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A Comparative Study of 3 DOF Travel Techniques for Immersive Virtual Flythroughs: the Leap Motion and the Oculus Rift S Hand Controllers

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Abstract. This paper describes a comparative study of two different 3 degrees-of-freedom (DOF) flythrough techniques for immersive 3D environments. The results of this qualitative study indicate that the use of the Oculus Rift S hand controllers provides a greater usability than the use of Leap Motion free hand gestures system for a simple 3 DOF flythrough travel task inside immersive virtual environments. However, the correction of technical issues with the current Leap Motion free hand gesture recognition system could lead to different results.

Keywords: Travel techniques · Immersive virtual environments · Usability · Flythrough

1 Introduction

Travel and wayfinding are the two components of the navigation task. While travel relates to the motor task, wayfinding relates to the cognitive process of determining and following a route between an origin and a destination [1].

Virtual flythrough is a common travel metaphor used for viewpoint control in 3D virtual environments (VEs) [2, 3]. There is, however, a large set of possible travel techniques to achieve this metaphor and designers of VR systems should have access to some information regarding the usability of those travel techniques in order to guide them in the design of those systems [4].

Therefore, we conducted an experiment to help designers choose their travel technique when comes the time to implement a flythrough system for immersive virtual environments.

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[*] Please note that the LNCS Editorial assumes that all authors have used the western naming convention, with given names preceding surnames (first name then last name). This determines the structure of the names in the running heads and the author index. No academic titles or descriptions of academic positions should be included in the addresses. The affiliations should consist of the author's institution, town, and country.

2 Method

T General: a within-subject experimental design is used and the order of presentation of conditions is counterbalanced, i.e. half of the participants first tested the gesture UI and then the hand controllers UI, while the other half of the participants did the opposite.

2.1 Experimenter/Participants

A single experimenter with usability expertise introduced the participants to their tasks and the UIs. In total, 16 unpaid participants volunteered and completed the experiment. The participants were recruited by email inside the NRC. Fourteen of the participants were male, and two were female. Twelve of them were right-handed, four were left-handed and none was ambidextrous. All except two had medium or high familiarity with video games, the sample had the following age distribution of 25/60/45 (min/max/average). They all had normal or corrected-to-normal vision.

2.2 Task

Each participant had to travel inside the immersive 3D virtual environments by using each of the 3 DOF provided by the UI and reaching the largest sphere in the virtual environment.

2.3 Evaluation Environment

Physical environment: participants were initially placed standing upright on the floor at the centre of a 2 m x 2 m interaction zone.

Virtual environment: a 3D virtual environment composed of a blue horizon with several spheres located in it that acted as landmarks in this 3D space to improve wayfinding [5]. Each participant was equipped with a Head-Mounted Display (HMD), which allowed the participant to gaze around the whole virtual environment in real-time simply by moving the head around, hence the use of the qualitative word “immersive”.

2.4 Travel Techniques

Participants used two different 3 DOF travel techniques for their virtual flythroughs, namely travel with the Oculus Rift S hand controllers and travel with the Leap Motion free hand gesture recognition system.

2.4.1 Travel with hand controllers

Each of the two hand controllers (see Fig. 1) is equipped with a thumbstick.

Left-hand controller + right-hand controller

Fig. 1. Oculus Rift S hand controllers

Moving the left-hand controller's thumbstick forward or backward, moved the avatar forward or backward respectively in the environment's horizontal (x/z) plane. Moving the right-hand thumbstick forward and backward moved the avatar up/down along the environment's vertical (y) axis. Moving the right thumbstick to the right or left, rotated the avatar around the environment's vertical (y) axis in the same direction (Fig. 2).

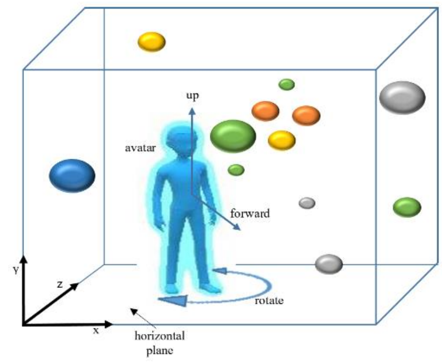

Fig. 2. Avatar motion

2.4.2 Travel with free hand gestures

The orientation of the palm of the hand determined the direction of travel with gestures. To move forward, the users would hold up either hand (or both hands) with the palm(s) facing forward. To move backward, the gesture was similar, but the palm faced backward (toward the user's body) instead, and similarly for (up/down)ward. To rotate, users would point their thumb in the direction in which they wanted to rotate (Fig. 3).

Forward **Backward** **Rotate right**

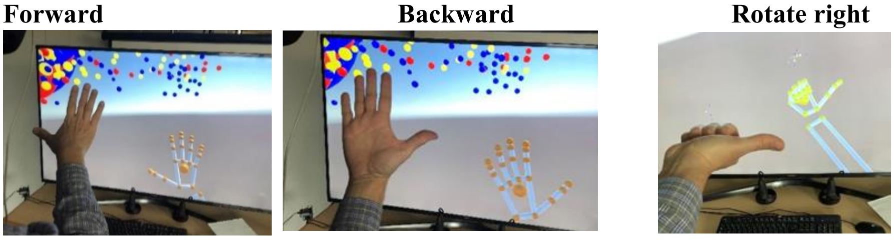

Fig. 3. Travel with free hand gestures

Another important difference between controller and gesture navigation involved the rotation of the avatar. When using gesture navigation, the user could rotate the avatar around the y-axis by turning his body to the left or right. The HMD-mounted gesture sensor detected when the user turned his body. The system then used this signal to smoothly change the avatar's orientation accordingly. The forward/backward gestures therefore always appeared to the users as producing forward/backward motion.

In contrast, the hand controllers did not detect changes in the orientation of the user's body. If the user turned her body left or right, the avatar maintained its orientation. The user's body orientation was then out of alignment with the avatar's. The consequence in such a situation was that executing either a forward or backward movement no longer appeared to the user as moving forward or backward. For example, if a user rotated his/her body 90° to the right, the avatar's forward direction would remain toward 0°. If that user then executed a forward movement, the avatar's movement would appear as a movement to the left instead, in alignment with the avatar's forward direction (Fig. 4).

This misalignment confused a few users momentarily. The experimenter explained the source of error and the users turned back to their original orientation.

Gesture recognition used a LeapMotion device fixed to the Oculus HMD along with the Leap Motion Orion beta version 4.0.0 of the software.

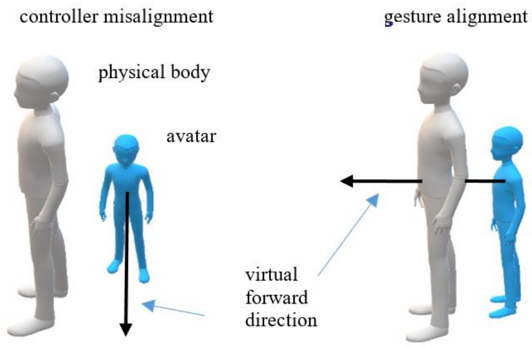

Fig. 4. Physical body/Avatar misalignment

2.5 Procedure

Upon arrival, participants were asked to read a consent document. If they agreed to participate, they signed it and were provided with instructions about the task and how to navigate with gestures and the controllers. The experimenter answered any questions they may have had about the documents or their participation.

The experimenter assisted the participants in putting on and adjusting the Oculus HMD. Each participant stood while using each navigation method in sequence.

After completing the tasks with each navigation mode, the participants were screened for signs of cybersickness [6]. They were also provided with the definition of the term usability as found in [7] and then asked to rank each of the two interfaces in terms of its usability to achieve the task. They were then asked to complete a commonly used System Usability Scale (SUS) [8, 9, 10] questionnaire for each of the two interfaces. Finally, they were asked for comments on the interfaces themselves and were requested to provide demographic information (age, gender, handedness, familiarity with computer games).

2.6 Instructions given to the participants

All participants were instructed to first simply to travel around the space. They were required to move up and down, turn to the left and right, and move forward and backward. Their second task was to locate a large blue sphere nearby, and to travel to it.

Participants often forgot the instructions and were reminded verbally by the experimenter on how to proceed. When participants experienced difficulties, the experimenter assisted them.

3 Results

12 out of the 16 participants ranked the hand controllers' interface as more usable than the gesture interface for 3 DOF travel inside the immersive virtual environment.

As for the SUS score, they are summarized in Table 1.

Table 1. Means and standard deviations for the System Usability Scale (SUS)

Statements	Total sample N; M (SD)	Gestures N; M (SD)	Controllers N; M (SD)
I would like to use this system frequently.	32; 3.59 (1.24)	16; 3.44 (1.26)	16; 3.75 (1.24)
I found the product unnecessarily complex.	32; 2.16 (1.27)	16; 2.56 (1.36)	16; 1.75 (1.06)
I thought the system was easy to use.	32; 3.28 (1.51)	16; 2.94 (1.53)	16; 3.63 (1.45)
I think that I would need the support of a technical person to be able to use this system.	32; 1.84 (1.19)	16; 2.00 (1.21)	16; 1.69 (1.20)
I found the various functions in the system were well integrated.	32; 3.06 (1.37)	16; 2.69 (1.30)	16; 3.44 (1.36)
I thought there was too much inconsistency in the system.	32; 2.50 (1.55)	16; 3.00 (1.59)	16; 2.00 (1.37)
I would imagine that most people learn to use this system very quickly.	32; 3.75 (1.22)	16; 3.56 (1.21)	16; 3.94 (1.24)
I found the system very cumbersome to use.	32; 2.56 (1.46)	16; 2.75 (1.53)	16; 2.38 (1.41)
I felt very confident using the system.	32; 3.41 (1.21)	16; 3.00 (1.10)	16;3.81 (1.22)
I needed to l earn a lot of things before I could get going with this system.	32; 2.00 (1.14)	16; 2.06 (1.00)	16; 1.94 (1.29)
Overall SUS scoring	32; 65.1 (23.4)	16; 58.1(21.5)	16; 72.0 (23.8)

From the table, we can see that the hand controllers again scored a much better SUS than the freehand gestures interface (72.0 vs. 58.1). An analysis of variance (ANOVA) with pseudo-F test reveals that this difference is almost significant, $F(1, 15) = 3.76$, $p = 0.071$. The largest differences between the two interfaces are related to system integration (poor for gestures) and inconsistency (high for gestures).

Generally, the participants commented that they found the gestures unreliable (as reflected in the corresponding SUS scores). However, they also stated that that they would have liked to use the gestures if they had been more reliable.

Two participants reported minor cybersickness symptoms: light-headed and postural instability. Both reported after one set of tasks but both reported they wanted to continue anyway. Symptoms were no worse following second block.

4 Conclusion

We compared the usability of two 3 DOF flythrough travel techniques in immersive 3D virtual environments. The first travel technique was based on free hand gestures, using the Leap Motion device while the other used the Oculus Rift S hand controllers.

Results indicate that the hand controllers are more usable than the current freehand gesture travel technique. However, the poor reliability of the gesture-based technique might have influenced the results though so that improvements to this technology might change the results in its favour. As such, it is not possible to draw solid general conclusions about free hand gestures interfaces.

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