Combining Interaction Techniques and Display Types for Virtual Reality

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Published in:
Proceedings of OzCHI 2001

Publication date:
2001

Document Version
Early version, also known as pre-print

COMBINING INTERACTION TECHNIQUES AND DISPLAY TYPES FOR VIRTUAL REALITY

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ABSTRACT

Full and partial immersion in virtual reality are fundamental different user experiences: partial immersion supports the feeling of "looking at" a virtual environment while full immersion supports the feeling of "being in" that environment. Working with a range of interactive virtual reality applications using different display systems we have found that the use of six-sided caves and panoramic displays results in different requirements to interaction techniques. These can be related to specific categories of interaction: orientating, moving and acting. In this paper I present a framework for the evaluation and design of interaction techniques for virtual reality focusing on the relations between interaction techniques and display types.

KEYWORDS

Virtual Reality, Interaction Techniques, Interaction Devices, Display Types, Field of View.

1. INTRODUCTION

A central issue within human-computer interaction is the creation of better ways of interacting with computers (Dix et al. 1998, Preece et al. 1994, Shneiderman 1998). Designing good interaction techniques in new areas of computing such as virtual reality is, however, not trivial. Interaction devices and display types are numerous and general knowledge on the implications of combining the two is needed. How are interaction techniques influenced by the use of different display types? Which parts of the interaction is influenced by which display types and why? How can display types be categorized appropriately in relation to interaction? In this paper I address these questions. I start out by presenting the experiment. I then present an overall categorization of display types for virtual reality and a division of the concept of interaction based on our findings. The categorization of displays and division of interaction are then related in a matrix summarizing our evaluation of interaction techniques.

2. THE EXPERIMENT

A qualitative pilot investigation of interaction in virtual reality was conducted over a period of 6 months. For this investigation we used two different display systems: an 8x3 meter cylindrical panoramic display covering a field of view (fov) of 160° and a six-sided cave measuring 2½ meter on each side. For interaction we used Polhemus Fastrak motion tracking, an SGI Spacemouse (3D mouse), a "magic wand" (3D joystick) and a wireless trackball from Logitech with tracking via the Polhemus system. During the investigation we implemented and evaluated the usability of more than 40 interaction techniques for specific combinations of these displays and interaction devices. The interaction styles were tested within a number of virtual reality applications ranging from industrial design and simulation to interactive games and virtual reality art. The interaction techniques were tested in random order.

Figure 1: The six-sided cave

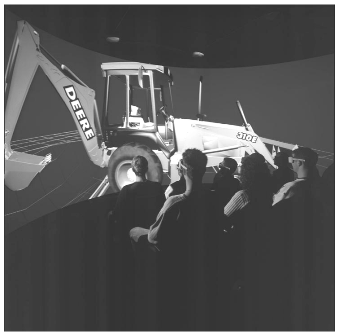

Figure 2: The panoramic display

Six test users participated in the experiment. The test users were all experienced with virtual reality but had no particular experience with the specific applications. The tasks to be performed by the test users primarily addressed orientating and moving in the virtual 3D spaces of the applications as well as selecting and manipulating 3D objects. The test sessions lasted approx. 10 to 15 minutes pr. interaction technique. Data was collected through qualitative observations of use and statements by the test users noted during and after the test. The test users were asked to describe their experience with the interaction technique: was it hard to learn? Was it hard to operate? Did it cause any problems? Did it limit any part of the interaction? Some statements led to the immediate development and test of further interaction techniques.

3. VIRTUAL REALITY DISPLAYS

The literature on virtual reality indicates use of a wide range of different display types: fishtank virtual reality, head-mounted displays (hmds), boom-mounted displays (booms), holobenches, large panoramic screens and caves with a different number of sides (Schneiderman 1998, Dix et al. 1998, Stuart 1996). These different displays have fundamental different characteristics, potentials and limitations (cf. Buxton et al. 1998, LaViola Jr. 2000).

3.1 Full and partial immersive displays

Full and partial immersion in virtual reality are fundamental different user experiences: partial immersion supports the feeling of "looking at" a virtual environment while full immersion supports the feeling of "being in" that environment (Schneiderman 1998:221-222). The potentials for immersing the user in a virtual environment is often measured from the *field of view* (fov), which describes how much of the user's view can be covered. This suggests that e.g. panoramic displays are more immersive than head-mounted displays. However, as the fov is measured from a fixed position in a fixed direction and users interacting in a virtual environment are typically *not* remaining still, other properties should also be considered.

Figure 3: Full immersive displays for virtual reality: six-sided caves, hmds and booms (hmd mounted on stand and operated by hand)

I suggest the notion of *available field of view* describing the fov available in *any* given viewing direction. If a display always provides an available field of view, it is considered a *full immersive display*. If a display does not always provide an available field of view, it is considered a *partial immersive display*. Using this notion, display types for virtual reality can be categorized as shown in figure 3 and 4.

Though hmds and booms have relatively low fov compared to holobenches and panoramic screens, it is available in all directions the user may be orientating due to the construction of the display. This makes hmds and booms full immersive. The opposite is the case with most large stationary virtual reality installations such as holobenches, powerwalls, panoramic screens and 3-5 sided caves. These display types only provide their (high) fov within a given direction. Of special interest is the fact that caves fall into both categories depending on the availability of the 6^{th} side. Six-sided caves thus surround the user completely and can be characterized as full-immersive displays whereas 3-5 sided caves are only partial immersive.

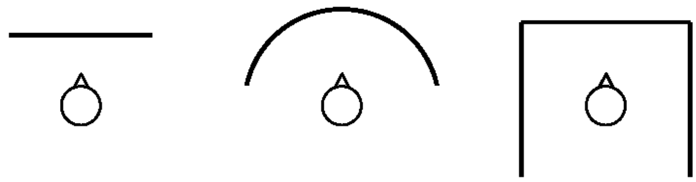

Figure 4: Partial immersive displays for virtual reality: monitors/holobenches, panoramic screens and 3-5 sided caves.

The partial immersive displays depicted in figure 4 are characterized by the fact that they do not provide their optimal fov in all directions. When using partial immersive displays the immersive experience is highly vulnerable to the user changing viewing direction, because the display simply leaves out an area where the virtual environment is not projected. When using full immersive displays this is not a problem.

4. INTERACTION IN VIRTUAL REALITY

The literature on interaction in virtual reality suggests that conceptual frameworks for interaction can influence significantly on the quality of interaction techniques. A characterization of universal interaction tasks in virtual reality and taxonomy for interaction techniques is presented in Bowman (1998) and used in Bowman et al. (1998) to create a highly interactive virtual reality application. The prototype, however, makes solely use of a head mounted display and is not considered in relation to different display types. It could be interesting to see how the techniques perform with other displays. A theoretical framework for analyzing manipulation techniques and a testbed for experimenting with different interaction techniques is presented in Poupyrev (1997) followed by taxonomy of manipulation techniques based on a number of prototypes in Poupyrev et al. (1998). The prototypes tested, however, make exclusively use of head-mounted displays. How different display types could contribute to the taxonomy would be interesting.

4.1 Dividing the concept of interaction

We found that using simply the notion of *interaction* made it hard to describe and clearly differentiate the specific problems we encountered. There may be several reasons for this. First the concept of interaction and interactivity suffer from long-term use as buzzwords. Second virtual reality calls for fundamentally new ways of interacting with computers, supporting the user being present inside a virtual world. We therefore found it suitable to divide the concept of interaction into three more specific categories: *orientating, moving* and *acting.*

Orientating oneself in virtual reality addresses the need for being able to look around in a virtual environment developing a sense of presence. A common approach is rotating the virtual world while the user remains still.

Moving in virtual reality addresses the need for being able to move around in a virtual environment. This is typically done by motion tracking. But because virtual worlds are typically larger than the physical area within which they are explored, alternative solutions are necessary. A common approach is letting the user move the virtual world by e.g. a joystick while remaining still.

Acting in virtual reality covers both the tasks of selecting, moving, rotating and transforming objects in the virtual environment as well as control on a system level. Acting is typically supported by variations of *virtual hand* or *virtual pointer* techniques (Poupyrev et al. 1998). Others go beyond this trying to support “natural” acting in virtual environments by means of gesture recognition (Moeslund 2000).

5. DISPLAY TYPES AND INTERACTION TECHNIQUES

In the table below, the lessons learned from our experiment are organized in relation to display types and interaction techniques. Headtracking with "active zones" and "mapped 1:2" is described in section 5.1.

TABLE 1

LESSONS LEARNED: RELATIONS BETWEEN INTERACTION TECHNIQUES AND DISPLAY TYPES

<table>
<tr><th colspan="2">Interaction technique</th><th>Partial immersive displays
(Panorama)</th><th>Full immersive displays
(Six-sided cave)</th></tr>
<tr><td rowspan="6">Orientating</td><td>Headtracking</td><td>1) Problematic because the user can't orientate 360° by simply looking in the desired direction.</td><td>2) Very intuitive because the user can orientate simply by looking around as in the real world.</td></tr>
<tr><td>Headtracking with active "zones"</td><td>3) Limits freedom of movement. Conflicts with orientating in the physical world.</td><td>n/a</td></tr>
<tr><td>Headtracking mapped 1:2</td><td>4) Easy to learn and fast in use. However makes it hard to gain feeling of presence.</td><td>n/a</td></tr>
<tr><td>Joystick</td><td>5) Easy to use. Better than trackball for fast/continuous rotations.</td><td rowspan="2">6) Supports viewing the virtual environment from "odd perspectives" as addition to headtracking. Frees the user from moving physically. Trackball supports more precise rotations than joystick.</td></tr>
<tr><td>Trackball</td><td>7) Easy to use. Better than joystick for precise/absolute rotations</td></tr>
<tr><td>Spacemouse</td><td>8) Supports rotating and moving the virtual world at same time. Hard to learn how to operate smoothly.</td><td>9) Can be used with hmds but is not well designed for hand-held use in the cave without additional tracking.</td></tr>
<tr><td rowspan="4">Moving</td><td>Position tracking</td><td colspan="2">10) Very intuitive to use within the limits of the physical space available. However, typically demands further support for moving the virtual world (e.g. by means of joystick, trackball or Spacemouse).</td></tr>
<tr><td>Joystick</td><td colspan="2">11) Flying in the direction the stick is moved. Easy to use but not suited for both fast and precise movements. Need "gears" to control flying speed. Supporting orientating with same device is problematic – demands shifting between several modes of operation.</td></tr>
<tr><td>Trackball</td><td colspan="2">12) Flying in the direction the ball is rolled. Great feeling of control over small movements. Not suited for moving long distances. Supporting orientating with same device is problematic – demands shifting between several modes of operation.</td></tr>
<tr><td>Spacemouse</td><td>13) Works fine if user remains still. Performs well along with headtracking but is hard to learn to operate smoothly.</td><td>14) Does not work well. Device must stay in fixed orientation in relation to the display. Is hard to learn to operate smoothly.</td></tr>
<tr><td rowspan="2">Acting</td><td>Virtual hand (using tracking)</td><td>15) Does not support "close-by" acting unless user stands close to the screen.</td><td>16) Can be projected close to physical hands but the user's body might occlude graphics.</td></tr>
<tr><td>Virtual pointer (using tracking)</td><td>17) Large screens have good affordances for "pointing at" objects in a VE.</td><td>18) May support moving in pointing direction by indicating direction visually</td></tr>
</table>

From the data summarized in table 1, we identified a number of interesting issues. Due to limited space, however, only four of these issues are described in detail in the following sections.

5.1 Untraditional use of headtracking

We implemented two interaction techniques that rotated the world by the use of headtracking (table 1, issue 1-4). These techniques each had significant downsides. Mapping the horizontal orientation of the headtracker 1:2 to the horizontal rotation of the virtual world facilitated "turning around" in the virtual environment by looking only 90° to the left or right. Though satisfied with the speed ease and speed of use, test users complained that the technique made them disoriented and seasick. Using a technique that rotated the virtual world in a given direction by looking towards the edges of the display ("active zones"), did not result in these problems. Test users, however, complained that they could not face away from the display without spinning the virtual world. A button for deactivating the active zones was suggested. Though having potentials for orientating in partial immersive displays, mapping the user's orientation this way thus challenges the boundary between interacting in the virtual and the physical world.

5.2 Complementing headtracking in full immersive displays

Using full immersive displays, test users expressed a need for viewing the virtual environment from perspectives, which were hard to obtain by moving physically. We therefore developed techniques for rotating the virtual world in the cave by using joystick or trackball while remaining still (table 1, issue 6 and 9). All users expressed satisfaction with this technique as a supplement to headtracking. Observing test users playing CAVEQuake in the six-sided cave, however, revealed that it caused the users to *always* use the joystick when "turning around" rather than turn around physically. Test users at the same time surprisingly expressed, that the level of immersion in the six-sided cave was not much higher than when using the panoramic screen. We then disabled rotation by means of joystick, forcing the user to turn around physically. The immersive effect was enormous. Test users reported a significant higher level of immersion and within few minutes had difficulties defining the position of the cave-walls and identifying which one was the door. Complementing headtracking in full immersive displays by means of joysticks thus may be relevant in some applications but involves a possible loss of immersiveness in others.

5.3 Use of 3D interaction devices

We implemented interaction techniques, which used a Spacemouse providing 6 degrees of freedom. Pushing the top of the Spacemouse caused the user to "fly" in that direction. Twisting it rotated the virtual world (table 1, issue 8, 9, 13 and 14). When seated in front of the panoramic screen with the Spacemouse located on the armrest, test users reported that the technique worked fine – though it demanded some use experience. When using the Spacemouse in a full immersive display, however, the test users reported that the technique was unintuitive. If not holding the device the correct orientation in relation to the display, moving it e.g. forward thus caused the user to fly in a completely different direction. This was reported very confusing. When keeping the Spacemouse in the correct orientation, however, the test users reported that the technique gave them a good feeling of control compared to the use of joysticks and trackballs. Compensating for the orientation of the device by motion tracking was suggested – but not implemented.

5.4 Supporting different techniques for acting

We implemented and tested a virtual hand and a virtual pointer technique (table 1, issue 15-18). Virtual hand techniques provide representations of the user's hands while virtual pointer techniques to a large extend resemble the use of laser pointers. Using the full immersive display, test users reported that the virtual hand approach was very intuitive for "close-by" interaction. Picking up, moving and rotating virtual objects was reported unproblematic. The user's physical hands, however, sometimes occluded the graphics. The test users reported less satisfaction with the virtual hand approach when using a partial immersive display. Due to the lack of a floor display in the panoramic display setup, the virtual hands could not be projected close to the user's hands unless standing very close to the display. The virtual pointer was reported usable in combination with both the panoramic display and the cave when having to point at or pick something in the virtual environment. Moving and rotating objects with the virtual pointer was, however reported problematic in both the partial and the full immersive display.

6. CONCLUSIONS

The primary conclusion from our experiments is that the same interaction techniques does not work equally well with panoramic displays and six-sided caves. Displays for virtual reality can be categorized as full or partial immersive depending on their *available field of view*. Using this categorization in relation to a division of interaction into *orienting, moving* and *acting* reveals a series of issues for the design of human-computer interaction in virtual reality applications. We specifically found that:

1. Untraditional use of headtracking may support orientating in partial immersive displays, though introducing a problematic boundary between interaction in physical and virtual space.

2. Rotating the world in full immersive displays using e.g. joysticks may complement headtracking by letting the user view the VE from odd perspectives but might limit the feeling of immersiveness.

3. Non-tracked 3D interaction devices work fine for orientating and moving in partial immersive displays but can be problematic in full immersive displays if the user turns around physically.

4. The virtual hand approach has different potentials in partial and full immersive displays. The virtual pointer approach works fine for picking 3D objects but is problematic for rotating and moving them.

For new and better ways of interacting in virtual reality to emerge, system developers must optimize combinations of devices/techniques and displays in specific application contexts. The framework presented in this paper may support a structured approach to this task. The presented framework should be developed further by structured and quantitative explorations of the relations between interaction techniques and display types.

7. ACKNOWLEDGEMENTS

I wish to thank Peer M. Ilsøe for implementation, Lars Qvortrup, The Staging Project and VR-MediaLab for funding and access to VR systems. I also thank the test users: Peer M. Ilsøe, Tom Nyvang, Thomas D. Nielsen, Carsten B. Larsen, Gabriel S. Hansen and Claus A. F. Rosenstand. I thank Jan Stage and Mikael B. Skov for reviewing the paper and Erik Granum for inspiration and constructive comments on my work.

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