Intuitive, Hands-free Travel Interfaces for Virtual Environments

Steffi Beckhaus, Kristopher J. Blom, Matthias Haringer
interactive media / virtual environments
University of Hamburg
Vogt-Kölln-Str. 30, 22527 Hamburg, Germany
steffi.beckhaus@uni-hamburg.de

Abstract

Navigation is one of the most important tasks in virtual environments. We present two novel interfaces for navigation, a dance pad based and a chair based interface. Both interfaces are designed to be intuitive to use by novice users and leave the user's hands free for other tasks like object manipulation or system control. In an informal study, both interfaces were immediately usable by novice VE users using a ground following travel metaphor without any prior explanation of how the interface functions. In addition, the chair based interface was found to be highly intuitive, effective, and fun to operate.

1. Introduction

Navigation is one of the most important tasks in Virtual Environments (VE). In [3], Bowman and Hodges define the three main navigation tasks as exploration, search, and maneuvering. The first two tasks require travel, large-scale movement through the environment to a distant target, while maneuvering is a local process involving small local adjustments of the user's position.

Various interaction devices and techniques have been developed for navigation. One of the reasons for this is that the task of exploring a VE is more difficult than the exploration of real space [4]. In immersive virtual environments, the most intuitive methods for local movement (maneuvering and travel within the boundaries of the physical space) are actions people do in real environments, such as walking or ducking under an object. Once the user reaches the borders of the physical space of the VE system, other method for movement must be used. A travel method is employed, in which the scene itself is moved relative to the physical space.

Travel is often understood to be manually controlled steering of motion through a virtual environment. This means that the user controls the direction and the speed of motion, typically with a physical tool. Various travel metaphors and interfaces have been developed to accomplish this motion task. The most common interface for travel in VEs is through a wand like interface commonly deployed in the VR system [2]. In many VR systems the wand serves as a general device, and is often equipped with a multitude of buttons. These interfaces have a number of shortcomings. Travel methods created with the pointing device metaphor tend to have a high learning curve. We believe that this learning curve is often a major problem for adoption of VR, as interaction experiences tend to be limited in extent. Also, poor navigation of the environment tends to have severe effects on the users, from irritation to cybersickness. This is particularly true for passive viewers of the environment. Therefore, navigational control in the VR system is typically only performed by the researchers or experts, while the remainder of the users become passive viewers.

The use of hand-coupled interfaces for navigation raises a number of additional issues. Having a travel interface, a selection interface, and other necessary interactions coupled to hand-held devices creates a situation where modes must be introduced to switch between tasks. As has been found in various HCI studies, handling different modes introduces additional difficulties for the user [8]. In addition to the increased number of modes, having to use the hand-coupled interface for travel purposes also engages at least one hand fully thereby limiting the number of devices which simultaneously can be operated.

In this paper we introduce two physical interfaces for travel in VE's: the Dance Pad, using a game interface with directional arrows, and a Chair Based Interface using an ergonomic stool described as "Seating in Motion" [1]. Both interfaces are controlled with the body, leaving the hands free for other tasks. As both interfaces are dedicated to the navigational task, there is no need to switch modes. Both interfaces are meant to be intuitive for novice users. In the next section we introduce the two interfaces in full. An informal user study performed on these devices follows.

Finally, a discussion of the results of the study, our impression of the interfaces, and future directions of research are given.

2. Interfaces

This section presents two interfaces for travel in VE's. These interfaces are primarily intended for use in fish-tank or single wall immersive projection environments, although they could be used in other settings. Our goal in this research was to develop intuitive navigation methods and devices that meet the following requirements:

- allow navigation in standard VE applications or games involving travel and exploration of large-scale scenery. We use ground following (2D travel metaphor) to limit the effects of cybersickness
- reduce the cognitive load usually involved in travel interfaces
- intuitive, with a short learning curve
- enjoyable to use
- a new method of control, preferably with a non hand-coupled interface

Both presented interfaces are built using commercially available hardware components. The devices were integrated into the AVANGO virtual reality toolkit [5].

2.1. Dance Pad Travel Interface

Dance pad based games have recently gained popularity for home use. The pads originate from Dance Dance Revolution™(DDR), a physically engaging, revolutionary arcade game from Konami [7]. Arcade consoles and the more recent pads for game consoles, consist of a pad with arrows pointing in four directions: forward, backward, left, and right. In DDR, players have to step on the direction arrows in a specified order and timed to the music. While the pad we have obtained is constructed for heavy use, similar pads are available as very cheap plastic mats. Although most pads were developed for use with game consoles, inexpensive adapters allowing PC usage through a USB interface are available.

The pad we have obtained has six buttons, the four directional arrows described previously and two additional arrows pointing at 45°angles. Figure 1 shows our dance pad. With the Pad oriented towards a screen or wall display, the mapping of the four arrows in a cross to positional transformation is relatively straight-forward. These movements are then forward, backwards, and left/right translation. More complex to find is a natural metaphor for rotating the viewing direction. For our study we mapped the diagonal buttons to rotational movement around the user's position. The left diagonal button rotates the scene counter-clockwise, the right diagonal rotates clockwise.

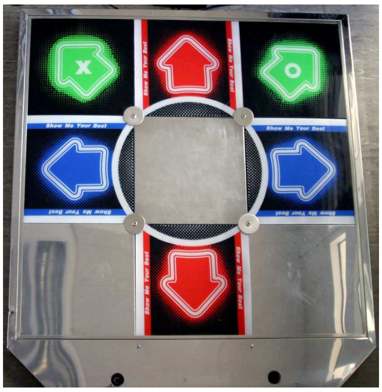

Figure 1. Dance Pad.

2.2. Chair Based Travel Interface

Our second interface is based on a novel seat, the Swopper™ [1] (See Figure 2). The stool is designed as an ergonomic seat for use in an office environment. It has the following properties:

- rotatable seat
- 360°pivot point
- height and damping adjustment.
- a linkage arm consisting of a spring/shock combination

The chair's seat is on a linkage arm connected to the base with a ball pivot point. The ball pivot point allows the entire seat to tilt in any direction. The linkage arm consists of a spring/damper system. In contrast to a standard office chair, this allows the seat remain at a level higher and potentially allowing the user to continually bouncing if desires. To adjust to different users, the seat height and the spring strength of the stool can be altered. The seat itself is on a rotational system on top of the linkage arm, allowing it to smoothly and freely rotate.

We map physical movement of the seat to viewpoint/direction movement in the Virtual Environment. The movement is computationally divided into the components translation and rotation. Translation of the current viewpoint is performed by tilting of the seat in any direction. For example, to move forward the user tilts the seat forward. In order to help maintaining a motionless position, we have slightly enlarged the area within the center which causes no translation. The translation speed is linearly mapped to how far in the direction the user tilts the stool, allowing them to travel at higher speeds by tilting the seat further in the direction of travel. Rotation of the environment around the

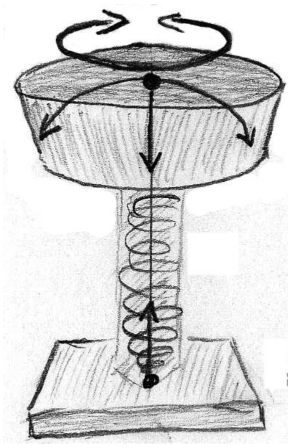

Figure 2. Chair Interface: Modes of Motion.

user's position is performed by rotation of the seat. This rotation functions regardless of the tilt of the seat for the translational component. As with translation, we have increased the area of zero rotation to make a motionless state easily maintained. Figure 3 shows the device in use.

The current method of determining the input from the user is done using positional information of two points on the seat determined by a magnetic tracker. An initialization procedure sets a few initial values used in the calculation, such as the rotation of the seat and the position of the chair. From the two positions we are able to obtain the translational component from the initial position. We are also able to calculate the rotation of the seat by applying the inverse tilt transform to the seat and comparing with the initial rotation. This method was chosen primarily for its robustness in initializing the interface.

3. Informal User Study

We have performed an initial informal user study of the two interfaces with 9 people aged between 24 and 55. The experience of the users with VE's was distributed from no experience at all to expert VE user. The users navigated an architectural VE, a model of a market place in Bonn, Germany. The market place has many objects and pathways through a large number of densely grouped stands, e.g. fruit stands. It also has some open spaces and a set of stairs to climb. Both interfaces were attached to the same application.

Questions were asked of the users both before and after the user experience. The questions asked before pertained to the users previous experience with: gaming, devices such as joysticks and 3D mice, and VE's and other 3D navigation. The users were given four navigational tasks, once for each device. There was no training phase. Users were

Figure 3. Chair Interface Used for Travel in VE.

given the tasks with neither an explanation of the interface nor its use. The first task was to navigate through one of the aisles of the market place without running into the stands. The second task was to navigate in a circle around a circular billboard stand, as commonly seen in Germany. To test their ability to rotate the viewpoint while navigating, they were ask to keep the billboard in view while circumnavigating the stand. The third task was to travel to the Rathaus which is located across the market from their position. During their navigation to that point we attempted to engage them in conversation to determine if they could perform the navigation task while being distracted by a conversation. To provide an advanced task, the user was asked to climb on the narrow, serpentine entrance stairs of the Rathaus, which is a difficult task with most interfaces.

4. Results

The user study had questions with either a free form response or selection on a 1 to 5 scale, e.g from simple (1) to difficult (5).

For the Dance Pad Interface the following results were found

- tasks one and three were easily performed by all users. The circular movement was reported as difficult to impossible, climbing the stairs was given a middle rating.
- intuitive use: average 3.1 (intuitive to complicated)
- perceived cognitive load for travelling to a target: average 3.1 (no load to high load)
- for circling target: average 3.9 (no load to high load)
- perceived difficulty to do other tasks (to converse) simultaneously: average 2.1 (no to high difficulty)
- further comments: good precision, arrows make mapping easy understandable, rotation was not intuitive, balance problem when trying to use both feet, static speed was found problematic.

For the Chair Based Interface the following results were found

- besides the second task all tasks were easily performed by all users. The circular movement was reported on the full range from easy to difficult.
- Intuitive use: average 1.3 (intuitive to complicated)
- perceived cognitive load for travelling to a target: average 1.1 (no load to high load)
- for circling target: average 2.1 (no load to high load)
- perceived difficulty to do other tasks (to converse) simultaneously: average 1.0 (no to high difficulty)
- further comments: very intuitive interface (most users), among the best ever used navigation method (experienced VR users), two users complained about difficulties in standing still, two had qualms about moving (tilting) backwards.

5. Discussion

The two interfaces have various strengths. For novice users, both interfaces were highly successful as intuitive device for travel in Virtual Environments. The users were immediately able to use the devices to navigate, with neither training nor explanation. While the dance pad functioned, the interface became too difficult to use for complex tasks. In particular the rotational aspects of the interface could be improved on. This problem did not occur with the chair based interface. While we observed that for some users it took slightly longer to learn how to operate the interface (still less than 20s), they were able to perform the complex movement of the circling task with minimal trouble only moments later.

We have found the Chair Based Interface to be an excellent interface for navigation. In our collective experience it ranks as one of the best interfaces for VE navigation we have experienced. It is not only easy to use, it is enjoyable. We heard this comment from the users often. Our impression of the interface is that it requires a very low cognitive load to use, something we feel is a very large advantage of the device. Our informal study seems to support this impression, as the users were able to converse with us while travelling and circling around objects in our test environment.

6. Conclusion and Future Work

We have presented two novel interfaces for navigation, the Dance Pad and a Chair Based Interface. The Dance Pad is a very inexpensive possibility for simple navigation with VE's. We feel it could be a good interface in non-guided public and even outdoor installations. We intend to investigate other button mappings, methods for rotation, and the use of other iconic representations on the buttons.

Supported by the user study, we feel that the chair based interface is a highly intuitive interface with a large potential for additional tasks. We plan to investigate use of the bouncing movement provided by the spring system in various interaction metaphors. For further development and testing of the interface, we are considering testing it with 3D first person games and 2D desktop applications.

The physical components for both interfaces are relatively inexpensive for use in VR. As the chair we used costs a few hundred dollars, we are looking at less expensive seating apparatuses for use and also those used in a nearly standing position. Also, we are working on integrating a more cost effective tracking system based on ARToolKit [6].

References

[1] aeris Impulsmbel GmbH. The Swopper™. http://www.aeris.de.

[2] L. Arns. *A new taxonomy for locomotion in virtual environments*. PhD thesis, Iowa State University, Ames, 2002.

[3] D. A. Bowman and L. Hodges. Formalizing the design, evaluation, and application of interaction techniques for immersive virtual environments. In *Journal of Visual Languages and Computing*, pages 37–53. Academic Press, 10 1999.

[4] D. A. Bowman, D. Koller, and L. F. Hodges. Travel in immersive virtual environments: An evaluation of viewpoint motion control techniques. In *Proceedings of the Virtual Reality Annual International Symposium (VRAIS)*, pages 45–52, 1997.

[5] Fraunhofer IMK. AVANGO Virtual Reality Toolkit. http://www.avango.org.

[6] H. Kato and M. Billinghurst. Marker tracking and hmd calibration for a video-based augmented reality conferencing system. *International Workshop on Augmented Reality*, 1999.

[7] Konami Digital Entertainment, Inc. Dance Dance Revolution™. http://www.konami.com.

[8] J. Spolsky. *User Interface Design for Programmers*. Apress, Berkley, CA., 2001.