Mixed-Reality Interfaces to Immersive Projection Systems

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Abstract

In our everyday presentations of an immersive projection technology (IPT) system we have noted some problems and issues that can detract from the overall experience. In this paper we take the view that in order to make a successful demonstration of an IPT system, it is important to consider the complete experience, from preparation to enter, to retirement from the place of the demonstration. This view is grounded in previous work on the sense of presence in virtual environments. We discuss some possible solutions to some of the problems we have found in our IPT presentations and illustrate a few of these by presenting some observations from a recent workshop where we implemented some of these solutions.

1. Introduction

In Milgram and Kishino's *virtuality continuum* [4] immersive projection technology (IPT) systems inhabit an extreme point, where the user inhabits a purely virtual environment (VE). An IPT system can completely enclose a user or a small user group in the VE and exclude all interaction with the real environment within which the IPT is situated.

However in our experience it is rarely the case that the IPT actually provides a completely virtual experience. For example it is the nature of many demonstrations, that users enter and leave the IPT whilst the demonstration is in progress, or that conversation takes place between the users inside the IPT and users outside. Indeed, sometimes the IPT is used more like a large screen, with discussions or instructions taking place on the threshold to the IPT.

This gives most demonstrations of IPT systems, some elements of a more mixed-reality system, since the real world leaks back into the virtual experience because the IPT does not exclude the real-world.

In our previous studies we have often returned to the problem of how to enhance presence because we believe that there is a large class of problems where a high sense of presence is important. There has been a lot of discussion about what elements of the VE can enhance or detract from the sense of presence, but less work on how that sense of presence is achieved in the first place and how it eventually gets broken when the user exits the environment.

There is an obvious tension between trying to demonstrate an IPT to a large group of people, and trying to maximize the sense of presence for a single person or small group, but in this paper will we discuss a few techniques and experiences that might help.

What we have found in previous experiments is that a notion of traversal or distancing can be useful in convincing the user that the VE is a space which they can interact with [9]. In essence, presence in the VE can be supported by the exclusion of the real world since real world cues might interfere or be inconsistent with the model presented by the VE.

More generally we suggest that the users might be more likely to feel a higher sense of presence in the IPT space if:

- The VE can be presented as a persistent space that can be entered and exited and is not dependent on the user seeing or entering it.
- The traversal into the VE involves some notion of travel or detachment from the real world.
- The VE is known to be a place that can be inhabited by other persons with whom the user can interact.

To achieve this we can use ideas from theme park design [10] and existing immersive VE examples. In this paper we will explore the potential of traversal boundaries and other techniques from mixed-reality in order to convey the sense of separation and traversal away from the real-world context. We will first explore the phases of the presentation of an IPT demonstration or application and then discuss some issues with the demonstration processes we have previously used. We will then present some scenarios that illustrate alternatives and our implementations of elements of these.

2. Phases of the Virtual Experience

We can distinguish several stages in the experience of a virtual environment:

1. Instruction
2. Entry
3. Boot-Strapping
4. Main Experience
5. Exit

The distinction is useful because each stage either involves a physical transition to or from the IPT system or involves an outside party such as an instructor or demonstrator. Thus phases 2, 3 & 4 take place inside the IPT but, if not handled properly, the third stage can be disruptive since it might involve several interventions by the instructor.

2.1. Instruction

Almost all VE experiences incorporate some form of pre-entry instruction. Even theme park rides do this to a certain extent with, for example, instructions for glasses and where to sit. With an IPT, where the experience is not so constrained, there are far more instructions such as what to wear on your feet, how the joystick or controller works and what the task is in the environment. The instruction phase may or may not take place with a view of the inside or outside of the IPT system, and the IPT may or not be on and showing a view of the VE.

In addition to direct instruction, the pre-entry phase may, depending on the goals of use, also seek to prime the user's expectations. For example, the user may be introduced to the subject matter of the experience, or it may be suggested that they will see or experience particular things.

2.2. Entry

By entry we refer to the few seconds where the user actually enters the system, usually by walking into the projection space or by having the system start up.

The entry to the VE is important for several reasons:

- Real-world information is blocked out and thus there is a separation between the user and their current situation.
- The virtual-world is introduced and this might be very different to the previous situation.
- The participant must build a cognitive model of the virtual-world to be able to understand how they interact with it.
- The participant may have a set of expectations about what the VE will look like. These might be based on previous experience with games or upon some of the more outlandish descriptions found in the media.

Imagine for a moment that a VR system existed where the transition between real-world and VE were seamless. Imagine that the metaphor was walking through a door way into a virtual space. Given that the user has experienced a real transition (walking) as well as a consistent virtual transition (going into the VR), we should expect "presence" to be high.

Without such a smooth transition, the "jump" that occurs can be disconcerting for users and might lead to a reduced sense of presence.

2.3. Boot-Strapping

The next couple of minutes when they learn the controls are less crucial than the immediate entry, but note that in some ways, entry into the VEs can be facilitated by a prior knowledge of the potential interaction techniques and application conventions that might be encountered.

As long as the experience is consistent and learnable, then the user will eventually be able to operate within the environment. This does not mandate a realistic modelling and representation strategy, but these are often used when novice users have to be supported by the application, since it is expected that there will very limited training time.

2.4. Main Experience

The main experience takes place once the user is familiar with the controls. It generally proceeds without serious problem unless there are further elements of the system to learn that are not immediately available or obvious to use.

2.5. Exit

The exit phase is interesting because, although we expect that re-orientation to the real world will be fast, there is a jump from the virtual model back to the real model. For some concerns (e.g. where you are trying to get people through the experience quickly) this jump is less important. However there are again some interesting expectations: the participant has a memory of the real place where they were, and they probably expect the experimenter/ride assistant to be there. For example, participants are often dis-oriented or surprised at the direction they are facing when they take off a HMD.

3. Issues and Problems

3.1. Maintaining a Sense of Presence

What we have seen and experienced in our own demonstrations are several processes that can detract from the sense of presence.

For technical and experiential reasons, the traversal into the IPT space is a problematic moment. The first few seconds of a virtual experience are often confusing while the participant gets their bearings and gets an impression of their location. This might be exacerbated by technical problems such tracking not synchronising until the participant is inside the IPT. In fact, it is common in the instruction and entry phases for tracking to be disabled until a sensible picture can be displayed.

The next stage, boot-strapping, is also problematic since the IPT interface and VE might be unusual even for non-novices. Thus an expert upon entering the environment will probably experiment with or ask the following types of question:

- Which buttons do what?
- Is gravity/collision detection enabled?
- Can I pick this/that up? Do I point or go over there?
- Does this or that do anything?

However, we often forget that novices who don't understand the interface can misunderstand some very basic concepts (c.f. [5]). For example, we commonly have to tell people that they can look around by moving their head, stretch to pick up an object just out of arm's reach or crouch when they want to look under something. With novices, who haven't experienced a range of applications and interfaces, this can lead to their having to ask questions of an experimenter. Indeed we often resort to repeating the instructions in context.

What happens in practice with an IPT is that the demonstrator often goes into the reactor with the user and shows them how to operate the controls. If the purpose is then for the user to experience the environment on their own, for example as might be required in a training scenario, then the demonstrator has to leave. However we have noted that on occasion, the user will call out for further instructions. There are two possibilities for their believing that this is possible. Either the user must be assuming the demonstrator is part of the environment, which in itself might violate a premise of the experiment, or they have experienced a break in presence [8,12] (see section 3.2 below).

Finally, the exit stage might seem less important, but in an experimental context this is often the moment for application of a questionnaire where it is important that the user reflect on the experience of the IPT. Thus there might be a controlled exit such as a prompt to leave given from inside the environment.

3.2. Breaks in Presence

Breaks in presence (BIPs) are moments where the user disengages with the VE task and becomes aware of the real context. In our previous work [8] we have considered presence as a gestalt, where the user switches between two hypotheses, "I am in the virtual environment", "I am in the real environment". Such switches, and particularly the ones from virtual to real are obviously significant events because they mean the participant has switched focus and is, to some extent, ignoring the alternate environment. Switching takes a period of time to occur, so after a BIP we believe that there is must be a period of re-engagement where the user regains their focus and attention. When a BIP occurs from virtual to real for a reason such as demonstrator intervention, we can thus expect there to be a short period of re-adjustment after the end of the intervention.

We have observed BIPs occurring for many reasons. For example, noises from outside, cables getting tangled, colliding with the walls, un-natural behaviours of objects, embarrassment and spontaneous realisation of the demonstration situation.

In the style of IPT demonstration where a group circulates in and out of the IPT, there are plenty of opportunities for BIPs to occur. These can result purely from interruptions such as visual or audio distraction or for more subtle reasons, such as a group presence in the IPT not making sense with respect to the story-line of the experience which might assume a single user role. For example, consider a first-person action game where spectators in the IPT might appear to the main player to be targets because they are not hiding behind the scenery as would be expected when under attack.

We can minimize some BIPs by careful staging and choices of technology. Others can be minimized through attention to usability within the application design. However users have a variety of expectations when entering the IPT and thus in the following sections we will discuss techniques to prime their expectations so that BIPs will not be so prevalent.

4. Boundaries and Traversals

To alleviate some of these problems we propose several scenarios that can be used to ground a wide variety of applications. In each scenario we aim to emphasise the separation of the user from the real environment, and their potential integration into the VE.

4.1. Virtual Ante-Room

One of the problems mentioned with the entry phase is that it can be quite abrupt, leaving the users confused because they do not know what to expect to see and experience. The virtual ante-room technique employed in [9], originally for an experiment with a HMD system, can help with this entry. In that experiment, when the participant put on the helmet they saw a virtual copy of the real world. The real world in this situation was a small partition of a laboratory, with an arch that had been replaced with a doorway. The main experience took place in a VE through the doorway, and the final step of preparation was to go through the new door into the main virtual space. This splits the transition into two steps, the second of which (the transition from virtual lab to main VE) is a continuous experience.

In [9], Slater & Steed used this two-step transition to aid the giving of instructions to the users. They found that when participants don the HMD they often totally forget the instructions for the experience because they had not been given in context. Once they repeated the instructions in the Virtual Ante-Room the participants usually did not forget them.

With an IPT display the entry to the display device is very different. It requires entering the IPT space, which is a physical transition. However this space is itself quite detached from the laboratory, since it consists of white or black walls (if the display is off), or the virtual environment (if the display is on).

With a HMD the physical and virtual can be thought of as overlapping, but with only one currently visible (compare augmented reality systems, in which both are simultaneously visible). In an IPT the situation is more "tardis-like"[1]. It can seem almost as if there is no physical space, since the IPT itself is a plain white space, and the user need not attend to it while the IPT is active. The user also does not know if there is anything behind the walls. There is a sense in which the IPT "pushes away" or separates the participants from real space.

The IPT equivalent of the virtual ante-room would be a model of the IPT, projectors and system. When entering the IPT the screens would appear to be transparent and the participant would see virtual models "behind" the screens. Participant would then put on the glasses and hold the tracker, and could move around a small amount in the virtual-IPT. Then the real lights would be dimmed as the main VE was faded in over the virtual-IPT, or the VE could be accessed through the door back into the entry space.

4.2. Virtual Presenter

With the virtual ante-room the experimenters repeated the instructions once the participant was inside. We could take this further by representing the experimenter or another user inside the environment. This could be a virtual puppet controlled from a desktop, or a tracked user on another system. We could invest time in making a realistic avatar for the experimenter and have them also traverse into the display. This could make the traversal process social, and a virtual actor is in any case a good immersive cue [7]. We could reinforce the sense of traversal by having the virtual experimenter be seen to leave and go back to the real world.

4.3. IPT Garden

The IPT garden is based on lessons from theme park rides. Theme park rides often show participants something of what they can expect when the ride starts. For example, introducing the characters and back-story of the experience or even describing the controls. Such familiarization can make the environment less surprising when actually entered. It also conveys the impression that the VE exists before the user enters it and has a life of its own. Such impressions can assist with the entry and bootstrapping phases of the experience.

In practice we can achieve such effects quite easily by setting up displays outside the IPT where fragments of the VE “leak out” in the surrounding space. For example, the user might see limited views of the environment through windows that might be explained as if they were remote cameras.

4.4. Traversable Display

In some ways this is the logical extension of the IPT garden. The participant goes from observer to participant by stepping through some kind of screen [3]. Several aspects of the experience change; the display go from exo-centric to ego-centric viewpoints and thus the scale

[1] http://www.bbc.co.uk/cult/doctorwho/

and orientation of the VE are resolved; and direct manipulation rather than ray based selection becomes possible, i.e. body-centred interaction becomes possible.

4.5. Wearable Interfaces

One of the aspects of training for VE tasks is that we often resort to giving the instructions twice: once before the experience and once just after the user has put the helmet on or entered the IPT. One reason for this is that it is hard to describe some controls (e.g. point and press to fly) abstractly and without the user experiencing the visual flow that results. Similarly some actions that are easy to explain (e.g. put your hand on the object and press to pick) are actually harder to perform than the user might expect. Thus some coaxing and re-iteration of the actual actions to perform might be necessary simply because they did not remember the action, thinking it obvious, or misinterpreted the instructions. A further reason is that reminding of the task whilst in-place reinforces the task description.

Using a wearable interface may simplify this transition, by allowing the user to don the interface devices before entering the system. They could also rehearse tasks such as pointing and pressing using tangible artefacts with suitable real-world feedback. This could be as simple as audio feedback or objects lighting up if pointed at. This could be done in front of a semi-immersive display such as a large screen. Ideally the wearable would incorporate the tracking devices (and stereo glasses) so the user could then walk straight into the IPT.

5. Demonstration

We have implemented elements of these scenarios in a recent demonstration. We reflect on how they affected the process of demonstration from the point of view of the demonstrators and the visitors.

5.1. Overview

The demonstration used the UCL ReaCTor that has three walls and a floor. It is driven off an SGI Onyx2 that has eight R10000 processors, 8GB ram and four Infinite Reality pipes.

Outside the ReaCTor there is a small curtained area that is itself partitioned off from a control area. For this demonstration, we additionally used a small room beyond the curtained area which was used for the mobile digital assistant described below.

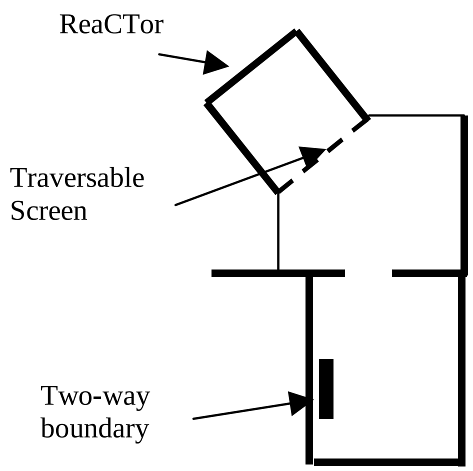

Figure 1 Overview of the IPT space showing the sites of the different projections

5.2. Traversable Boundary

A two-layer paper screen was placed in front of the ReaCTor completely covering the open fourth side. The paper screen was cut into vertical strips, with the two layers being overlapped so that the light did not normally leak in or out. The two layers prevents the projection from the outside being visible inside, and thus this fourth wall is plain and dark on the inside.

A small projector cast an image on the outside of the screen. The viewpoint for this image was a fixed point at an average eye-level outside the IPT and this was fixed relative to the IPT co-ordinates. This meant that the image appeared to be a window onto the space that followed the IPT user as they navigated the space. An avatar was drawn in the view, so that observers could effectively see the user inside the IPT. In Figure 2, a user can be seen exiting through the traversable screen.

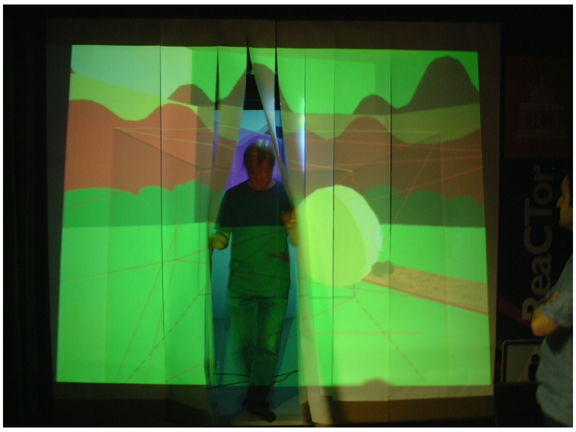

Figure 2 The traversable curtain.

With regard to the logistics of a demonstration, users inside the IPT are partitioned away from those outside. Additionally users outside can see the system in use, which helps when explaining the system to waiting attendees. Thus we can have two groups in different stages of a demonstration without the groups interfering with each other.

Given the relationship of external video projection and IPT co-ordinate system, we can have the demonstrator present the system from inside the IPT by having them face the paper screen and talk towards the users currently standing outside. This in itself is quite a novel experience, but the demonstrator can emphasise the transition from real to virtual by stepping out through the screen. At the transition point it can be arranged for the avatar to disappear by having the near clipping plane of the outside camera view be coincident with the paper screen.

From the user's point of view there is a definite transition point from the outside into the VE. They will also have an idea of what to expect inside the VE and they will have seen that the VE has a life of its own.

A final advantage is that the user can don the tracker and controls outside the system under observation of a demonstrator who can check simple things such as the stereo glasses being properly turned on. Once set up, the projection is live as soon as the user steps through the curtain. This in itself streamlines the bootstrapping phase of the demonstration, and there need not be so much demonstrator interference for technical reasons during the actual demonstration.

5.3. Mixed-Reality Collaboration

We further blurred the boundary between the VE and the real world by having an additional mixed reality window and collaboration with an external user.

A two-way boundary screen was set up in the room outside the ReaCTor. This screen, a large plasma display, showed a view of the VE from a fixed point in the virtual space. Through this visitors could see the environment and, occasionally, the IPT user. A video view from a camera on top of the plasma display allowed the IPT user to see who was watching the screen. This video view was pasted onto a model of the plasma display within a virtual model of the room. Thus the plasma display became a two-way window.

A single user within the real space could carry a PDA (a HP Jornada) that was tracked using an ultrasonic tracker [6]. Within the VE we modelled an avatar at this position and this allowed the IPT user to see in actual scale what the real user was pointing at. The PDA displayed a map so that the real user could follow the movements of the IPT user.

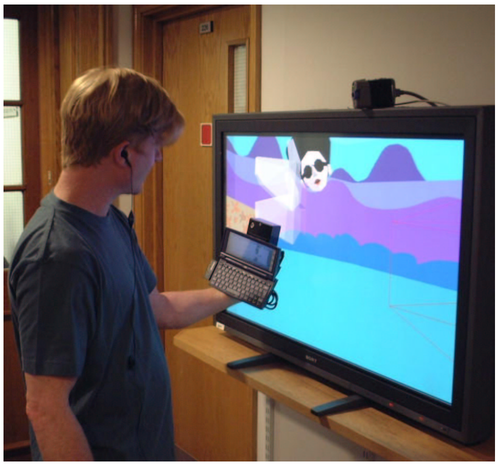

Figure 3User with PDA facing the two-way boundary. The IPT user's avatar can be seen on the display. The IPT user would have been able to see the PDA user via the video camera on top of the display.

Finally a second one-way video boundary was set up within the VE. The video texture showed a view of the area immediately outside the IPT as if it was the view through open wall. The IPT user could view this screen as part of the VE. Note that we could consider the projection on the traversable paper screen and this video texture in combination as a two-way boundary. However note that, unlike the other two-way boundary, the spatial relationship between the users is not known, because the traversable screen display follows the IPT user's navigation, but the video texture is fixed in the VE world co-ordinates. This makes an asymmetrical spatial relationship between users inside and outside. The user(s) inside the IPT see the video image of the others receeding as they navigate away from the boundary. However the user(s) outside always see the avatar image of a user inside as being relative stationary.

For the demonstrator, the two-way boundary served to emphasise to the IPT user that they are in a live, persistent space within which they can collaborate with others. We could have supported collaboration with another VE user on a desktop or another IPT, but in this demonstration we wanted to emphasise collaboration with a real space through the use of an IPT. This collaboration further blurred the boundary between the real world and the VE because it established an overlap between the real space that the PDA user inhabits and the virtual space projected on the IPT.

For the IPT user these techniques served two of purposes. First the two-way boundary window served to introduce elements of the VE to waiting users, making the VE more familiar. Second, the one-way boundary emphasised the notion of traversal away from the real space.

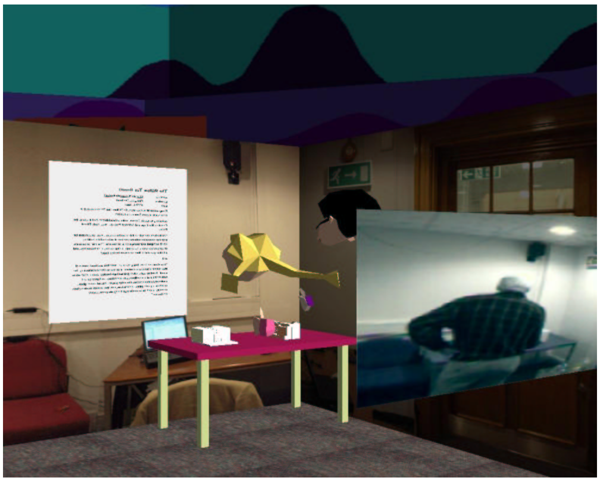

Figure 4 Third person view looking at the two-way boundary view back into the real space with the VE model of the real space. The avatars of the real user and the IPT user can both be seen facing a table.

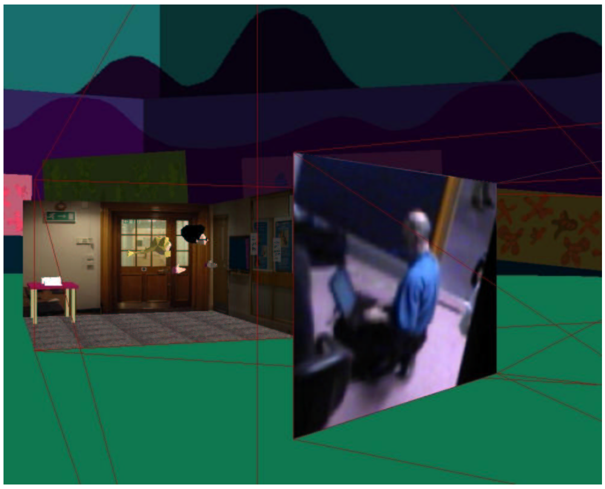

Figure 5 View of the one-way boundaryshowing someone outside the IPT. This view emphasises the traversal of the IPT user away from real space as they navigate in the virtual space.

5.4. Implementation

The demonstration was implemented with the Equip platform (www.equator.ac.uk/equip). This provides a real-time data sharing mechanism that builds upon experience from earlier CVE platforms, particularly Massive [2]. Any number of processes can connect to an Equip data-space and add and access data elements within it. A data-space can discover implementations of data elements at run time, and can dynamically load supporting classes. The run-time supports both Java and C++ clients and hides the serialisation process.

Equip was designed to allow data sharing between very different classes of device. In particular, IPT support has been added through an Equip client that is written on top of VRJuggler [1]. All six rendered views (four in stereo for the ReaCTor, one for the traversal screen and one for the plasma screen) were generated by the SGI using with a suitable VRJuggler configuration.

The PDA used software written in C++ with the Windows CE toolkits. A wireless network provided base connectivity and the PDA communicated with Equip through a proxy server. Custom software was used on the PDA for map drawing. The Java version of Equip will itself run on some pocket PCs, but we did not use that facility in this demonstration.

6. Conclusions

We hope to have shown that there are many ways in which to vary the presentation of an IPT system. By looking at the traversal into and out of the space we have emphasised that an IPT system is not always used as "pure" virtual environment system and that there are definite stages within the presentation where the interface is more mixed. We have presented some scenarios and subsequent demonstrations where we have explored the relationship between "real" and IPT users, and how the sense of presence for IPT users might be affected. We anticipate doing more in-depth experiments to investigate the effects on presence for the users.

In the coming months we will implement more of the scenarios presented here. We are specifically working towards using the PDA both in the real space and as an interface within the IPT. This will allow us to train the users with the PDA and then have them carry the interface into the IPT. This should further relieve the problem of explanation. We will then look at experiments on the quality of collaboration between the real and IPT user.

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References

1. Bierbaum, A., Just, C., Hartling, P., Meinert, K., Baker, A., Cruz-Neira, C. VR Juggler: A Virtual Platform for Virtual Reality Application Development, IEEE VR 2001, Yokohama, March 2001
2. Greenhalgh, C., Purbrick J., Snowdon, D., Inside MASSIVE-3: Flexible Support for Data Consistency and World Structuring, Proc. of ACM Conference on Collaborative Virtual Environments (CVE2000), San Francisco, USA, pp. 119-127
3. Koleva, B., Schnädelbach, H., Benford, S., Greenhalgh, C. Traversable interfaces between real and virtual worlds, Proceedings of the CHI 2000 conference on Human factors in computing systems, April 1 - 6, 2000, The Hague Netherlands, pp 233-240
4. Milgram, P., Kishino, F. A taxonomy of mixed reality visual displays, IEICE Transactions on Networked Reality, E77D (12), 1321-1329, 1994.
5. Pierce, J., Pausch R., Sturgill, C., Christiansen, K. Designing a Successful HMD-Based Experience, Presence: Teleoperators and Virtual Environments, 8(4), August 1999, pp. 469-473
6. Randell, C., Muller, H. Low Cost Indoor Positioning System. In Gregory D. Abowd, editor, Ubicomp 2001: Ubiquitous Computing, pages 42--48. Springer-Verlag, September 2001.
7. Slater, M., Sadagic, A., Usoh, M. and Schroeder, R. Small Group Behaviour in a Virtual and Real Environment: A Comparative Study. Presence: Teleoperators and Virtual Environments. 9(1), 37-51, 2000
8. Slater, M., Steed, A. A Virtual Presence Counter, Presence: Teleoperators and Virtual Environments, 9(5), October 2000
9. Slater, M., Steed, A., McCarthy, J., Maringelli, F., The Virtual Ante-Room: Assessing Presence through Expectation and Surprise, Virtual Environments '98 Conference & 4th Eurographics VE Workshop.
10. Stapleton, C. Theme Parks: Laboratories for Digital Entertainment, in Digital Illusion, Dodsworth Jr., C, Addison Wesley, 1998, pp 425-438.
11. Steed, A., Slater, M., Sadagic, A., Tromp J.,.Bullock, A Leadership and collaboration in virtual environments, IEEE Virtual Reality, Houston, March 1999, p112-115, IEEE Computer Society
12. Usoh, M. ,Arthur, K., Whitton, M. , Bastos, R. , Steed, A., Slater, M. , Brooks Jr., F., Walking > Walking-in-Place > Flying, in Virtual Environments Siggraph 1999, Computer Graphics Proceedings, Annual Conference Series, Los Angeles, 1999, pp. 359 – 364