3D USER INTERFACE STUDY IN THE VR CAVE

Toward A Virtual City Navigation

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Abstract. In this research, we implemented the 3D interactive interface for city navigation, and used an infrared 3D tracker as an interaction input device in VR CAVE. The design of 3D interface was evaluated by cognitive approach while navigating with a handheld sensor in the VR CAVE. According to the results of cognitive experiment, some revised design guidelines are proposed for further 3D navigation interface.

1. Introduction

The development of digital media, especially in the way of presentation, is more concerned with interactive and immersive qualities (Maria Roussou, 2001). What distinguishes virtual reality from other media is that users have a great deal more control over what they see and experience. (Carroll, Smyth & Dryden, 2004). In order to achieve better performance in virtual reality, it is necessary to narrow the interactive gap between users and VR.

There have been a great number of researches on the user interface, and particularly the user interface design in three-dimensional space has further become one of the research topics that is critical and deserves investigation in the virtual environment application (Bowman et al., 2004). Most of the previous VR works focused on the interactions between the 2D interface of a computer and input devices such as a mouse and a keyboard. As for the 3D user interface in VR CAVE, the input devices are no longer merely a mouse, but a combination of more diverse devices such as a 3D tracker, data glove, force feedback arm, and more. When moving from a 2D to a 3D interface, it is clear that the interface becomes a more complicated 3D virtual environment for users to operate in.

Moreover, there are greater interaction tasks — navigation, selection/manipulation, and system controls — in this virtual environment (Bowman et al, 2001). Thus what are the guidelines of a 3D interface design for users to interact with when involved in a 3D virtual environment? Navigation is one of the important concepts that people explore in the real world. Where is that? How do I get to there from here? In a virtual environment, the fundamental importance of an effective navigation is that it allows the two above questions to be answered quickly and efficiently (Darken & Sibert, 1996; Parusha & Berman, 2004).

In this paper, we attempt to implement a 3D interface by taking a virtual city navigation as an example, and use an infrared 3D tracker as an interaction input device in VR CAVE (Wu et al., 2004). By so doing the tracker can turn a sensor of a physical space into a control point which can move in the virtual space. The design of 3D interface was evaluated by cognitive approach while subjects navigate with a handheld sensor in the VR CAVE. According to the results of cognitive experiment, some revised design guidelines are proposed for further 3D navigation interface.

2. The Frame of Environment

2.1 HARDWARE DEVICES

The hardware devices of passive VR CAVE were developed by The Industrial Technology Research Institute (ITRI) in Taiwan (Fig.1a). The computational system of VR CAVE was constructed by a cluster. The stereoscopic vision was displayed by six projectors which were connected by 6 client PCs. The client PCs were connected to a server side PC by a networked protocol TCP/IP. The server side PC as a central hinge processed data which was input from a 3D position tracker and then transmitted to 6 client PCs. The images displayed on 3 screens of VR CAVE would be changed at the same time (Wu, 2003). The input device for interaction was a 3D position tracker which is an image-based system. When the user held a marker (Fig1b) and moved it, the 3D position of the marker was computed to the server side PC by the 3D position tracker and transmitted by the transmission interface RS-232 (ITRI, 2002).

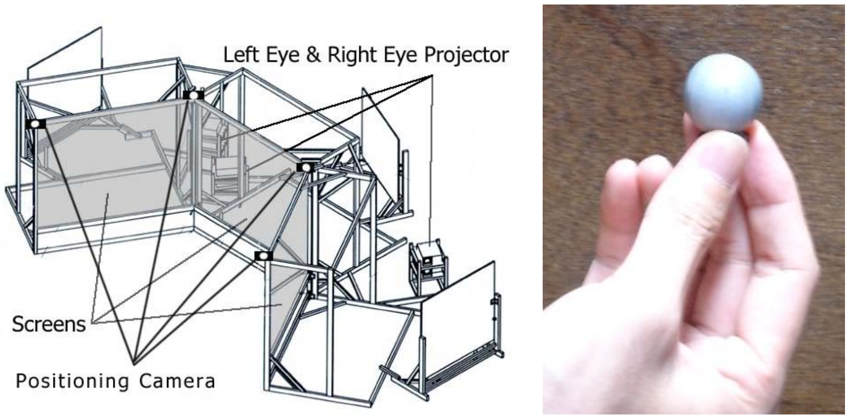

Figure1. a. The hardware devices of passive VR CAVE. b. The handheld marker.

2.2 SOFTWARE AND SCENE CONSTRUCTION

The software used for the developmental tool was 3D VR Director 8.5 and included a networked software Multiuser. They were not only used to display the virtual environment of real-time interaction but also used to solve the problem of synchronization for showing each frame. Therefore, the computer program in the server side controlled the display of each frame synchronously and transmitted the 3D position data to each client PC by Multiuser (Wu, 2003; Wu et al., 2004). In regards to the interaction of the virtual environment a 3D position tracker system transmitted the 3D position of the marker to the server side PC and the server side program was based on the position data to sense the interactive zone in order to change the point-of-view.

The virtual scene of construction for the study is based on a finished database of digital city models with high polygons. But in order to display the high polygons model real-time in the virtual environment, these models need to reduce the polygons and the textures for each building in the digital city. So the digital city model will display smoothly and present high quality images in the VR CAVE.

3. Preliminary Implementation

Previous studies indicate that the design principles of navigation in a VE are based on those of the real world (Darken & Sibert, 1996). Besides, in spite of the inner/outer perception from the human body, a series of feelings such as "up-down", "left-right", "front-back", as well as "center" can be developed by the positive orientation of the human body. (Bloomer & Moore, 1977). In addition to guides like metaphors or maps, people rely on the need to be provided with direction to avoid disorientation in virtual space (Cheng, 1998).

According to the above-mentioned, the study chose part of Chung-Chêng road in Hsinchu City, Taiwan (since people in the project are familiar with it) as the virtual scene for preliminary implementation. First we defined the basic tasks for city navigation which included going forward and backward, turning left and right, and raising the head. Therefore the 3D interface contained these functions as part of the design as viewpoint references in virtual space (Fig.2a). Also used were directional signs like front, back, left, and right standing for the metaphor of going forward, backward, turning left and right, and the red ball was used as the position of the handheld marker in the virtual space. These provided visual feedback while operating. In addition, the interactive technique adopted is a point that can make one move or touch with the model-based interface (Fig.2b), thereby resulting in an interactive trigger by which users interact with the virtual city.

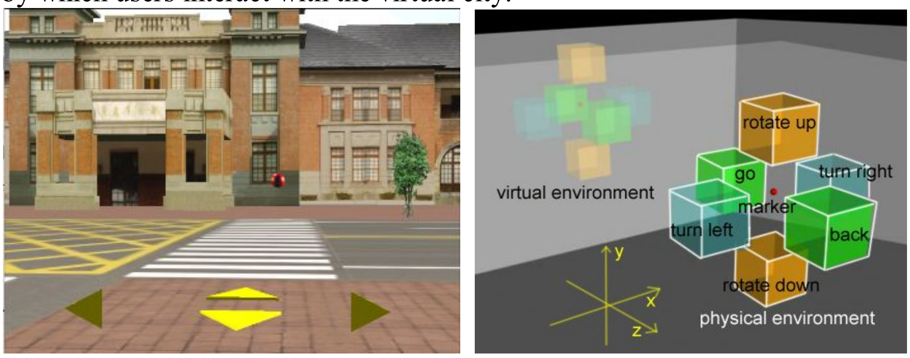

Figure2. a. Navigation interface for recognizing direction. b. The allocation of interactive sense area in physical environment.

4. Cognitive Experiment

The second stage of the cognition experiment was to apply the “think aloud” method of the protocol analysis. It was used to evaluate the city navigation interface for the preliminary implementation. This experiment recruited 5 subjects good at verbal expression and computer manipulating experience to operate the 3D interface for navigation in CAVE environment individually. (Fig.3)

Figure3. Subjects navigate and operate in CAVE environment.

Before the beginning of the experiment, the testers were introduced to the experimental environment, the manipulating procedure and the whole procedure. They then went to the experimental phase. The experiment was chiefly divided into two parts. In the first part, some tasks were assigned to the subjects whereby they were told to move to certain locations under constraints until they achieved the mission, and got used to the navigation interface. The second part was to have the subjects travel through the environment freely without any rules. Due to the data collected by the "think aloud" method the subjects were asked to self-report simultaneously during the process, trying to describe the problems encountered while navigating. The difference between the cognitive behavior and practical interaction through the interface under the operation of the subjects was noted. Some questions or cues were given to the subjects whenever needed. The whole process was recorded on video.

5. Analysis and Revision

This study attempts to explore the possible problems of preliminary implementation of 3D navigation interface by cognitive approach. After analyzing and integrating the verbal data collected by the experiment, some improvements were proposed regarding travel and wayfinding aspects (Bowman et al, 2001).

In the travel aspect, travel is defined as the motor component of navigation; the movement of a given viewpoint from one location to another. During the experiment, the operation of viewpoint orientation can almost follow the intention to go forward, stepping back, turning left, and turning right, but most subjects still reflected that they could not exactly and correctly control the movement on their own. For example, it was easy to turn left/right over a given range but the choice of a specific direction or movement was difficult. Besides, in order to completely match a human's behavior when navigating through a real physical environment, it is also recommended that the rotational center be adjusted and the function of raising/lowering the head should be considered as well. On the other hand, the integration of travel and input device refers to the range setting of the sense area from infrared rays. Subjects with a handheld marker could not actually predict the mapping of the physical movement and the virtual movement. They also suggested that it would be more natural to design the sense area of a handheld marker for velocity control. As far as the input device is concerned, most subjects requested to improve the operation of the handheld device.

In the wayfinding aspect, wayfinding is described as the cognitive process of a path through an environment, determined by the spatial knowledge acquired from the given environment. During the later half of the experimental process while traveling, subject's navigation or path can be influenced if there are obvious landmarks or identification signs, such as a McDonald's signboard, Belisha Beacon, building with particular or identifiable details or motor objects in the virtual space. In addition, part of the subjects suggested that directional signs can be presented on the same axis, and their shape and color should be changed, in order to improve the visibility and the natural mapping of the marker manipulation and the representation of directional signs. Moreover, some identification of feedback had to be improved during navigation, which consisted of the introduction of locations, when a person stops, and the bumping into something without permission.

After summarizing the mentioned analysis and evaluation, the study further attempted to revise the 3D interface for navigating a virtual city and resolve the problems which resulted from the preliminary implementation (Fig.4), and then bridged the interactive gap between the users and the virtual world as possible.

Figure4 . A revised 3D navigation interface of virtual city.

6. Conclusions and Future Works

From the implementation of the 3D navigation interface and the evaluation by the cognitive approach, some phenomenon was found by this study. When navigating the virtual city through a 3D interface, it is necessary to first investigate the user task and user experience within the real-world environment, which can then be integrated into the characteristics of an input device. According to this, users can perform the navigation tasks in the virtual space without complexity following natural mapping as is similar to real-life experience. In addition, the study also found that how the elements are organized or designed in a given space can influence wayfinding performance. An effective wayfinding can support travel skills, and then effectively build up the overall understanding of the physical world. Therefore, one concludes that a proper integration of travel and wayfinding results in useful navigation and better interactive or immersive experience.

In this research, we implemented the 3D interactive interface for city navigation by the VR CAVE hardware device and the 3D interactive device, the Microsoft Windows platform system of PC clusters, and used Director as the main software. The implementation was then evaluated by the cognitive approach when the user navigated the virtual space: Thus some problems with the interface through handheld 3D tracker were explored to provide for further revision. Furthermore, some design guidelines of 3D navigation interface proposed are expected in VR or other applications. In future studies, it is possible to study the cognitive behavior by experimenting with other combinations of interactive devices that may advance the design guideline of 3D navigation interface. We can also further propose the design principle for a 3D user interface based on interaction tasks of selection/manipulation and system control.

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