Designing A Successful HMD-Based Experience

Abstract

For entertainment applications, a successful virtual experience based on a head-mounted display (HMD) needs to overcome some or all of the following problems: entering a virtual world is a jarring experience, people do not naturally turn their heads or talk to each other while wearing an HMD, putting on the equipment is hard, and people do not realize when the experience is over. In the Electric Garden at SIGGRAPH 97, we presented the Mad Hatter's Tea Party, a shared virtual environment experienced by more than 1,500 SIGGRAPH attendees. We addressed these HMD-related problems with a combination of back story, see-through HMDs, virtual characters, continuity of real and virtual objects, and the layout of the physical and virtual environments.

1 Introduction

Entertainment is an obvious application for virtual reality based on head-mounted displays (HMDs) (Sutherland, 1968). However, our experiences using HMDs for entertainment show that most successful HMD-based virtual experiences must overcome at least five key problems with the guest experience:

1. Entering a virtual world is a jarring experience. In most virtual experiences, the guest enters the virtual world by putting on an HMD, which is already displaying the virtual world or has it ''switched on'' moments later. An abrupt transition from the real world to the virtual world forces guests to spend time adjusting to the new space. Informal observations (Brooks, 1988) by researchers suggest that this time is approximately thirty to sixty seconds, depending on the complexity of the world. We need to develop methods to shorten this time, especially for entertainment applications where the guest's experience is only four to five minutes long.
2. Guests do not turn their heads, as documented in Disney Imagineering's Aladdin project (Pausch, Snoddy, Taylor, Watson, & Haseltine, 1996). We do not believe that guests failed to turn their heads simply because of the weight of the HMD or because they were engaged in flying. Other researchers have commented on this phenomenon (Fred Brooks, personal communication), and our experience is that guests have been trained by viewing television and film screens, where head turning is counterproductive, and do not fully grasp that they can turn their heads while wearing an HMD. If we cannot get guests to turn their heads while wearing an HMD, there is little need to go to the expense of creating a system using head tracking and an HMD: a large projection screen would provide a wider field of view and a higher-resolution image.
3. Putting on an HMD is an isolating experience: guests do not talk to each other. Many new virtual experiences are shared multiperson worlds. Guests are often reluctant to talk to each other in these worlds: they have trouble identifying which avatars are their friends, and wearing an HMD can discourage conversation.
4. Putting on the equipment is cumbersome. To keep high throughput, entertainment applications need to load and unload guests quickly. Because the HMD blocks out the real world, guests have a

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Figure 1. *A guest turns her head at the Mad Hatter's Tea Party*

hard time finding and grabbing any objects they need to hold as part of the experience. Grabbing these objects beforehand is usually impossible because guests need both hands to don most HMDs.

5. Guests do not know when to take off the HMD. When the virtual experience ends, many guests are not sure if the experience is over. Virtual experiences need to clearly communicate when the experience has ended.

We debuted the Mad Hatter's Tea Party (Figure 1), a multiperson shared virtual environment, in the Electric Garden at SIGGRAPH 97. Our goal was to design a virtual experience that overcame all five problems by applying as many VR design principles as possible. We achieved our goal by using a combination of back story, graceful transition from the real to virtual world, and careful choice of content.

2 The Virtual Experience

The show concept was to have four guests participate in a virtual tea party. The guests sat at a circular table in a darkened area; an HMD and a functioning flashlight (with a tracker inside) were on the table at each seat. (See Figure 2.) The HMDs had see-through and opaque modes, with a software control to switch between them. We implemented the see-through mode

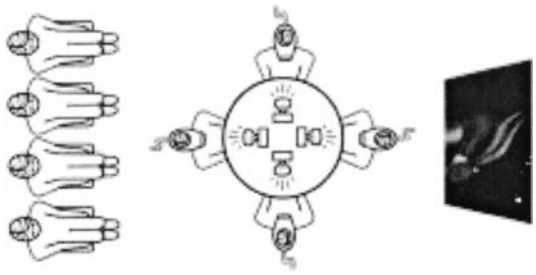

Figure 2. *The layout of the Tea Party. People in the queue area on the left could see the guests and a screen displaying in real time what one guest was seeing.*

using a video camera attached to the HMD; another possible implementation would be to use an HMD with a semitransparent display and then control the lighting conditions. The show began with the HMD in see-through mode. At this point, guests were typically looking at each other through the HMD and illuminating each others' faces with their flashlights.

We then flashed strobe lights, avoiding frequencies known to cause photoinduced epilepsy. While the strobe lights were flashing, we switched the HMDs to display the virtual world, within which we were flashing a virtual strobe light. When we stopped the virtual strobe light, guests found themselves seated around a circular table in the virtual world with three avatars in the same positions that their friends had been in the real world. We originally considered a video fade transition, but using the strobe lights masked the misregistration of the real and virtual worlds.

In the virtual world, just as in the real world, guests could wave to each other, or illuminate objects and each other with their flashlights. Pushing a button on the flashlight while pointing it at an object caused that object to respond in a humorous way: tea cups might zoom away like rockets, saucers might levitate off the table, and tea pots might swell up and explode. At the end of the experience, a dragon burst through the table (Figure 3) and breathed fire on each of the avatars, one after another. When the dragon finished, we started the real and virtual strobe lights flashing again, then switched the HMD back to see-through mode. When we stopped the real strobe lights, guests found themselves back in the real world.

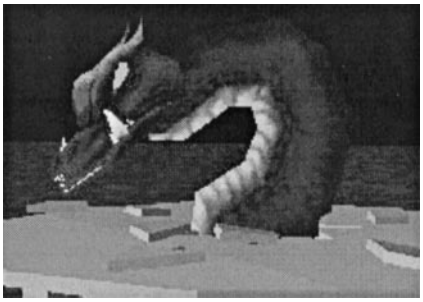

Figure 3. *The dragon from the Tea Party.*

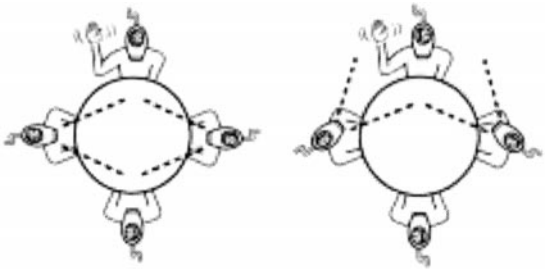

Figure 4. *Guests had to turn their heads to see the guests on their left and right. The figure shows view frustums for the guests on the left and right.*

2.1 Entering the Virtual World

A good ''back story'' reduces the time guests need to assimilate the virtual world. The back story tells guests what to expect when they enter the virtual world. Disney used the movie *Aladdin* as the back story for the Aladdin project, and many location-based entertainment (LBE) and theme park attractions use the queueing area to tell the back story for the attraction. For the Mad Hatter's Tea Party, we used *Alice in Wonderland* for our back story. An existing story is not critical; the most important part of the back story is to show guests a visual preview of the exact imagery they will see during the experience. Concept artwork is not as effective as showing guests the same images they will see in the HMD; this may be especially true for more abstract virtual worlds. At SIGGRAPH 97, guests knew what to expect in the virtual world because they could see the image being displayed in one of the HMDs while waiting in the line.

We also made use of cues to ground the guest in the transition from the real to the virtual world. We seated guests around a circular table in both the real and virtual worlds. In addition to providing continuity, this meant that guests could actually feel the table in the virtual world. We made the seating arrangements the same in both worlds to make it easier for guests to identify the three avatars as their friends. The flashlights also illuminated objects in both worlds.

2.2 Turning Heads

Because guests started the experience looking at the real world through the HMD, they very naturally turned their heads: they simply assumed they could. The smooth transition from the real to virtual world made it natural for them to continue turning their heads in the virtual world.

We chose the seating arrangements to encourage head turning: because of the 60 deg. horizontal field of view of the HMD, a guest had to turn his head to see his two friends to the left and right (Figure 4). If all four guests did not know each other, we made sure that two friends sat next to, rather than across from, each other; in most cases, this happened naturally. We found that where characters look in the virtual world directs attention. We updated the avatars' head position in the virtual world to match where the guests were looking: this led some guests to turn their heads to look where the other avatars were looking. The dragon was particularly effective in this respect: guests would turn their heads to look at the guest the dragon was breathing fire at. We encouraged this by charring that avatar's face.

2.3 Communication

Because guests identified the avatars with their friends, they talked to each other during this experience. We also tried to encourage talking by applying the principle that guests care about their self-image: pointing the flashlight at another avatar and pushing the button caused that avatar's head to turn into something humorous, like a snowman's head. When guests realized this, they would often tell a friend what his head looked like, and ask about their own head's appearance.

2.4 Reducing Load Time

Having the camera on the HMD reduced load problems because, after donning the HMD, guests could still see the real world to pick up their flashlights. One load issue we did not address was the time required for guests to physically don the HMD; Disney solved this problem for the Aladdin project by having the guests put on an inner liner for the HMD in the queueing area. The HMD then quickly snapped in place over the liner.

2.5 Taking off the HMD

The transition from the virtual to the real world clearly communicated that the virtual experience was over. Because the quality of the camera's output in the HMD was worse than looking at the world unimpeded, guests had an incentive to remove the HMD. As soon as the strobe light stopped the vast majority of guests immediately removed the HMD. Prior to this project, we experimented with other methods of communicating that the experience was over, and discovered that most guests will sit and watch *anything* dynamic in an HMD, even if head tracking is turned off. One exception is scrolling credits (Mark Bolas, personal communication).

3 Related Work

A variety of virtual worlds exist for scientific, entertainment, and artistic purposes, but most of the literature describing this work does not discuss the guest experience beyond describing the virtual world itself. Instead, this body of literature focuses on the engineering, artistic purposes, and scientific implications of these systems. Azuma and Bishop (1994), Pausch et al (1996), and Davies (1995) are representative of this body of work.

There are now several commercial HMD-based attractions. The ''Fire Bull'' attraction at Joypolis (Joypolis, 1997) also uses cameras to create a see-through HMD. Two guests sit in a helicopter pod where all the window surfaces are green. Computer-generated imagery is ''green screened'' into those areas, and through the HMD a guest sees interior theming, himself, and his friend set against the virtual backdrop.

In Disney Imagineering's original Aladdin VR attraction, guests donned an HMD and flew a magic carpet around Agrabah collecting pieces of the genie's lamp. This project was a first step toward telling interactive stories using virtual reality, and raised many of the difficult issues in creating a successful virtual experience. More recently, Disney opened DisneyQuest at Disney World in Orlando (DisneyQuest, 1998). DisneyQuest features several multiperson HMD-based attractions, including the six-person ''Ride the Comix'' and a four-person version of ''Aladdin's Magic Carpet Ride.''

4 Conclusion

Based on informal observation of and feedback from the more than 1,500 SIGGRAPH attendees who experienced the Mad Hatter's Tea Party, we believe we were successful in presenting an entertaining and enjoyable show. The success of our show required overcoming five key problems:

1. **Entering a virtual world is a jarring experience.** We used Alice in Wonderland for our back story, showed the guests the exact imagery they would see in the HMD while they were waiting in the queue line, and created a smooth transition from the real to the virtual world using strobe lights and see-through HMDs that helped ground the user in the virtual world.
2. **Guests don't turn their heads.** We used see-through HMDs, virtual characters, and careful layout of the real and virtual spaces.
3. **Wearing an HMD is an isolating experience.** We made it easy for guests to identify the avatars with their friends, and utilized the fact that people care about their self image.
4. **Guests have difficulty picking up equipment while wearing the HMD.** We used see-through HMDs so guests could see the equipment.
5. **Guests aren't sure when the experience ends.** We

used a transition sequence that clearly communicated when the experience was over.

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