From the Disappearing Computer to Living Exhibitions: Shaping Interactivity in Museum Settings

John Bowers[1,2], Liam Bannon[3], Mike Fraser[4], Jon Hindmarsh[5], Steve Benford[6], Christian Heath[5], Gustav Taxén[1], and Luigina Ciolfi[3]

[1] Centre for User-Oriented IT-Design, Royal Institute of Technology, Stockholm, Sweden
[2] School of Music, University of East Anglia, Norwich, UK
[3] Interaction Design Centre, University of Limerick, Ireland
[4] Department of Computer Science, University of Bristol, UK
[5] Work Interaction and Technology Research Group, Department of Management, King's College London, UK
[6] Mixed Reality Laboratory, University of Nottingham, UK

1 Introduction

While considerable technical ingenuity is being devoted to making the computer "disappear", comparatively few research endeavours have concertedly explored the issues which arise when innovative artefacts are deployed in public settings. Innovations in "mixed reality", "augmented reality" and "ubiquitous computing" tend to be confined to demonstrations, circumscribed trials or other controlled settings. However, a number of projects have begun to devote themselves to putting such technologies into the hands of the public and reflecting on the design and development issues that are encountered as a result. In particular, the SHAPE project was concerned with deploying innovative technologies in public settings, most notably museums. Over the course of our research, we developed an orientation to design which combines social scientific study, close collaboration with museum personnel and visitors, and a characteristic approach for technology deployment. In this chapter, we describe this orientation, exemplify it through accounts of the exhibitions the project has built at a number of museums in different European countries, and assess its broader implications for research on human-computer interaction, ubiquitous computing, and allied concerns.

Many researchers, following Weiser (1993), suggest that computers are more and more mass-market products with the potential of becoming part of the fabric of everyday life, rather than tools requiring expert skill, used in laboratories or high-tech offices. Our encounters with information technology are less exceptional, more everyday, and increasingly domestic, leisure-related and experienced in public places. Famously, Weiser contrasted this scenario with that typically explored in research on "virtual reality" (VR). While VR envisages future computing scenarios where users are *embodied* within a computer generated environment, research on ubiquitous computing is more concerned with *embedded* computing functionality in a multiplicity of artefacts. For Weiser, "ubicomp" is "VR turned inside out". However, there have been various attempts to articulate combined positions where the hybridisation of the physical and the digital is the research concern. "Augmented reality", "augmented virtuality" and "mixed reality" are all attempts to articulate new opportunities for tech-

N. Streitz, A. Kameas, and I. Mavrommati (Eds.): The Disappearing Computer, LNCS 4500, pp. 30–49, 2007.

nological innovation along these lines. Demonstrations of the interplay of physical and digital have been offered in domains such as tele-medicine (Milgram and Colquhoun 1999), education (Rogers et al. 2003), entertainment (Stapleton et al. 2002) and the arts (Bell et al. 2006).

A number of researchers have begun to look at museum settings as a potentially relevant application domain for mixed reality technology while also attempting to help create experiences for the public of genuine cultural worth (Brown et al. 2003; Caulton 1998; Fraser et al. 2003; Grinter et al. 2002; Schnädelbach et al. 2002). The museum setting seems to bring together a number of features which make it most appropriate for study. First, for some time, museums have embraced the use of interactive exhibits alongside more traditional methods of display of the physical objects which make up the museum's collection. Digital solutions have been offered to such well-known curatorial problems as how to make publicly available objects otherwise held in storage or how to bring alive what is known about the use or history of an object which the exhibition of the "mute" object alone does not make possible. In turn, a number of equally well-known problems with "interactives" have emerged. Museum staff express concerns that digital artefacts can detract from a visitor's imaginative appreciation of the actual physical objects (Caulton 1998; Jackson et al. 2002) in much the same way as extensive textual labelling is often held to do. Further, multimedia museum presentations are most commonly built as single-user applications leading to concerns that engagement with them can sometimes disrupt the sociality of the museum visit (vom Lehn et al. 2001). Finally, digital solutions can be controversial if they seem to replace or "de-skill" the role of museum helpers, interpreters or docents (as they are variously called). In all these respects, museums offer us a microcosm of fundamental issues in technology design and deployment, allowing us to address naturally what might otherwise seem abstract matters such as tradition and innovation, skill and automation, the digital and the physical, the social and the individual, and so on.

Research in ubiquitous computing anticipates the mass proliferation of interaction devices and information displays. However, much research is concerned with investigating individual innovative computerized devices, with concomitant reduced concern for how a multiplicity of devices might concertedly combine to fashion a coherent experience. In contrast, SHAPE took construction and management of an "assembly of artefacts" as a primary research topic. An assembly might consist in multiple projections, each presenting a different kind of information, a multi-channel and multi-speaker sound system, a family of manipulable objects used for interactive purposes, a variety of communication media, and so forth. How can such an assembly be organised to fashion a coherent thematic experience for its users? Museums, exploratoria and galleries are relevant areas to study with respect to how artefacts can be assembled, as well as promising domains for evaluating designed solutions. The practical condition many museums find themselves in is one of multiple co-existing displays and presentation technologies of varying age, rationale, design aesthetic and material manifestation. Displays differ in terms of the kinds of activity they support, personalisation, physical scale, cost, portability, commodity or bespoke, and many other factors. This diversity makes museums and related institutions an appropriate case study in managing and integrating assemblies of diverse displays and devices, as well as being a setting in need of genuine practical solutions. The exhibitions developed and in-

stalled in the SHAPE project have given us useful information and feedback on the issues involved in crafting scenarios and creating narratives that "hold in" the complexities of multiple artefact assemblies.

2 Studying and Designing with Museums

While there exist many exciting design ideas for embedded devices, there exists much less appraisal of prototypes in genuine use and very little user-study to closely motivate (from the start) how embedded computational artefacts should be developed. A common strategy is to pursue clearly articulated and appealing design concepts, motivating them by theory, by market considerations, or designer-intuition. In common with many creative design traditions, the design ideas tend to stop with their demonstration – a more thoroughgoing reflection upon a designed artefact deployed in a real-world context and encountered by people as part of their everyday lives is somewhat rare in the literature (Gaver et al. 2004, is perhaps an exception to this). While such "design-led" activities are important work, we felt it necessary to complement them with more extensive practical engagement with museum personnel and, where possible, visitors.

Our approach in addressing this challenge was to combine social scientific methods of empirical research (e.g. field studies and interaction analysis) with techniques for facilitating the development of technical systems drawn from the "Scandinavian" participatory design tradition (cf. Greenbaum and Kyng 1991) including envisionment exercises, future workshops, cooperative and low-tech prototyping, and scenario-based design.

2.1 Social Scientific Study

During the lifetime of the project, SHAPE conducted numerous field studies in a range of museums and galleries in several different EU member states. Amongst others sites, studies were undertaken at: Technorama, Technical Museum (Stockholm), King John's Castle (Limerick), Limerick City Museum, the Hunt Museum (Limerick), Castle Museum (Nottingham), The Science Museum (London), @Bristol Science Centre (Bristol), The National Portrait Gallery (London), The Victoria and Albert Museum (V & A, London), The Natural History Museum (London), The Serpentine Gallery (London) and The Transport Museum (London). Data collection was designed to enable us to compare and contrast action and interaction in different types of exhibition space, involving different types of exhibits in different configurations, ranging from "aesthetic" to "applied", from interactive to non-interactive, and involving different types of visitor and visiting arrangement. These field studies included periods of participant observation in which researchers visited museums, used exhibits and information technologies, explored exhibitions and observed people navigating and exploring the museum space.

In many cases this observational research was augmented by the collection of photographic images and, more importantly for analytic purposes, video materials of visitor behaviour. Video recording tended to focus on single exhibits, such as the cabinets of curiosities in the Hunt Museum, which offered people the possibility of closely ob-

serving museum objects contained within open drawers in a large cabinet display, or the jumping skeleton in @Bristol, an augmented physical skeletal model allowing participants to interactively explore the connections between different areas of the brain and the limbs they control. However, we were also been able to record hands-on workshops at the Hunt Museum, where groups of visitors are encouraged to feel and manipulate artefacts from the collection, in the presence of a museum docent. Furthermore, we have recordings of sessions at the V & A, where visitors bring artefacts in to have them assessed by curatorial staff. In addition, we conducted informal interviews with museum education officers, curators, content, exhibit and exhibition designers.

Analysis of this diverse and voluminous corpus of empirical data enabled us to address a number of issues. Let us highlight two in particular as these have fundamentally influenced the form that SHAPE's design work in museums has taken: interactivity and assembly.

2.2 Interactivity

"Interactivity" in the design of exhibits in museums and galleries is a very fashionable concern. This notion is key to the proliferation of interactive exhibit technologies and interpretative technologies in the field. However, we argue that "the myth of the individual user" pervades the design of technologies in museums and galleries often at the cost of supporting or facilitating interaction and co-participation. Our observational studies have revealed the significance of co-participation and collaboration to the museum experience and the ways in which the navigation of galleries, the discovery of exhibits, and the conclusions that people draw arise in and through social interaction – interaction not only with those you are with, but with museum guides and docents, and those who just happen to be in the same space (Ciolfi and Bannon 2003; Heath and vom Lehn 2004; vom Lehn et al. 2001). The activities of those others can influence which exhibits an individual or group approach; what they look at; how they touch, manipulate or otherwise interact with the exhibit and so forth. We have also studied some of the issues and problems that arise with and around conventional computer based "interactives" within museums and galleries and in particular the ways in which they delimit interaction with the system, transform co-participants into audiences, fracture the relationship between exhibits, and disregard objects and collections. Accordingly, in our own design work, we sought to make artefacts which were notably "open" for collaborative use (e.g. through the use of an interactive surface that several people could gather around). Furthermore, in considering the disposition of several such artefacts in a whole exhibition layout, we sought to facilitate the degree to which visitors could pick up on the conduct of others and reason on its basis (e.g. by developing artefacts which were interacted with by means of large-scale, and hence noticeable, gestures, and by giving particular artefacts a particular function).

2.3 Assembly

Reflection on our corpus of data encouraged us to expand our sense of "interactivity" to take in many of the practical activities of visitors which are commonly ignored in the design of exhibits – activities which are essentially social, collaborative and con-

tingent to the emerging character of the visit. This naturally led us to an equally expanded sense for "assembly". Our research increasingly manifested an interest in the social and interactional practices of "assembly"; that is, how participants themselves organise and create an assembly of artefacts. Accordingly, the technical work in SHAPE became pre-occupied with the production of assemblies of interconnected technical artefacts, whilst recognising the need to design to support everyday practices of assembling. That is, in SHAPE, "assembly" not merely denotes a set of interlinked artefacts, it also points to a characteristic feature of how people conduct themselves in museum settings. People actively assemble for themselves and display to others a sense of an exhibit which interconnects different aspects of their visit, including comparisons made with other exhibits or between co-visitors' different perceptions. Thus, in our own design work, we were aware of the need to provide a variety of supports for the thematic framing and integration of visitors' activities, while also enabling and encouraging visitors to flexibly engage with our interactive artefacts and formulate their own understandings of exhibition content.

2.4 Cooperative Design in Museums: Living Exhibitions

In addition to conducting social scientific studies with a broad base of museums and allied institutions, we worked very closely with three museums in the production of new exhibits. At Stockholm's Technical Museum, we developed an installation known as *The Well of Inventions* which presents some fundamental mechanical concepts through air and fluid simulations and interactive sound. *The Well of Inventions* is based around a table-top projection and an eight channel sound system allowing multiple participants to engage with the piece. The installation was developed through various iterations. First, a "quick and dirty" prototype demonstration of a number of graphical simulation techniques, sound synthesis and diffusion methods, and interaction principles was developed. This was proposed as providing technical "design responses" to some of the early themes emerging from the social scientific work in SHAPE. Following this, the demonstration was overhauled to more carefully engage with content and themes at the Stockholm Technical Museum, to be more physically robust as an unsupervised public exhibit, and to be of higher quality graphically and sonically. To deal with all these issues, we engaged in extensive collaboration with personnel at the Technical Museum through cooperative design workshops and other forms of collaboration (see Taxén et al. 2004 for details).

The Well of Inventions is a single exhibit. Our subsequent work sought to build on its emphasis for prototyping, iteration and collaboration with museum personnel but to more fully exemplify our concern for constructing assemblies of multiple interactive artefacts in a coherent exhibition. First at Nottingham Castle and then at the Hunt Museum in Limerick, we sought to collaborate with museum personnel at an even earlier stage of design to engage with the existing content and themes of the museums and, in particular, to explore ways in which physical-digital hybrid technology might help address genuine curatorial problems.

The design process that we evolved over the course of these exhibitions became increasingly dependent on the use of "scenarios". Having immersed ourselves in the museum setting, we engaged in initial brainstorming sessions and evolved a number of initial ideas of what the exhibition might entail. Lists of key themes and outline

sketches were produced at this stage. These sessions would involve SHAPE personnel as well as museum staff. Initial ideas were developed further in a second round of meetings, where early concepts were fleshed out and discussed, and some rejected. A third set of meetings were held where detailed storyboards of the exhibition concept and realization were produced, walked through, and refined with a wide circle of interested people, not only those in the SHAPE research group. This included, both in the UK and Ireland, working with local schools who typically visit these museums as part of their school education programmes.

Additionally, and again in both cases, we conducted many of our design activities on site at the museum in question. For example, we held cooperative design workshops with schoolchildren and teachers at Nottingham Castle. Our exhibition at the Hunt Museum allowed access to visitors and museum personnel several days before the formal opening, enabling them to comment on the exhibition and in some cases suggest some alterations that we were able to implement, even as it was about to go public.

3 Design Cases: The SHAPE Living Exhibitions

In earlier sections, we have provided some background to the issues of concern to the SHAPE team in the development of novel interactive environments for use in museum settings. Our views on mixed reality technologies, on the ways in which visitors interact with objects, settings and other visitors and guides, on the need for understanding the nature of museums, have all been outlined. Here, we wish to examine in some detail two of our major pieces of work within the SHAPE project, exhibitions designed in close co-operation with the museums in question, in order to give a flavour of the kinds of design decisions that were made, and the experiences visitors had when encountering these exhibits.

3.1 The First Living Exhibition: *Exploring Digital History* at Nottingham Castle, UK

Nottingham Castle was first built in 1067. Over the past millennium, various significant historical events have taken place at different locations around the site. Following the end of the English Civil War, the year 1651 marked the destruction of the castle. Around 20 years later, the Duke of Newcastle built a Renaissance-like "Ducal Palace" on the site of the castle remains. Notably, what is left on the site today bears little relation to the more complex medieval castle. In order to give visitors some sense of the castle, the on-site museum employs various mechanisms and technologies such as slide shows, medieval artefacts with associated text, interactive kiosks, signposts, guides, brochures and textbooks. Nonetheless, museum staff are constantly looking for further ways of helping visitors to understand the castle as it used to be, and the part it played in key historical events.

We designed the exhibition over the course of several months. The research process included consulting museum personnel over exhibit content and requirements. As many visitors are families or groups with children, we also conducted a series of de-

sign workshops and staged preliminary trials involving a head teacher and a class of 10 year-old school children.

As a result of these preliminary workshops and discussions, the following exhibition design emerged. Visitors were invited to take part in a "history hunt". On arrival on site, they were given a pack of paper clues and told they were on the trail of a historical character that features in a particular period of the castle's history (either Richard I or Edward III). The visitors used their pack to find clues at various locations around the castle grounds and piece together their character's story. The overall experience was structured as follows:

- **Arrive at the gazebo.** Visitors receive an explanation of their task and pick up a pack of clues to guide their hunt.
- **Search the grounds.** The paper clues guide the visitors to places which feature in the story of their character. These places often only minimally resemble the location's appearance in history. For example, the Castle Green, an open area of grass, was the location for a large castle building called the Great Hall. In these locations they make drawings as instructed by the clue.
- **Back at the gazebo.** RFID tags are attached to the paper clues so that each piece of paper is categorised with a character and a location.
- **At the gatehouse.** The visitors encounter two different displays which they can interact with using their tagged clues. We describe these in detail shortly. The first display is the *StoryTent* which reveals one scene of the story, showing for each clue the event that took place at the location. The second display is the virtual *Sandpit*, at which visitors can dig for pictures that are related to either the character or place for each of their clues.
- **Depart.** Visitors take their paper clues away with them.

3.2 Revealing Scenes in the Storytent

The Storytent occupies one side of the castle gatehouse. It consists of a tarpaulin construction with either side acting as a projection screen (see Green et al. 2002). The projections can be seen from both inside and outside the tent. This provides an intimate projected space inside the tent, and a larger, public space outside.

The tent contains an interaction device, the Turntable, which combines an RFID tag reader and a potentiometer. The reader allows tagged paper to be identified by the tent, whilst the potentiometer allows rotational input around the vertical axis. A UV lamp is positioned over the top section of the Turntable. When a paper clue is placed on top of the Turntable, "invisible writing" is revealed, which is marked in UV ink on the paper. The UV writing describes the historical event related to the particular clue. The tag reader and potentiometer are both connected to a PC running a virtual model of the medieval castle, which is projected onto both sides of the tent. Rotating the top of the Turntable rotates the view of the castle model.

Seven different tag types (four for Richard I and three for Edward III) trigger seven different scenes within the tent. Placing a tagged paper clue onto the Turntable, then, causes a number of simultaneous occurrences.

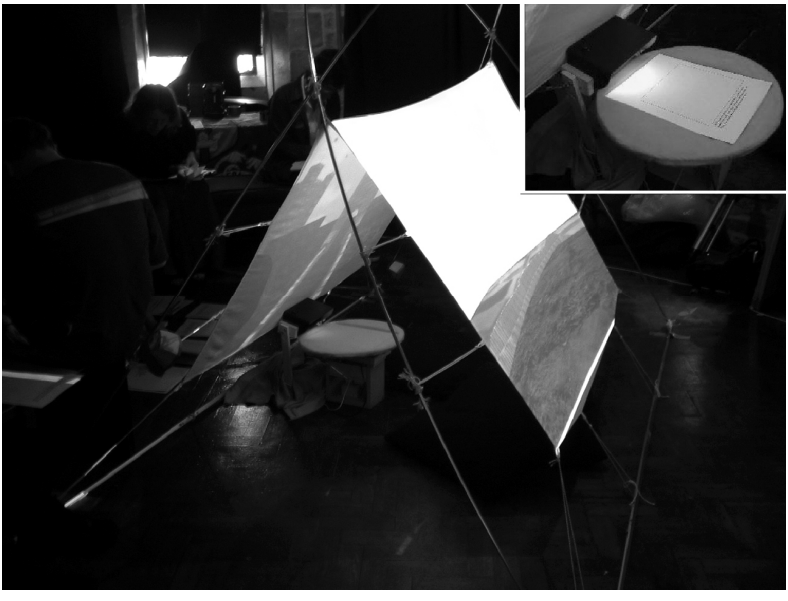

Fig. 1. The Storytent with close-up of the Turntable interaction device with a clue placed on top (inset)

- The invisible writing on the clue is revealed;
- The tag reader detects the tag and moves the 3D viewpoint projected on the tent to the relevant clue location in the model;
- Sounds associated with the historical event for the clue are played;
- An image selected from the information space is displayed on the public side of the tent.

3.3 Digging for Images in the Sandpit

The virtual Sandpit was positioned in the other side of the gatehouse. The Sandpit was a top-down floor projection enabling groups to gather round it. The Sandpit is a graphical simulation of a volume of sand. Visitors can dig in the sand using one or two video-tracked torches to control animated cursors on the floor projection. Pictures of the castle site, portraits of key historical figures, scanned visitor drawings and other images are "buried" in the sand. When an image is revealed, by "digging" with the torches, it spins up to the top of the projection and then disappears. Nottingham Castle is built atop a sandstone cliff and the metaphor of impressions of the castle's history enduring in the sand seemed suggestive.

There is an RFID tag reader placed under a sandbox on a pedestal next to the Sandpit. Placing a tagged clue onto the sandbox selects the set of images buried in the sand. The images are related either to the character or the place for the particular clue. The Sandpit also includes some sound for ambience and feedback that indicates the tagged clue has been recognised.

Fig. 2. The Sandpit with close-up of the Sandbox device with a clue placed on top (inset)

3.4 Reflections on *Exploring Digital History* at Nottingham Castle, UK

The actual exhibition was "live" for three and a half days in July 2002. In that time, more than 200 visitors experienced the exhibition. Visitors ranged from individuals to groups of seven or eight; and from very young children to elderly citizens. Some participants completed all the clues, some completed only one or two. Generally, visitors found the experience to be extremely engaging and educationally relevant. In terms of the dwell-time metrics which are commonly used to evaluate exhibits, our Storytent and Sandpit were spectacularly "attractive". However, a number of important issues emerged on closer examination. These included:

- The coherence of the experience was critically dependent upon the "scaffolding" provided by the research team itself in explaining to people what was going on, how to use the artefacts, and what the historical events were to which the clues referred.
- The assembly of artefacts enabled people to make a variety of connections as they assembled a sense of the individual clues, of the relationships between displays, and between displays and their activities exploring the castle grounds. However, people rarely combined information across clues to develop an integrated sense of particular historical happenings. The "big picture" did not seem to spontaneously emerge.
- The design of some aspects of our artefacts seemed a little arbitrary. Why exactly use a torch to uncover images from a virtual sandpit? Relatedly, the motivation for some of the exhibition's content seemed a bit unclear. What exactly (e.g. from a pedagogical standpoint) was a visitor supposed to learn of the history of the site through uncovering images or navigating a 3D model?

In sum, we learned a number of things from designing, building and evaluating this exhibition. The sheer scale of the effort involved in marshalling resources, both human and technical, and ensuring that the exhibits worked for the duration of the exhibition was considerable. This is noteworthy in the light of the usual kinds of experimentation teams perform in research projects, where large public demonstrations are rarely attempted. Further, while effort was expended on creating a thematic structure for the visitors, in the sense of the overall conception of the hunt for clues, some features of the design were overly determined by the available technologies that could be deployed.

3.5 The Second Living Exhibition

In our second living exhibition, we sought to address some of these difficulties through having a stronger identity for the overall unifying activity and a more careful selection of appropriate content to be displayed to visitors. One idea that appealed from the first exhibition was the attempt to allow the visitor to add content of their own to the exhibition in the form of a drawing. In *Re-Tracing the Past*, we decided to more thoroughly support visitor-supplied content. As a result we sought to create and assemble a corpus of material, drawings, writings, recordings or thoughts from the visitors about the Hunt collection in order to make our exhibition a truly "living" one, with elements of the exhibition being created daily during the life of the exhibition.

We were also motivated by our strong interest in people's experience of place, and sought to ensure that our augmented space would be sensitive to the specifics of the Museum space and its history and context (Ciolfi and Bannon 2005). In addition, we reflected on the traditional role of docents and interpreters and sought to incorporate them actively in facilitating people's visits. As before, we worked closely with the personnel from the host institution, the Hunt Museum, in formulating the overall design and in working through a number of specific scenarios.

The SHAPE Second Living Exhibition, *Re-Tracing the Past*, was hosted by the Hunt Museum in Limerick, Ireland and remained open to the public from the 9th to the 19th of June 2003. We worked with the museum curators and docents to design an exhibition that supported exploration of the issues related to the interpretation of the museum objects. Visitors were challenged to propose their own interpretation of one or more mysterious objects through interaction with different exhibits. Each element of the exhibition revealed particular evidence about the object that contributed to the visitor's own interpretation. The theme of the exhibition thus had the goal of making people reflect on the way the museum's classification of objects is not something given and unchangeable, but rather the product of investigation, conjectures and discussions among museum docents, art experts and curators. This rationale would also give the visitors the chance to leave a unique trace in the exhibition, thanks to the possibility of recording their opinion about an object and leave it for other visitors to interact with further.

A gallery on the lower ground floor of the museum was reconfigured into two connected spaces for the exhibition. The first space, the Study Room, enabled visitors to explore the backgrounds of the mysterious objects by revealing several kinds of evidence that can be used to interpret them. The second space, the Room of Opinion, contained accurate physical reproductions of the objects, allowing visitors to touch and manipulate the objects, as well as providing a recording station where visitors could leave an opinion on the objects' possible use, contributing new ideas for future visitors.

Fig. 3. Overview of the Living Exhibition space in the Hunt Museum

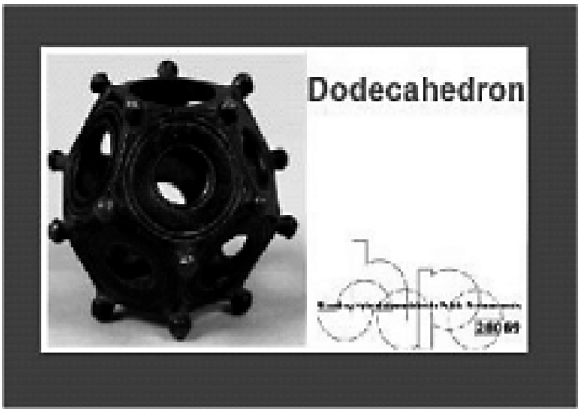

Fig. 4. A laminated keycard for the Dodecahedron object

Fig. 5. The Combination Machine

Groups were met at the entrance by a guide who monitored and supported the visit. Visitors could choose one or more objects to investigate. Each mysterious object had a corresponding keycard. The keycard was a small colour-printed laminated card showing the picture and the original museum label for the object. Each keycard also contained a Radio Frequency Identification (RFID) tag. The embedded tag allowed visitors to control each exhibit, primarily to activate or de-activate each installation and to explore the associated information.

There were four exhibits contained within the Study Room. Each was designed to provide information that visitors could progressively discover, without having to follow a prescribed sequence of actions. These were the Combination Machine, Virtual Touch Machine, Interactive Desk and the Radio.

The Combination Machine (Figure 5). When a card was placed inside the trunk, the visitors were provided some information about the context where the object was found (a burial, a religious site, etc.) If two cards were placed into the trunk together, some fictional and some possible connections between objects were suggested, to prime visitors' imagination about objects and encourage creativity and playfulness when recording their own opinions in the Room of Opinion. This installation was designed to encourage visitors to think about the objects in a playful and creative way using the information gathered at other stations, as a basis for developing their own interpretation of an object.

The Virtual Touch Machine (Figure 6). This installation focused on the material qualities and details of the objects. The Virtual Touch Machine enabled visitors to examine virtual models of the objects in fine detail – zooming in and zooming out to examine traces of the physical workmanship involved in the production of the objects and the patterns on the objects (the raised segments and grooves on the carved stone ball, for example). A "magic wand" was an integral part of the installation and, by handling it and turning it, visitors could manipulate the object model on the screen and reveal details that would otherwise be invisible. The machine also allowed visitors to explore the material qualities of the objects, as the wand allows users to "tap" the 3D objects on the screen in order to hear the sound they would produce if tapped in reality.

The Interactive Desk (Figure 7). The desk enabled visitors to trace the provenance of the objects. Placing a card on specific locations on an overlaid map on the desk displayed information related to the objects' geographical origin and their relationships with other parts of Europe.

The Radio (Figure 8). The radio enabled visitors to listen to the collected opinions, theories and stories of other visitors about the objects. By changing channels on the radio, visitors could browse the myriad of opinions on each object. By tuning within a band, individual opinions were progressively revealed. This installation helped visitors shape their opinions, giving them an opportunity to compare their evolving ideas on the origin of the objects with those left by others. Listening to other people's stories also motivated them and reinforced their involvement in the activity prior to their visit to the Room of Opinion. After recording their opinion in the other room, most visitors returned to the radio installation to listen again to their own and other visitor opinions.

Fig. 6. The Virtual Touch Machine

Fig. 7. The Interactive Desk

Fig. 8. The Radio

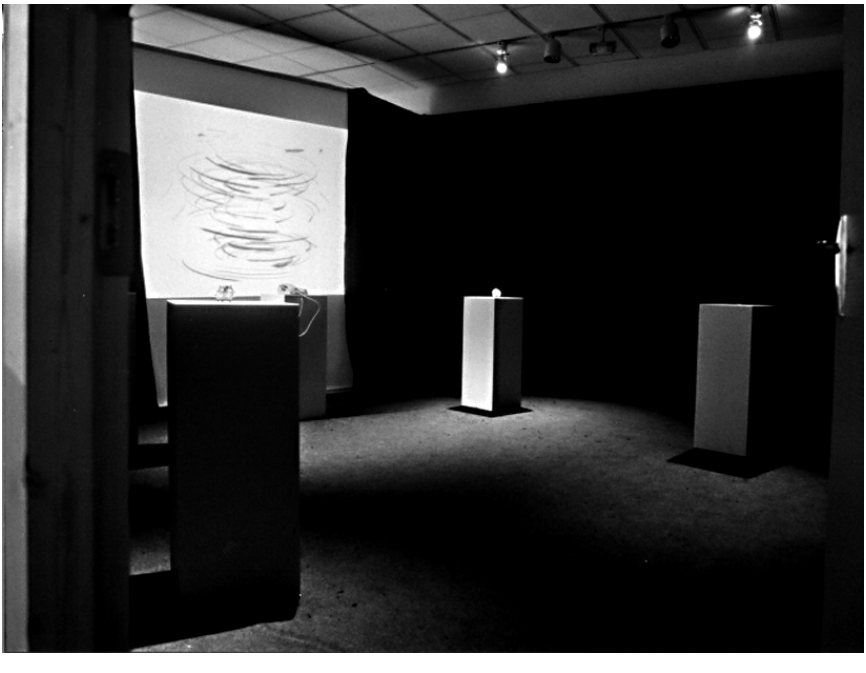

Fig. 9. Room of Opinion with plinths and Interactive Painting

Based on their explorations within the Study Room, visitors could then express their own opinions of the objects in the Room of Opinion. Visitors were given a chance to examine exact physical replicas of the objects, each placed on a plinth, before recording their opinion and leaving their own mark on the exhibition. The room contained an ever changing soundscape of voices, some clear, some murmuring, offering fragments and occasionally whole opinions regarding the objects. This soundscape, drawing on visitors' recorded opinions, was diffused through a four channel sound system with a speaker embedded in each plinth.

The visitors could record their opinion by dropping their keycard in a slot speaking into a phone. The recording subsequently became part of the collection of opinions available on the Radio in the Study Room. A new element was also added to the Interactive Painting, a visualisation back-projected into the room to represent the collection of visitors' opinions. After recording an opinion, a visitor could see a graphical brush stroke become part of the painting, contributing to the swirling pool of opinions. The painting was designed to make visitors aware that their contribution had a role in shaping the exhibition and it was now part of the collection.

In attempting to design for social interaction, we ensured that all of our interactives would have an "open" interface that would encourage more than one person to be around the artefact, and allow for people to collaboratively interact, or at the very least, view the interaction. Thus there are no multimedia computer screens and PC keyboards for individual use in the exhibit. Most of the visitors to the space were couples, groups of students, or family groups, and the openness of the exhibits encouraged interesting social interaction around the exhibits. In addition, we wished to support the idea of visitor's interacting with the opinions of others – not just those who might be visiting as part of the same social group. Our concern to record and make available visitor opinions to other visitors is, then, a way of extending the forms of inter-visitor interaction which museums normally support.

Over 900 people visited the exhibition with a similar highly mixed demographic to that observed at Nottingham Castle. As with the First Living Exhibition, we collected an extensive corpus of material to facilitate evaluation of the exhibition. The exhibition was highly valued by museum personnel and visitors for its aesthetic and design quality. Great attention was paid to creating environments of strong aesthetic character and, between the two rooms, contrast. This was strongly appreciated as complementary to the task of exploring mysterious objects. Indeed, we believe that one of the most important features of the Second Living Exhibition was the very powerful effect the designed space had on visitors, in that the space provided a warm, welcoming, yet intriguing environment that encouraged exploration, discussion and interaction, both with artefacts and with other people in the space. Thus, not only does the space literally embody the Disappearing Computer philosophy, in that no computers or keyboards appear anywhere, but, more importantly, it engenders a range of visitor activities such as handling, testing, exploring, discussing, listening, speaking, et cetera. We believe the fact that visitors are not only encouraged to explore and interact with objects, but even more importantly, are asked to reflect, question, and even articulate an opinion on the objects is pedagogically highly relevant (Ferris et al. 2004; Hall and Bannon 2006). Not only are these experiences and behaviours intrinsically valuable, but at another level, they hint to visitors that Museums do not always have "all the answers" and are not simply repositories of undisputable facts. Finally, visitor opinions

are not simply requested, but are visibly and audibly encoded and made a part of the experience, and even more importantly, are collected so as to form a continuous, cumulative thread of visitor opinion, thus providing a corpus that can be accessed by other visitors and museum docents during the lifetime of the exhibit itself, as well as being of interest as a permanent record of visitor interest and opinion.

4 Discussion

In the SHAPE project we had very wide ranging concerns from the cultural significance of museums through to the details of exhibition design, from technical issues in mixed reality and ubiquitous computing to the details of interaction design in practical contexts. Let us finish this chapter by discussing a little further just two aspects of our work: the approach to design that we have begun to develop and our orientation to technical issues in contemporary computing research.

4.1 Design

Over the course of our two living exhibitions and in the production of our long term exhibit *The Well of Inventions*, the SHAPE project has evolved a characteristic way of doing design in museum settings. This has involved the varied contribution of four related approaches.

- **Social scientific studies.** These have had manifold influences upon our design work from causing us to reformulate the concept of "interactivity" in museum settings through to specific "groundings" for design details. Essential to the SHAPE approach has been the recognition of the social interactional nature of people's conduct in museum settings at the "exhibit face". We have consistently emphasized the varied ways in which people participate as they and others interact with exhibits and attempted to develop exhibits of our own which are "open" to different forms of engagement and participation. To develop further the impacts of such studies on museum design, we have formulated a set of *design sensitivities* and methods for working with *low-tech prototypes* (for further details, see SHAPE 2002, 2003b).
- **Cooperative, participatory design.** We have extensively consulted with museum personnel to enable various features of our exhibitions to be co-designed with them. Our two living exhibitions contain numerous examples of design details which emerged in collaboration with museum personnel. In addition, where possible we have worked with groups of people who can be taken as exemplary visitors. Most notable is our concern to involve children and their teachers in the First Living Exhibition and the classroom activities associated with the Second Living Exhibition (Hall and Bannon 2005, 2006). Taxén et al. (2004), and SHAPE (2003a) also note how we worked with museum personnel to ensure the durability of an exhibit intended to run unsupervised.
- **Scenario-based design.** Especially in the conduct of the Second Living Exhibition, we found it useful to organise design ideas around scenarios where visitor-interaction with an artefact was envisioned (Ferris et al. 2004). Scenarios

also proved valuable in communicating the current state of design with museum personnel without getting bogged down in (potentially changeable) technical details.

- **Constructional workshops.** While we have not had space to discuss these in detail, we kick started the project with a number of constructional workshops. These were project-wide internal workshops where we committed to the construction of functional prototype within a few days' work. This activity proved valuable in demonstrating our competence to potential external collaborators. It also enabled us to explore design concepts which were specifically tailored to provide a response to early social scientific findings (Hall and Bannon 2005). Taxén et al. (2004) describe how some of our earliest demonstration work triggered more extended collaborations with museum personnel and formed the basis for *The Well of Inventions*.

While we have built single exhibits, our most characteristic contributions to museum design have been through our multi-artefact "living exhibitions" at Nottingham and Limerick. Our exhibitions have been "living" in four notable senses.

- **Co-design.** The exhibitions have been co-designed at least in part through living collaborative relations with visitors and museum personnel.
- **Working in public.** Both exhibitions have involved a concerted presence of the SHAPE team on-site. We have participated in numerous "tie-in" activities in relationship to the exhibitions. The exhibits have "lived" through our continued engagement with them.
- **Evolving design.** From time to time, this has involved modifying the design of the exhibition in response to public feedback, even after the exhibition has opened. In both of our main exhibitions, we were on-site (yet available to the public) before the official opening. During this time, visitors were welcome to inspect the work in progress and make design suggestions. The official opening indicated that our designs were intended to be more robust, to be sure, however designs could still be modified.
- **Visitor-supplied content.** Most notably at the Hunt Museum, we developed exhibitions where visitors supply at least some of the content of the exhibition. This is a further sense in which the exhibition can be said to be "living", in that the exhibition itself is changing and growing over the lifetime of the installation.

4.2 Assembling Technologies: Ubiquitous Computing Revisited

We discussed at the outset of this chapter how we were concerned with studying not merely single artefacts but *assemblies* of them – multiple artefacts working in concert. We also argued that museums are ideal settings for pursuing this interest. Our experience in such settings has suggested to us an effective "design schema" for assembling diverse artefacts. Let us posit the following five **Assembly Principles**.

1. Coherence is given to the experience by defining a *unifying overall activity* in which the visitors are to be engaged. At Nottingham Castle, this took the form of a history hunt, while, at the Hunt Museum, visitors identified mysterious objects.
2. An underlying *common information space* is designed which contains a variety of interrelated items that can be revealed as the activity progresses. At Nottingham Castle, we formulated a "time-space matrix" which linked historical events to different parts of the site. Images and views on a virtual model et cetera were linked to cells in this matrix. At the Hunt Museum, different kinds of information about the objects were revealed (e.g. provenance, materials) and a database of opinion was incrementally added to over the lifetime of the exhibition.
3. An *assembly of interactive displays* is used with each display supporting a particular part of the overall activity and revealing a sub-set of the common information space. At Nottingham, there were two artefacts: the Storytent and the Sandpit. At the Hunt Museum, there were two different rooms each containing multiple displays, both visual and sonic.
4. To promote the coherence of the experience *common or related interaction techniques* are provided across different displays. Throughout, we rejected standard desktop multimedia interaction techniques and devices in favour of working with everyday artefacts. Where possible these artefacts were idiomatic for the overall design aesthetic. For example, in the Study Room at the Hunt Museum, all the interactives are based upon traditional artefacts one might expect to find in a scholar's study.
5. To further enhance the overall coherence of the visitor experience, a *portable artefact* is provided to enable visitors to accumulate a record of their visit and/or support their identification as they move around the site. At Nottingham Castle, we worked with tagged paper to "glue" the experience together. At the Hunt Museum, cards with an embedded RFID tag served the same purpose.

Having identified these technical features of our design work, we are in a position to identify what is distinctive in our approach to contemporary computing research. To focus this, let us consider what might be meant by "ubiquitous computing". In common with much work under this rubric, we are concerned to make computing in its traditional manifestations "disappear" into a specifically designed environment. We design hybrid artefacts which typically embed computing and support interaction in and around physical arrangements which do not follow the traditional appearance of a desktop computer. However, our "design schema" makes clear that we can offer a particular sense for "ubiquitous computing". For us ubiquitous computing is *multiply-located computing.* Computing and interaction with computing resources takes place at specific loci with purpose-specific things happening at a particular locus. Computing is made "ubiquitous" by the linkage of these specific loci. This is a very different design image from those which propose an "anything-anyplace-anytime" ubiquity. In our environments, special things are done in special places and, if the sequencing of the experience calls for it, at special times (e.g. the Study Room is worked in before the Room of Opinion, the castle site is explored before one encounters interactives in the gatehouse).

Providing *differentiated* computing environments has been very important for us as it enables, not just a differentiation of forms of participation and engagement with content, but enables different forms of participation to be "readable" by others observing. For example, in the Hunt Museum, it would be possible for a visitor to draw inferences about the conduct of others such as "if you are over there at the desk, you must be finding out about the provenance of something". A ubiquitous computing environment which did not embody the differentiations of activity and purpose that we have designed for would not support such situated inferencing about the conduct of others. To respect and enhance the sociality of the visit, we offer our perspective on ubicomp: ubicomp as multiply-located computing.

We also differ from another image of ubiquitous computing. Some researchers see ubicomp as entailing a "fading away" of devices so that computation is somehow "ambient". Again our image is very different. We see computing as located and visible as such (even if it does not appear in the form of the traditional desktop machine). We have separated digital presentations from encounters with physical museum objects. At the Hunt Museum, one encountered the mysterious objects in a separate room from digitally presented information about them – and this for principled reasons: to retain the specificity of character of each form of experience. We believe that this approach is to be commended for the deployment of advanced interactive technology in museums. However, we can further suggest that, whenever it is important to retain and display a variety of specific forms of interaction (with physical objects versus with digital content) our hybrid approach is viable and sometimes preferable to one where either the computational or the physical/traditional fades away.

Acknowledgement

The work presented in this chapter was funded by the European Union as part of "The Disappearing Computer" initiative in the IST-FET programme (contract number IST-2000-26069). In addition, Liam Bannon and Luigina Ciolfi wish to acknowledge the support of the Science Foundation Ireland (Shared Worlds project 02/IN.1/I230) in the preparation of this chapter.

References

Bell, M., Chalmers, M., Barkhuus, L., Hall, M., Sherwood, S., Tennent, P., Brown, B., Rowland, D., Benford, S.: Interweaving Mobile Games with Everyday Life. In: Proceedings of CHI 2006, pp. 417–426. ACM Press, New York (2006)

Brown, B., MacColl, I., Chalmers, M., Galani, A., Randell, C., Steed, A.: Lessons from the lighthouse: Collaboration in a shared mixed reality system. In: Proceedings of CHI 2003, pp. 577–585. ACM Press, New York (2003)

Caulton, T.: Hands-on exhibitions. Routledge, London (1998)

Ciolfi, L., Bannon, L.: Space, place and the design of technologically enhanced physical environments. In: Turner, P., Davenport, E. (eds.) Space, Spatiality and Technology, pp. 217–232. Springer, London (2005)

Ciolfi, L., Bannon, L.: Learning from Museum Visits: Shaping Design Sensitivities. In: Proceedings of HCI International 2003, Crete, June 2003, pp. 63–67 (2003)

Ferris, K., Bannon, L., Ciolfi, L., Gallagher, P., Hall, T., Lennon, M.: Shaping Experiences in the Hunt Museum: A Design Case Study. In: Proceedings of DIS, Designing Interactive Systems 2004, pp. 205–214 (2004)

Fraser, M., Stanton, D., Ng, K.H., Benford, S., O'Malley, C., Bowers, J., Taxén, G., Ferris, K., Hindmarsh, J.: Assembling History: Achieving coherent experiences with diverse technologies. In: Proceedings of ECSCW, pp. 179–198. Kluwer, Dordrecht (2003)

Gaver, W., Bowers, J., Boucher, A., Gellerson, H., Pennington, S., Schmidt, A., Steed, A., Villars, N., Walker, B.: The drift table: designing for ludic engagement. In: CHI Extended Abstracts, pp. 885–900 (2004)

Green, J., Schnädelbach, H., Koleva, B., Benford, S., Pridmore, T., Medina, K.: Camping in the Digital wilderness: tents and flashlights as interfaces to virtual worlds. In: Proceedings of CHI 2002 Conference Companion, Minneapolis, Minnesota, pp. 780–781. ACM Press, New York (2002)

Greenbaum, J., Kyng, M. (eds.): Design at work: Cooperative design of computer systems. Lawrence Erlbaum Associates, Hillsdale (1991)

Grinter, R.E., Aoki, P.M., Szymanski, M.H., Thornton, J.D., Woodruff, A., Hurst, A.: Revisiting the visit: understanding how technology can shape the museum visit. In: Proceedings of CSCW'02, pp. 146–155. ACM Press, New York (2002)

Hall, T., Bannon, L.: Designing ubiquitous computing to enhance children's learning in museums. Journal of Computer Assisted Learning 22, 231–243 (2006)

Hall, T., Bannon, L.: Co-operative design of children's interaction in museums: a case study in the Hunt Musuem. CoDesign: International Journal of CoCreation in Design and the Arts 1(3), 187–218 (2005)

Heath, C.C., vom Lehn, D: Misconstruing Interaction. In: Hinton, M. (ed.) Interactive Learning in Museums of Art and Design London. Victoria and Albert Museum (2004)

Jackson, A., Johnson, P., Leahy, H.R., Walker, V.: Seeing it for real: An investigation into the effectiveness of theatre techniques in museums and heritage sites. Arts and Humanities Research Board (2002)

Milgram, P., Colquhoun, H.W.: A Framework for Relating Head-mounted Displays to Mixed Reality Displays. In: Proceedings of Human Factors and Ergonomics Society, pp. 1177–1181 (1999)

Rogers, Y., Scaife, M., Gabrielli, S., Smith, H., Harris, E.: A conceptual framework for mixed reality environments: Designing novel learning activities for young children. Presence. MIT 11(6), 677–686 (2002)

Schnädelbach, H., Koleva, B., Flintham, M., Fraser, M., Chandler, P., Foster, M., Benford, S., Greenhalgh, C., Izadi, S., Rodden, T.: The Augurscope: A Mixed Reality Interface for Outdoors. In: Proceedings of CHI 2002, pp. 9–16. ACM Press, New York (2002)

SHAPE Deliverable 4.2 (2002). Available from http://www.shape-dc.org

SHAPE Deliverable 2.1 (2003a). Available from http://www.shape-dc.org

SHAPE Deliverable 2.2 (2003b). Available from http://www.shape-dc.org

Stapleton, C., Hughes, C., Moshell, M., Micikevicius, P., Altman, M.: Applying Mixed Reality to Entertainment. IEEE Computer 35(12), 122–124 (2002)

Taxén, G., Bowers, J., Hellström, S.-H., Tobiasson, H.: Designing Mixed Media Artefacts for Public Settings. COOP 2004, pp. 195–121 (2004)

vom Lehn, D., Heath, C., Hindmarsh, J.: Exhibiting Interaction: Conduct and Collaboration in Museums and Galleries. Symbolic Interaction 24(2), 189–216 (2001)

Weiser, M.: Some Computer Science Issues in Ubiquitous Computing. Communications of the ACM 36(7), 75–84 (1993)