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Patterns of Place: An Integrated Approach for the Design and Evaluation of Real and Virtual Environments

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1. Introduction

This chapter describes an approach to the development of virtual representations of real places. The work was funded under the European Union's €20m Future and Emerging Technologies theme of the 5th Framework Programme, "Presence", 2002 - 2005. The aim of the project, called BENOGO, was to develop a novel technology based on real-time image-based rendering (IBR) for representing places in virtual environments. The specific focus of the work presented here concerned how to capture the essential features of real places, and how to represent that knowledge, so that the team developing the IBR-based virtual environments could produce an environment that was as realistic as possible. This involved the development and evaluation of a number of virtual environments and the evolution of two complementary techniques; the Place Probe and Patterns of place.

There are two main approaches to the generation of virtual representations of places. In the traditional approach images are generated from 3D models of objects and scenes. This approach uses a compact data representation and has the flexibility to generate any new view that may be required. Its main drawback is the reliance on the availability of models. Many objects (such as trees, hair and flowers) and many physical phenomena (such as shadows) are very hard to model and as a result, synthetic images generated from models often appear artificial and lack a sense of realism. Another approach to creating virtual places is called Image-Based-Rendering (IBR), (Buehler, Bosse and McMillan, 2001, Shum and Kang, 2000). In this approach a scene is photographed from many points of view, and new images are generated through complicated computations, re-sampling and interpolation of this image collection. The main advantage of this approach is the realistic nature of the images. The main drawbacks arise from the necessity to have in storage every possible point of view of every possible point in space. As a result the storage load of this approach is huge, and the image acquisition is very tedious. In the past these drawbacks have made IBR impractical for most applications.

During the BENOGO project significant advances were made in the techniques used for image collection and rendering. These advances meant that environments could be rapidly photographed and stitched together to provide photo-realistic scenes with effective stereoscopic characteristics. These were rendered in different arenas; a six-sided fully immersive CAVE, a panorama, or in a head mounted display (HMD). The head movements of a person viewing the scene in an arena was tracked and used to select the images presented to the person. This produced a very realistic effect that the person was in a particular location and could look around, fully 360º. However, where there were no photographic images, there were gaps in the rendering. For example photographs taken with a fish-eye lens in a circle with a radius of 60cm would allow the person to see almost 180º up and down and 360º around. They could move about within the 60cm radius, but if they looked directly up or down the image was blank. The fish-eye lens also distorted the images in certain parts of the scene.

There were a variety of cameras used, employed in a variety of ways (rotated around a point, moved forward along a line and so on). These were rendered in different arenas (HMD, CAVE, etc.) using different algorithms that produced slightly different effects. The photo-realistic scenes could also be augmented with graphical images. This rich technology created one of the major challenges for the project. How should the different parts of the technological infrastructure be deployed to create what effects? For example where should the camera be positioned to photograph a scene? If it is placed at 1 metre high this might be suitable to create a realistic view for a child, if at 2 metres it might be suitable for a tall person. If photographs were taken every 10cm between 1 metre and 2 metres it would allow the viewer of the scene to move up and down, and could accommodate both child and adult views, but it would mean capturing and rendering in real time ten times as many images where each image requires several tens of megabytes of storage.

The development approach that was adopted to deal with these issues consisted of two parts. The first focused on understanding the essential characteristics of a place. We wanted to find what gave a place its 'sense of place'. This allowed us to compare any virtual representation of that place with descriptions and measures of the real place. It also allowed us to specify to the engineers and designers of the virtual environments which characteristics needed to be most realistic, and which were less important. The first part of this approach is known as the Place Probe, the second part consists of Patterns of Place.

In this chapter we will describe the specifics of this approach as applied in the BENOGO project. However, we also wish to recommend the general nature of the approach to understanding and representing sense of place. In section 3 of the chapter we introduce the characteristics of The Place Probe. Details of how this instrument was designed are described in (Benyon, Smyth, O'Neill, McCall and Carroll, 2006). The Place Probe was to inform the design of future virtual environments through the development of Patterns of Place. Based on the application of the probe a series of patterns were abstracted and categorised into three broad categories: physical properties; affect and meaning; and activities associated with place. The rationale for choosing these categories, along with illustrations of the patterns and how they can be applied are described in Section 4. These categories constitute the sense of presence in a particular place. Technological patterns specific to the IBR approach adopted within the BENOGO project were also developed. Together the technological patterns and the place patterns form the basis of a nascent "Pattern Book" aimed at connecting the case based approach to the measurement of sense of presence to the design of virtual environments. In order to frame the discussion, Section 2 provides a brief background to presence and place form a human-computer interaction perspective. Section 5 concludes the chapter with a look forward to how the approach may be further developed and generalised.

2. A Human Computer Interaction based approach to Sense of Presence

One of the overarching themes that unified the European Commission's Future and Emerging Technologies Presence initiative in the 5th Framework programme was the relationship between the creation of virtual environments and the subsequent measurement of the sense of presence experienced by participants. A variety of tools and techniques for the measurement of sense of presence have been developed. The Immersive Tendencies Questionnaire (ITQ) was developed to identify real world tendencies (e.g. using computer games) that may affect a person's sense of presence, (Witmer and Singer, 1998). The ITC-SOPI was developed for the UK's Independent Television Commission. It is a cross-media questionnaire that explores spatial presence, levels of engagement, sense of naturalness and negative aspects that effect presence (Lessiter et al, 2000). The MEC questionnaire (Vorderer, Wirth, Gouveia, Biocca, Saari, Jäncke, Böcking, Schramm, Gysbers, Hartmann, Klimmt, Laarni, Ravaja, Sacau, Baumgartner, & Jäncke, (2004) was developed as part of the Presence initiative. It focuses on spatial presence.

These approaches have been primarily quantitative and designed to be applied post hoc to developed environments. Whilst such measures might be useful in some circumstances, there is little evidence to suggest how such measurements will inform the design of future environments. In contrast, an enduring belief of Human Computer Interaction (HCI) practitioners is the intimate relationship between the generation of requirements for future systems and the subsequent criteria for evaluation of those systems (e.g. Benyon, Turner and Turner, 2004). Requirements and evaluation are two sides of the same coin. One goal of our work, then, was to reconnect the measurement of presence to the articulation of requirements for the design and development of virtual environments, to their evaluation and re-design.

Another key feature of our approach from the HCI perspective is that we reject a traditional cognitive view of presence and instead adopt a conceptual framework based on the concept of embodied interaction (or embodiment). Embodiment is a development of the phenomenological school of philosophy developed by Edmund Husserl at the turn of the Nineteenth century and used, changed and expanded by philosophers such as Heidegger, Merleau-Ponty and more recently Dourish (Dourish, 2001). For Husserl, an individual's experience was the experience of *something*. By focusing attention on the act of this 'experiencing of' rather than on the thing being experienced or the person who was having the experience, he aimed to produce a new kind of knowledge that could account for things beyond the reach of science. Heidegger introduced 'Beings', entities which exist in the world and are able to reason about Being, Continuing in the phenomenologist tradition, Merleau-Ponty's account of 'being-in-the-world' emphasises the importance of the body. He places the body at the centre of our relation to the world and argues that it is only through having bodies that we can truly experience space..

In *Where the Action Is* Paul Dourish develops his ideas on the foundations of embodied interaction (Dourish, 2001). The embodied interaction perspective considers interaction ‘with the things themselves’. For Dourish, phenomenology is about the tight coupling of action and meaning. Actions take on meaning for people. Coupling is concerned with making the relationship between actions and meaning effective. If objects and relationships are coupled then effects of actions can be passed through the system. Dourish uses the familiar example of a hammer (also used by Heidegger) to illustrate coupling. When you use a hammer it becomes an extension to your arm (it is coupled) and you act through the hammer onto the nail. You are engaged in the activity of hammering.

These ideas are important to a study of presence. If you feel present, you are unaware of any mediating technology: indeed presence has been defined as the illusion of non-mediation (Lombard and Ditton, 1997). A sense of presence may be true of some communication technology such as a phone or video screen that really makes you feel that you are dealing directly with other people (called social presence). Alternatively it may be that you are able to operate a remote vehicle with all the accuracy as if you were there and with the full range of tactile, auditory, olfactory and other feedback that being in the real place would allow. Designing for presence is about designing the illusion of non-mediation. When you put on a head mounted display you are immediately transported into the computed world beyond the headset. You are not aware that there are two tiny displays sitting close to your eyes; that part of the interaction is apparently unmediated.

But presence is nothing if it is not about place (Turner and Turner, 2005). Presence is the sense of non-mediation; it is the sense of ‘being there’. The Heideggerian phenomenology of being leads us to understand that ‘to be’ is to be *somewhere*. Being is’ being-in-the-world’, or *dasein* as Heidegger called it. Presence is inherently commingled with place. Given this view of presence and our project’s interest in representing real places, lead us naturally to investigate the philosophy of place.

Sense of place has been considered extensively in environmental psychology, sociology, geography, literary and media theory. Relph's (1976) monograph takes an explicitly phenomenological and holistic stance towards appreciating places. He defines three components of 'place identity': physical setting; activities afforded by the place; meanings and affect attributed to the place. Relph's model of place provides us with the basic framework within which we developed the Place Probe and subsequently the Patters of Place. However we also explored the idea of place from the perspective of Gustafson's conceptualization (Gustafson, 2001). He draws on empirical work in the form of an interview survey and builds on a review of earlier conceptualizations of place to identify three poles that can be used to understand places; self, environment and other people. Other accounts of space and place, notably the work of Edward Casey (e.g. Casey, 1997), Y-F Tuan (1977), and Jorgensen and Stedman (2001) have also informed our work.

As a means of trying to better understand the criteria that contribute to sense of presence, a series of studies of real places were undertaken (Turner et al, 2003, Turner and Turner, 2003, Smyth 2005 and Turner, Turner and Carroll, 2005). Figure 1 is an image from a photo realistic virtual representation of a glasshouse in the Prague botanical gardens. Participants experienced a 360 degree panorama of the interior of the glasshouse via a head-mounted display. Figure 2 is a series of images of the Jenck's Landform in Edinburgh that was a location for one of the early studies of place. Each of the studies formed the basis of the initial BENOGO demonstrators and critically shaped both the approach to the measurement of sense of presence in both real and virtual environments, but also the subsequent debate as to what constituted presence and its relationship with place.

Figure 1: An image captured from the Botanical Gardens in Prague, (Turner, Turner and Carroll, 2005)

Figure 2: Series of images from the Jenck's Landform, Edinburgh, (Smyth, 2005)

In their paper *Place, Sense of Place and Presence,* Turner and Turner (2005) provide a detailed consideration of both empirical and theoretical evidence for a phenomenological view of presence and place. They point to the need for a more complete understanding of place than is provided by the cognitive. Affective and conative aspects are clearly present in people's descriptions of places. They also identify the importance of semantic associations that people have with places and the importance of individual associations. Whilst they identify four components of place, these correspond to the activities, meanings and affect and physical characteristics identified by Relph (1976). They conclude by pointing put that presence and sense of place are first-person constructs, experienced by individuals and they highlight the difficulty of creating virtual representations that capture the multi-sensory, impressionistic nature that characterises people's feelings about places.

Despite these inherent difficulties, we were faced with the demand to create virtual representations of real places that achieved a real sense of presence, or sense of place, for the people experiencing these environments. Our approach is to capture the essential features of places as best we can — through the Place Probe — and to represent our accumulating design knowledge as number of templates or, Patterns of Place.

3. The Place Probe

Probes are collections of stimuli and data gathering instruments to help in design. Cultural probes (Gaver, Dunne and Pacenti, 1999) were used for the generation of rich data related to the context of use of technology. Technology probes (Westerlund, Lindquist and Sunblad, 2001) have been used to explore the use of technology in primarily domestic settings. Typically these probes contain a diary, notebook, several disposable cameras, address envelopes and a pen in order to generate information about the nature of communications between family members. The Place Probe was designed to enable the articulation of experiences at a specific time and place. We wanted to organise a number of complementary techniques into an easy to administer instrument that would allow us to understand the essential characteristics of a place.

The Place Probe was developed over a period of three years and involved a whole range of techniques that were tested, used, reviewed and discussed (Benyon, et al., 2006). These were mostly qualitative techniques based on talk-aloud protocols, video, questionnaires and so on. The final version of the Place Probe is included in appendix 1. It includes three sections. The first gathers impressions of the place using a number of techniques. The second part includes a number of semantic differentials that seek to distinguish the main characteristics of a place along pre-defined dimensions in a quick and intuitive way. Lawson (2001) uses semantic differential to understand people's perceptions of place in a similar way. The final part of the Place Probe is a short version of the MEC spatial presence questionnaire (Vorder, et al., 2004).

As the Place Probe has evolved, the different components have been used in a variety of settings such as a real environmental architecture (Smyth, 2005), a real botanical garden (O'Neill and Benyon, 2003), a virtual environment representation of a botanical garden in an HMD (Turner, Turner, Carroll, O'Neill, Benyon, McCall and Smyth, 2003), a university stairwell rendered in an HMD, a city view of Prague rendered in an HMD (O'Neill, McCall, Carroll, Smyth and Benyon, 2004), a virtual environment of the Technical Museum in Prague in both a fully immersive, six sided CAVE and HMD (McCall, O'Neill, Carroll, Benyon and Smyth, 2005). The main contributing studies to the development of the Place Probe are summarized in Table 1.

Table 1: Summary of the Methods utilized within the BENOGO Project.

Location	Date	Mediating Technology	Participants	Data Analysis Methods
Real study: Edinburgh Botanical Gardens	February 2003	Video Camera (subjects talked whilst videoing the scene).	4 male	Quantitative analysis of ITQ and SOPI questionnaires. Qualitative analysis and identification of reoccurring themes of talk aloud and structured interview data.
Virtual Study: Prague Botanical Gardens	February 2003	Head Mounted Display	29 - 22 male, 7 female	Quantitative analysis of ITQ and SOPI questionnaires. Qualitative analysis and identification of reoccurring themes through video talk aloud and structured interviews.
Virtual Study: Stairway at university in Prague	April 2003	Head Mounted Display	32 - 20 male, 12 female	Quantitative analysis of ITQ and SOPI questionnaires. Qualitative analysis of talk aloud, structured interviews and repertory grids.
Real Study: Viewpoint in Prague	November/ December 2003	None	30 - 17 male, 13 female	Qualitative analysis and identification of reoccurring themes based on Gustafson's Place model, based on Place Probe version 1.
Virtual Study: Viewpoint in Prague	March 2004	Head Mounted Display	30 - 17 male, 13 female	Qualitative analysis and identification of reoccurring themes based on Gustafson's Place model based on Place Probe version 1.
Technical Museum, Prague	December 2004	Head Mounted Display and CAVE	28 – 17 male, 11 female	Quantitative analysis of distance estimates, and MEC questionnaire data. Qualitative analysis of Place Probe version 2.
Comparative Study – Image-based rendering vs. modeled scene	August 2005	Head Mounted Display	40 – 22 male, 18 female	Quantitative analysis based on Place Probe version 3 (including MEC questionnaire).

During the studies of places we have identified specific elements that are experienced within each of the three categories of our model. For example our initial Place Probe study of the Prague Technical Museum people described it as bright and open and one felt close to objects. It was exciting, interesting and so on. This then amounts to our understanding of the experience of being in, being present in, the Technical Museum in Prague. This is the sense of place as approximated by the Place Probe.

Accordingly each of the three elements of the place model was given its own section in the semantic differential part of the Place Probe. The Activity differential includes ratings on the scales: passive-active, free-restricted, disorientated-oriented, inside-outside, mobile-immobile. The Physical differential focuses on characteristics of the space: small-big, empty-full, light-dark, enclosed-open, permanent-temporary, colorless-colorful, static-moving, responsive-inert, far-near, untouchable-touchable. The Affective/meaning differential is rated on the scales: ugly-beautiful, pleasant-unpleasant, stressful-relaxing, harmful-harmless, exciting-boring, interesting-uninteresting, memorable-forgettable, meaningful-meaningless, confusing-understandable, significant-insignificant.

Ratings on these dimensions can be used to inform the design of representations of the place (see Table 2). People's ratings on these differentials can be used to compare representations of the place with the real place or with another representation. For example in the studies of the viewpoint in Prague, ratings on the differential scales were consistently less pronounced in the virtual environment than in the real (Benyon, et al., 2006). We took this to indicate that the experience of the virtual place was less engaging than the experience of the real place. A portion of this is shown in Table 2.

Table 2 Semantic differential tables of the Real (Left) and virtual (Right) environments

	Very	Quite	Neither	Quite	Very	
Attractive	23	3	1	1	1	Ugly
Big	7	12	6	2	1	Small
Colorful	5	12	8	4		Colorless
Noisy	4	8	5	8	4	Quiet
Temporary	1	7	6	8	7	Permanent
Available	4	11	10	4		Unavailable
Versatile	2	11	8	7	1	Limited
Interactive	5	8	5	6	5	Passive
Pleasant	23	5			2	Unpleasant
Interesting	19	6	2	1	1	Boring
Stressful	1	1	3	4	20	Relaxing

	Very	Quite	Neither	Quite	Very	
Attractive	7	15	7			Ugly
Big	2	11	13	2	1	Small
Colorful		14	5	9	1	Colorless
Noisy	3	7	9	6	4	Quiet
Temporary	3	6	8	8	4	Permanent
Available	1	9	11	5	2	Unavailable
Versatile	2	6	12	7	2	Limited
Interactive	1	7	6	10	5	Passive
Pleasant	4	16	5	4		Unpleasant
Interesting	8	11	5	4		Boring
Stressful		5	5	11	8	Relaxing

While we know that it is almost impossible to directly reproduce the exact experience of being in a real place, we also know that the BENOGO technology offers new opportunities to produce experiences that are as close to the real experience as we can make them. In developing the BENOGO technology what is important to understand is the aspects of the technology that affect the elements of the experience. In other words how can we develop BENOGO technology towards the illusion of non-mediation.

Thus in the final version of the Place Probe we included a semantic differential specifically aimed at eliciting views on how effective the technology was and hence how aware people were of its mediating effect in the VE. Images are rated as: grainy-clear, realistic-unrealistic, unbelievable-believable, distorted-accurate. The movement of images is rated as smooth-jerky, broken-unbroken, slow-fast, consistent-erratic.

Data from the fifth study undertaken (see Table 1) provided some interesting insights into the importance of the various aspects of sense of place in virtual environments. 28 participants took part in a number of experimental settings over a period of two days and data was gathered using a variety of methods, including the Place Probe.

The data from the semantic differentials indicated a few statistically significant differences. Adding an augmentation to the HMD arena made the environment feel bigger (p=0.0023) and more permanent (p=0.0027) and the objects in the HMD felt more touchable (p=0.0051). In the CAVE, when there were no graphical augmentations compared to when there were, the environment feel bigger (p=0.0026) and more permanent (p=0.009) but less responsive (p=0.004). Images were less believable (p=0.0165) and felt slower (p=0.011). The environment made people feel less free (p=0.0301).

Another interesting similarity is the sense of space. Participants in both arenas felt that they were looking into the technical museum as opposed to being totally there. Two quotations from participants illustrate this:

> *I thought it looked real, it was …I got the feeling it was a museum …and but I don't think I got the feeling I was there I was kinda of looking into it so…but fun experience* (Female, Cave)

> *I really felt I was standing in a room and looking at this old museum.* (Female, HMD)

And when asked what they thought their function in the environment was, participants replied:

> *Ya well I felt a bit awkward because it felt like it was after closing hours ha ha …I would loved to be there as a tourist but it felt more like I was a thief or maybe as a cleaning lady …so dark…. so something like that maybe a cleaning lady.* (Female, Cave)

The general impression from both arenas is a positive one, even though some participants were annoyed with the restricted movement. When asked how they could improve the experience, participants replied:

> *Well I would have liked to have been able to walk down a stairs and walk in between the old steam locomotives and cars* (Male, Cave)

> *I want to touch …no maybe I would have been much more satisfied if I could have got closer to see more specific details. Ok* (Male, HMD)

> *Movement restriction has to be altered and to a lesser extent* (Male, Cave)

> *Well I was very restricted in movement I couldn't see what the signs said.* (Male, Cave)

While the Place Probe was considered to be successful in revealing some of the essential attributes of place, it failed to adequately engage with the specific needs of the designers of such technologies. Discussions with the designers generated the requirement for the method to produce detailed findings about specific technological issues associated with the creation of virtual environments. For the second part of the approach we looked at producing patterns of place.

4. A Pattern Based Approach to Design

While the final version of the Place Probe was undoubtedly better tuned to the requirements of the designers of virtual environments, it was still found wanting. It failed to bridge the 'design gap'. A more formal mechanism was required to assimilate the probe data and to enable its application during the design process associated with future environments. To specifically address this issue a pattern based approach was undertaken.

Patterns have long been used in Software Engineering (e.g. Gamma, et al., 2005). The use of patterns in Interaction Design, HCI and related fields such as web design and GUI design is gaining momentum in practice. Initial research into the applicability of patterns in Interaction Design (Borchers 2001) has paved the way for the production of pattern books (van Duyne et al 2002, Graham 2003 and Borchers 2001), together with a growing number of on-line pattern resources, reflecting the dynamic nature of the approach (van Welie 2006, Tidwell 2005). While individual patterns may provide a valuable resource for designers, their potential impact is dramatically increased when they are constructed into a pattern language.

The pattern approach was inspired by the work of Christopher Alexander (1977) in the field of architecture. Alexander attempted to formalise architectural knowledge based on case studies through the use of templates that described a series of patterns referring to the layout of urban spaces. For example, if an urban planner had the requirement to increase the sense of community associated with a particular location, they might choose to adopt the pattern that suggests the creation of squares and plazas that incorporate seating and spaces for cafes at appropriate road junctions. The strength of Alexander's approach lies, not in the individual patterns that superficially can appear simplistic, but in their connectedness resulting in a 'pattern language'. In a pattern language, each pattern is linked to others, some more specific, some more general, giving the designer a sense of the implications associated with particular design decisions. The pattern based approach to place aims at harnessing a similar gestalt.

The pattern based approach is a method designed to formalise the knowledge gained through the application of the Place Probe. The patterns described in the remainder of this report reflect the aggregation of the understanding of sense of place through the studies conducted as part of the BENOGO project. The approach encapsulates design knowledge and makes it available to the creators of virtual environments. Further applications of the Place Probe will provide more data that, in turn, can contribute to existing patterns, or the creation of new ones. The strength of the patterns is that they provide designers of virtual environments with grounded evidence to support design decisions and the choice between alternatives. Both of these factors are characteristic of the early phase of design that the patterns aim to support. The patterns, while informed through the data generated from the use of the Place Probe, can be used independently of the probe and, it is contended, contribute to the design of virtual environments.

As the pattern based approach has been developed from the Place Probe, the underpinning structure is based on Relph's model of place (1976), but also reflects the development of the probe and includes a category concerning the impact of technologies on the experience of a virtual environment. The patterns are, therefore, organised into the four components; technology, spatial characteristics, meanings and affect, and activities. Our aim in presenting these patterns is not to suggest that the endeavour of producing a definitive set of patterns of place is complete. Quite the reverse. Our aim is to illustrate the idea and to suggest that the overall structure of the patterns is valid. We expect the list of patterns to grow as the approach is more widely adopted and the experience of others feeds into the language.

4.1 Technology Patterns

There are currently fifteen patterns relating to the IBR technology. These include three that relate to the arena (pattern 8) in which the environment is displayed. The panorama arena is described in pattern 9, the Cave in pattern 10 and the HMD in pattern 11. Four patterns are concerned with the quality of the display. Display resolution is pattern 7, image quality is pattern 5, field of view is pattern 6 and frame rate is pattern 4. Three patterns relate to motion resolution (pattern 12) including three different types of the important 'region of exploration' (REX). Pattern 13 describes the point REX, pattern 14 describes the disc

REX and pattern 15, the line REX. Pattern 1 describes the acquisition point, pattern 2 is the acquisition resolution and patter 3 is the texture resolution.

These patterns refer specifically to the IBR approach adopted within the BENOGO project. Of course other technologies will have other technological patterns associated with them. The pattern describing the Acquisition Point (Pattern 1) is illustrated in Table 3. This pattern relates to the location from which images are captured. As with all the patterns, the aim is to capture key aspects of design and engineering knowledge associated with a particular design problem. The standard format that we use is to identify a general description, the other patterns that are influential on the main design problem that is the focus of this particular pattern, the problem to be addressed, the solution proposed, and other patterns affected. The rationale for this pattern may be explained as follows.

Evidence from the Place Probe suggests that it is important to establish a position from which to capture images of a place in order to represent it in an optimum manner. Factors that impact on this decision are firstly, the nature of the scene that is to be portrayed and secondly, what activities are to be supported within the scene. A solution to this requirement is to scope the real place as early and often as possible. By observing the activity and behaviour of individuals at the real place, it is possible to establish a suitable acquisition point that is in keeping with the technological objectives of the study and captures the important features of the real place. The Place Probe can capture the elements that are perceived within the environment and these can, in turn, be turned into a design template. Furthermore it is important that an appropriate REX be selected to enable the observed behaviours to be replicated within the virtual environment.

Table 3: The Acquisition Point Pattern relating to the BENOGO IBR technology.

1. ACQUISITION POINT
Description Specific to Benogo IBR. The acquisition point is the specific location where the images are captured. **Influential Patterns** **Problem** It is important to establish the best position to acquire the images from, in relation to representing the real place in the best way. This requires taking into account what scene the images will portray and what type of activities might occur there. **Solution** The best way to solve this problem is by Scoping the real place first, as well as performing a Place Probe. By observing the activity and behaviour of individuals at the real place, it is possible to establish a suitable acquisition point that is in keeping with the technical objectives of the demo while making sure the most important features of the real place are captured in the images. The Place Probe captures elements of the environment that can be turned into a design template. It is also essential that the appropriate type of REX e.g. Point, Disc, or Line is chosen in line with the requirements derived form the real environment. **Affected Patterns** **Acquisition Resolution (2), Point REX (13), Disc REX (14), Line REX (15)**

4.2 Patterns of Spatial Characteristics

Analysis of the various applications of the Place Probe as it developed over the lifetime of the project revealed a series of common themes relating to the properties of both real and virtual places. These patterns of place are divided up into spatial characteristics, activities in the place and meaning and affect engendered by the place. Patterns 16 to 27 deal with the spatial characteristics and broadly speaking map onto the spatial differentials of the place probe. The patterns are: big/small (17), open/closed, (18) full/empty (19), colourful/colourless (20), identifiable features (21), dark/light (22), static/moving (23), touchable/untouchable (24), responsive/inert, (25) near/far (26), permanent/temporary (27). Spatial characteristics (16) is a super ordinate pattern that is required to link with activities and technology.

Table 4 presents the pattern entitled Big/Small and relates to the responses participants have to the volume and scale of different places. In certain cases the perceived volume of a place can be either magnified or diminished as an attribute of the technology used to represent the place. This pattern also illustrates how supporting evidence for the design knowledge can be included in the patterns. Indeed Alexander's patterns often ran to several pages and included illustrations, rich descriptions, quotations and other forms of qualitative data. It is exactly this interweaving of patterns and capturing of rich, qualitative data that gives the pattern language approach its strength.

Table 4. Big/Small Pattern relating to the Physical Properties of Places

17. BIG/SMALL (P)

Description

Different places are different sizes in reality. They can be big, small or somewhere in between. The technical museum for example is a large room, while the viewpoint is much smaller but feels bigger due to being outside **Open/Enclosed(18)** .

'It was a very large room I couldn't see what was on the other side of the room very well' (technical museum)

' scale was too small… seemed artificially too small' (botanical garden)

Influential Patterns

FOV(6), Acquisition point (1), Motion Resolution (12), Arena (8)

Problem

Size Matters. Getting the size right for IBR environments is about combining different factors. The problem is in understanding how these factors relate to one another. Our studies of the Technical Museum for example identified that it was considered to be a **big** place, that it was also **enclosed (18)** and **full (19)** of objects.

Solution

Important things to consider in sizing a virtual IBR space are firstly how do the spatial characteristics relate to one another and secondly how can the technology support this relationship in the rendered environment. For example we have already seen how the museum is big, full and enclosed. It was important in terms of technology that these three aspects of the environment were supported. It was therefore imperative that the **Acquisition point (1)** was established that was at least open to the large scale of the room on one side and yet close enough to the objects in the room to make it feel full.

Another important thing to consider is whether people are moving through the environment **Motion resolution (12)**. A **Disc REX (14)** was used in our version, which allowed some movement but not exploration. Therefore the sense of scale in the IBR environment was different from the real because participants could not **explore (29)** the IBR environment fully. However the sense of scale was enhanced locally by the parallax provided by the Disc REX i.e. near objects occluded objects that were further away but moving allowed you to see them.

Affected Patterns

Explore (29); Interesting/uninteresting (40)

An illustration of this comes from our efforts to develop a virtual representation of the Prague Technical Museum. Pattern number 18 entitled Open/Enclosed and Pattern number 19 Full/Empty pointed to the importance of capturing, accurately, the spatial characteristics of a place.. Further supporting evidence was provided by the inclusion of quotations from participants in studies that highlighted the issue of the perception of size with respect to the environment. From a technological perspective Pattern 17 was linked to Field of View (6), Acquisition Point (1) Motion Resolution (12) and choice of Arena (8). Participants in the study of the real Technical Museum reported that they saw the environment as big, full and enclosed. This finding places a requirement on the technology and specifically the choice of Acquisition Point (1) such that it was open to the large scale of the location but also was close enough to objects contained within to give the viewer the impression that the room was full. Furthermore, if there is a requirement for people to be able to move through the environment this impacts on Motion Resolution (12). In the case of the BENOGO technology a Disc REX (14) was used which allowed some movement but not real exploration. This design decision resulted in the perception of scale in the IBR environment being different from the real environment because participants could not Explore (29) the environment fully. However the sense of scale was enhanced locally by the parallax provided by the Disc REX (14) resulting in objects near to the viewer occluding objects further away but supporting head movement so occluded objects could be revealed.

4.3 Patterns of Meanings and Affect

Analysis of the meanings elucidated by the participants in the real and virtual environments studied as part of the BENOGO project resulted in the themes relating to meanings and affect engendered by the place. Patterns 31 to 40 aim to capture key features of the meanings and emotional response that people have to a place. They map onto the meaning and affect differentials of the place probe: stressful/relaxing (31), meaningful/meaningless (32), ugly/beautiful (33), harmful/harmless (34), pleasant/unpleasant (35), significant/insignificant (36), confusing/understandable (37), exciting/boring (38), memorable/forgettable (39), interesting/uninteresting (40).

In order to explore this class of pattern the Stressful/Relaxing (31) will be described in more detail (see Table 5). Some environments are more relaxing, or conversely more stressful than others. The degree of relaxation or stress associated with a particular place is deeply linked to a person's subjective experience of activity in that place; as such it cannot be designed - only designed for. For example outdoor places have the potential to be more peaceful and allow an experience of nature at an easy steady pace are often considered relaxing, whereas outdoor places where people encounter unexpected testing circumstances might be considered stressful, (i.e. bad weather conditions, or a loss of orientation).

Table 5. The Stressful/Relaxing Pattern relating to the Meanings Associated with Real and Virtual Places

31. STRESSFUL/RELAXING (M)

Description

Some environments are more relaxing, or conversely more stressful than others. The degree of relaxation or stress associated with a particular place is deeply linked to a person's subjective experience of activity in that place; as such it cannot be designed - only designed for. For example outdoor places that are peaceful and allow an experience of nature at an easy steady pace are often considered relaxing, where as outdoor places where people encounter unexpected testing circumstances might be considered stressful, i.e. bad weather conditions, or a loss of orientation. In the case of VR there is the added dimension of the mediating technology interfering with the experience. A beautiful and relaxing scene might be rendered in an HMD and yet the technology might create stressful affects by displaying poor quality images that are hard to focus on, or by disorienting the participant.

'Very good view but only from one place as trees get in the way everywhere else. Paths are poor and there is no information to direct or explain' (viewpoint)

'There was some text but it was unreadable but I could easily identify the object' (technical museum)

'Viewpoint close to the monastery, very beautiful view, peace, relaxing' (viewpoint)

Influential Patterns

Image quality (5); acquisition point (1); activity (14); motion resolution (9)

Problem

VR mediation is essentially illusory. Interference in this illusion can cause stress and often leads to breaks in presence. In the case of rendering a relaxing scene, it is important to try and ensure that factors such as **image quality (5)** and **REX (13, 14, 15)** do not interfere with the experience. Low quality out of focus images as well as blind spots and image drop out all lead to disorientation and stress, distracting the user from a possibly relaxing experience. Similarly, in creating a stressful scene such as a cliff edge for example the same attention to detail is necessary to make it believable.

Solution

To avoid this, it is important to have high **image quality (5)** and a suitable **REX (13, 14, 15)** that does not impede the user experience i.e. it is important to choose an appropriate environment (**Acquisition point (1)**) and activity type that is compatible with the expectations of the participants. Also a useful aid is to augment images where small details such as text cannot be read.

Affected Patterns

Pleasant (35), exciting/boring (38)

In the case of virtual environments there is the added dimension of the mediating technology interfering with the experience. A beautiful and relaxing scene might be rendered in an HMD and yet the technology might create stressful affects by displaying poor quality images that are hard to focus on, or by disorienting the participant. The Stressful/Relaxing pattern has been found to impact primarily on Technology patterns, namely Image Quality (5), Acquisition Point (1), Motion Resolution (9) and the Activity related patterns

(41, 28, 29 and 30). Mediation with a virtual environment is essentially illusionary and any interference with this can result in stress on the part of the user and ultimately a break in presence. In the case of rendering a relaxing scene, it is important to ensure that factors such as Image Quality (5) and REX (13, 14 & 15) do not interfere with the experience. Low quality out of focus images as well as blind spots and image drop outs all lead to disorientation and stress, distracting the user and increasing the potential for a stressful experience. Similarly, if the intention is to create a stressful scene, for example a cliff edge it is important to concentrate on the detail in order to make the experience believable. To avoid such problems it is important to have high Image Quality (5) and a suitable REX (13, 14 & 15). The choice of environment and its associated Acquisition Point (1) is important, together with the activity type that matches the expectations of the participants. Another technique for reducing stress within a virtual environment is to augment images where small details, such as text, cannot easily be read.

4.4 Activity Patterns

Analysis of the real and virtual environments studied using the Place Probe during the BENOGO project revealed four main activities associated with place. Pattern 41 is another super ordinate pattern dealing with the overall feelings of ego motion. Patterns 28 (static/observational), 29 (local/explorative) and 30 (locomotive) deal with specific aspects of activity in BENOGO environments. The patterns are presented in full in the appendix. In the following sections examples are used to illustrate each of the different types of pattern. The Ego Motion (27a) will be considered in more detail in this section. Ego motion is the sensation of movement afforded to participants in virtual environments by the number of images or Motion Resolution (12) rendered by the system (Table 6).

In general, the more images that are rendered at run time, the smoother and clearer the feeling of movement through the REX (13, 14 and 15) resulting in a higher motion resolution. As in the previous example, quotations from studies that refer explicitly to ego motion are included in the pattern by way of illustration. From the perspective of the BENOGO technology, ego motion influences both Motion Resolution (12) and the REX (13, 14 and 15).

Pattern (41) describes the problem resulting from ego motion as follows. Natural ego motion always produces parallax and occlusion between objects in the environment. IBR ego motion attempts to reproduce this effect but is generally restricted by the massive processing power necessary to compute the position of potentially thousands of images. BENOGO IBR uses special algorithms that reduce the number of images necessary to achieve a realistic representation of natural ego motion. When considering the issue of ego motion it is important to establish the type of activity that users will perform in the rendered environment. Accordingly an appropriate REX (13, 14 & 15) should be selected together with suitable Motion Resolution (12). If restrictions are still evident then ego motion can be supported through the judicious use of augmentations that culturally enforce restricted movement (e.g.. a guide rope or railing). A related technique is to use augmentation as a distraction owing to its potential for parallax effects.

Table 6. The Ego Motion Pattern relating to Activities associated with Real and Virtual Places

41. EGO MOTION

Description

Ego motion is the feeling of movement that is afforded by the number of images, or **Motion Resolution (12)**, rendered by the system. The higher the motion resolution i.e. the more images there are rendered at run time, the smoother and clearer the feeling of movement through the REX.

'I noticed time when I turned my head world was moving a little' (botanics)

' I thought it looked real, it was … I got the feeling it was a museum… and but I don't think I got the feeling I was there I was kinda of looking into it so …' (technical museum)

Influential Patterns

Motion Resolution (12), REX (13, 14, 15)

Problem

Natural ego motion always produces parallax and occlusion between the objects in our environment. IBR ego motion attempts to reproduce this affect but is generally restricted by the massive processing power necessary to compute the position of potentially thousands of images. Benogo IBR uses special algorithms that reduce the number of images necessary, however no system as yet has come close to natural ego motion, although BENOGO despite some restrictions comes pretty close.

Solution

It is important to establish the type of activity that users will perform in the rendered environment. Accordingly an appropriate **REX (13, 14, 15)** has to be selected as well as a suitable motion resolution. If restrictions are still evident then ego motion can be supported through augmentation that culturally enforces restricted movement e.g. a guide rope or railing. Similarly augmentation might provide a focus of attention offering interesting parallax effects.

Affected Patterns

Static Observational (28), Local Explorative (29), Locomotive (30), Spatial Characteristics (16) Identifiable Features (21)

5. Conclusions

Existing tools and techniques for the measurement of the sense of presence in real and virtual environments have failed to provide formal mechanisms through which to inform the design process associated with their creation. From an HCI perspective this was viewed as a major shortcoming. An analysis instrument, the Place Probe has been introduced. The probe utilised a blended approach to the generation of both qualitative and quantitative data concerning the experience of place associated with a range of real and virtual environments. Based on the responses of developers of virtual environments, the design team and the experiences of several studies of real and virtual environments, the probe has been refined to include three parts: the qualitative parts, the semantic differentials and the MEC Spatial Presence Questionnaire (Vorder et al, 2000).

Associated with the Place Probe, a pattern based approach has been developed to articulate the data generated from using the probe into a form that is accessible and pertinent during the design phase associated with the creation of virtual environments. The Patterns of Place have been classified relative to participants' responses to a series of real and virtual environments developed over the course of the work into: the physical properties of the space, the activities supported, the meanings associated and affect engendered, and the technology necessary to create the illusion of non-mediation.

We conceptualise the situation as indicated in Figure 3. The characteristics of real and virtual places are represented in terms of the three characteristics of Relph's model of place. In between the real and the virtual representation of the place lies some technology. In our case this was the BENOGO IBR technology and so the current version of technology patterns refer to the BENOGO IBR approach. However, the method generalises to any other mediating technologies. These could include rich and complex technologies such as film where there are many, many technologies (set design, costume design, choreography, lighting, script, location and so on) that together provide the mediating technology for the

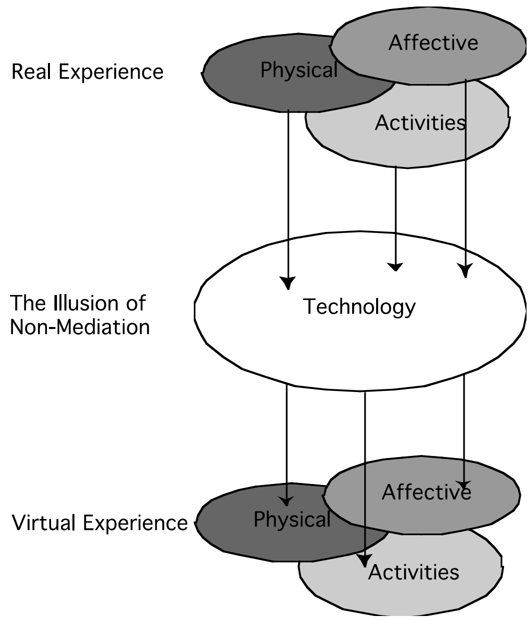

Figure 3. The characteristics of places and mediating technology

experience. They too could be used in conjunction with the Place Probe and could generate new patterns to be substituted into the existing set of patterns.

The integrated approach to the design of virtual environments presented in this chapter is an nascent attempt at connecting the measurement of sense of presence to the design of virtual environments. Presence demands a qualitative, phenomenological approach to its understanding. Presence is a personal response to a social and physical setting, experienced through an embodied interaction. A key part of presence is the sense of place; a person's feelings, understandings and attitudes to a place. If people are to experience a strong sense of presence through some technologically mediated interaction, they will need to experience a sense of place; that is they will need to feel that they are somewhere. The pragmatics of delivering this sensation comes from the designers and engineers of the technologies and their understanding of the experience of being there.

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Appendix 1 The Place Probe

Instructions

Please read the following questions carefully and answer all parts of the booklet. It should take around 10 minutes to complete. Once finished please return the booklet to the researchers. Thank you for your co-operation.

Background Information

Age: Sex:

Nationality:

First time visitor/Regular visitor:

1.1 Description

Please write a paragraph of description telling us about your experience of being in the place you have just visited.

1.2 Map

Please draw us a map of the place you have just visited. Indicate the most important features that you remember and the best place to stand to see them.

1.3 Features

Pick 3 features of the environment that you remember and rank them in order of importance:

1

2

3

1.4 Pictures

From the photographs provided, please select one that best captures your experience of being in the place you have just visited. Write down the number from the back of the photograph onto this page and tell us why you chose it (if no photographs are provided skip this section).

1.5 Sounds

Please describe any sounds that you remember from the environment you have just visited.

1.6 Words

Please write down six individual words that best capture your experience of being in the place you have just visited.

On the tables provided in each question below, please mark a cross in the box that best describes your experience in relation to the adjectives provided at either side. Below is an example for an experience that was ‘quite bad’ and ‘very light’.

(Example)

	Very	Quite	Neither	Quite	Very	
Good				x		Bad
Light	x					Dark

Did the images that were displayed seem?

	Very	Quite	Neither	Quite	Very	
Grainy						Clear
Realistic						Unrealistic
Unbelievable						Believable
Distorted						Accurate

Did the movement of the images seem?

	Very	Quite	Neither	Quite	Very	
Smooth						Jerky
Broken						Unbroken
Slow						Fast
Consistent						Erratic

Did you feel that you were?

	Very	Quite	Neither	Quite	Very	
Passive						Active
Free						Restricted
Disorientated						Oriented
Inside						Outside
Mobile						Immobile

Did you feel that the environment was?

	Very	Quite	Neither	Quite	Very	
Small						Big
Empty						Full
Light						Dark
Enclosed						Open
Permanent						Temporary
Colorless						Colorful
Static						Moving
Responsive						Inert
Far						Near
Untouchable						Touchable

Did you feel that the environment was?

	Very	Quite	Neither	Quite	Very	
Ugly						Beautiful
Pleasant						Unpleasant
Stressful						Relaxing
Harmful						Harmless
Exciting						Boring
Interesting						Uninteresting
Memorable						Forgettable
Meaningful						Meaningless
Confusing						Understandable
Significant						Insignificant

Please answer the following questions by placing a tick in the box that best expresses your feelings.
1 = I totally disagree
2 = I disagree
3 = I neither agree nor disagree
4 = I agree
5 = I totally agree

	1	2	3	4	5
Q1.1 I devoted my whole attention to the [medium].					
Q1.2 I concentrated on the [medium].					
Q1.3 The [medium] captured my senses.					
Q1.4 I dedicated myself completely to the [medium].					
Q2.1 I was able to imagine the arrangement of the spaces presented in the [medium] very well.					
Q2.2 I had a precise idea of the spatial surroundings presented in the [medium].					
Q2.3 I was able to make a good estimate of the size of the presented space.					
Q2.4 Even now, I still have a concrete mental image of the spatial environment.					
Q3.1 I felt like I was actually there in the environment of the presentation.					
Q3.2 It was as though my true location had shifted into the environment in the presentation.					
Q3.3 I felt as though I was physically present in the environment of the presentation.					
Q3.4 It seemed as though I actually took part in the action of the presentation					
Q4.1 I had the impression that I could be active in the environment of the presentation.					
Q4.2 I felt like I could move around among the objects in the presentation.					
Q4.3 The objects in the presentation gave me the feeling that I could do things with them.					
Q4.4 It seemed to me that I could do whatever I wanted in the environment of the presentation.					
Q5.1 I thought most about things having to do with the [medium].					
Q5.2 I thoroughly considered what the things in the presentation had to do with one another.					
Q5.3 The [medium] presentation activated my thinking.					
Q5.4 I thought about whether the [medium] presentation could be of use to me.					
Q6.1 I concentrated on whether there were any inconsistencies in the					

[medium].					
Q6.2 I didn't really pay attention to the existence of errors or inconsistencies in the [medium].					
Q6.3 I took a critical viewpoint of the [medium] presentation.					
Q6.4 It was not important for me whether the [medium] contained errors or contradictions.					
Q7.1 I am generally interested in the topic of the [medium].					
Q7.2 I have felt a strong affinity to the theme of the [medium] for a long time.					
Q7.3 There was already a fondness in me for the topic of the [medium] before I was exposed to it.					
Q7.4 I just love to think about the topic of the[medium].					
Q8.1 When someone shows me a blueprint, I am able to imagine the space easily.					
Q8.2 It's easy for me to negotiate a space in my mind without actually being there.					
Q8.3 When I read a text, I can usually easily imagine the arrangement of the objects described.					
Q8.4 When someone describes a space to me, it's usually very easy for me to imagine it clearly					