with an Interest in Public Spaces
Limerick, King's, Notts
TBD month 4 onwards, no documentation commitment at this stage
WP 3/2

Mixed Reality Rendering
KTH, Nottingham
Initial specification document with particular reference to MASSIVE integration, end May for first version, quick and dirty demonstration of components in February workshop and report in D4.1
WP2

ToneTable
KTH
KTH Workshop February, major component of D4.1
WP 4

Replaying Virtual into Physical
Notts, All partners
Notts Workshop, May, initial report as part of D4.1
WP 1/4

Projection Surfaces
Notts
Report by end April
WP 1

Interaction Surfaces
KTH
Report by end April
WP 1