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A Comparative Study of Three Bimanual Travel Techniques for Desktop Virtual Walkthroughs

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Abstract— **This paper presents the results of a formal experiment that compared three bimanual travel techniques for desktop virtual walkthroughs, each having a different number of degrees of freedom (DOF) for the control interface. When compared in a primed search task, results indicate that the use of a 4-DOF interface with integrated pitch control provides a more realistic travel experience by allowing full visual exploration around the scene, while slightly increasing completion time when compared to the use of a 2-DOF or 3-DOF interface. The evaluation method developed here could be used to conduct further experimentation to explore other desktop travel techniques and/or other types of virtual environments.**

Keywords- HCI; travel techniques; bimanual navigation

I. Introduction

Virtual walkthrough is a common travel metaphor used for viewpoint control in virtual environments and a large proportion of users perform walkthroughs on desktop virtual environments, for example in 3D video games.

In virtual walkthrough, the number of DOF varies between 2 and 4. Several interaction techniques are possible by using one or two-handed techniques, as well as different input/output devices and mapping functions. This provides a large search space that is not fully explored. As for other human-computer interfaces, the empirical evaluation of the possible travel techniques is important to improve our understanding and eventually develop more usable systems and theoretical models [1,2,3,4,5].

In fact, several studies have been conducted to evaluate walkthroughs techniques in virtual environments [6,7,8,9, 10,11,12,13,14,15,16,17], but the search space is large and lot of research needs to be done to fully characterize the usability of these techniques. For desktop walkthroughs, commonly found bimanual interfaces in video games uses are keyboard-mouse for PC games and two joysticks (on a gamepad) for console games. The use of these specific combinations appears to be driven by availability of the input devices and is not backed by published scientific analysis of the performance or usability studies on these interfaces.

This paper reports the results of an experiment that pursue on the exploration of the interfaces' search space by comparing the user's performance and preference when using three bimanual interaction techniques having different number of DOF to travel in a context of desktop virtual walkthrough. The choice of the input devices used by those interaction techniques, although not commonly found on generic gaming platforms, appeared to be well suited for a virtual 3D walkthrough task, as it is based on a joystick for displacing the avatar using rate control and a mouse with position control for controlling the gaze, i.e. the direction of the look.

II. Experiment

To evaluate the different travel techniques, we used a maze-like virtual world made of a complex trail offering an open view, so that users can always look around and/or keep an eye on the end point of the maze while they travel (Figure 1). The choice of an open-view setup was made because it offers more incentives to use all the available DOF as compared to traditional maze environments with high walls.

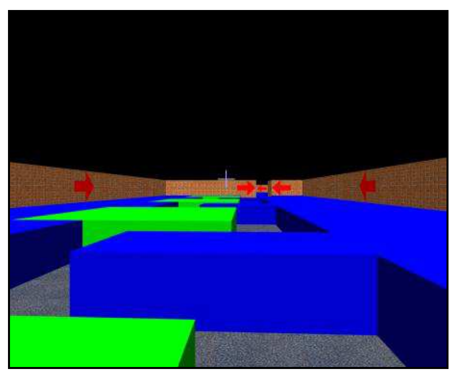

Figure 1. The walkthrough environment

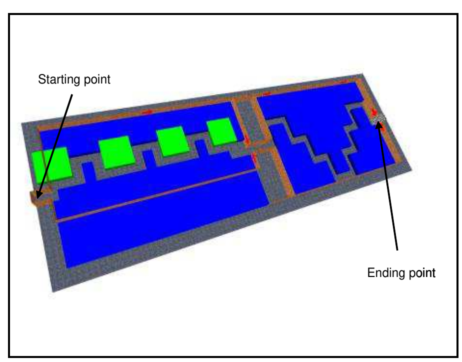

Figure 2. Top view of the environment.

A. *Participants*

In total, 12 unpaid volunteers (10 men and 2 women) participated in the experiment. All, except one, were right handed, they were all computer literate, had at least a college-level education, and had an age distribution of 24/57/34 (min/max/average). They all had normal or corrected-to-normal vision. Most of them had some experience with video games.

B. *Task*

Participants had to complete a primed search task, where they knew in advance where the target (end point) was positioned [1]. They were instructed to travel from the start point to the end point in the shortest time possible (Figure 2).

C. *System*

The system used a color desktop monitor with a diagonal size of 54 cm and a resolution of 1600x1200 pixels. The frame rate was 60 Hz, with system latency smaller than 120 ms. The viewing distance of the participants was 70 cm. The avatar had a radius of 0.25 m, a viewing height of 1.8 m, and a FOV of 75° x 60° (H x V). The virtual trail was 2 m wide with walls that were 3 m high and obstacles that were 1 m high, thus allowing seeing over them. The corridor was 160 m long (measured along the center line), with 15 turns to the right and 15 to the left (see Figure 2).

D. *Travel Techniques*

The first travel technique controls 4 DOF (Figure 3). Fore/aft movements of the joystick control fore/aft translations of the viewpoint. Lateral movements of the joystick control lateral translations of the viewpoint (a movement called strafe). Lateral movements of the mouse rotate the viewpoint in the horizontal plane of the scene (yaw movement). Finally, fore/aft mouse movements control upward/downward (a.k.a. pitch) rotations of the viewpoint on a range of ± 90° around the horizon. The second travel technique (3-DOF interface, Figure 4) is the same but without pitch control and the 2-DOF (Figure 5) is the same as 3-DOF, without strafe control.

All travel techniques used a joystick (Logitech Extreme 3D Pro) and a standard mouse (Microsoft Laser Mouse 6000). Collisions between the avatar and objects of the scene (obstacles or walls) were slippery.

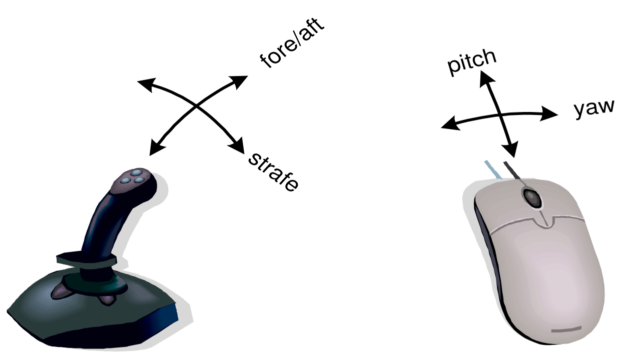

Figure 3. 4-DOF interface

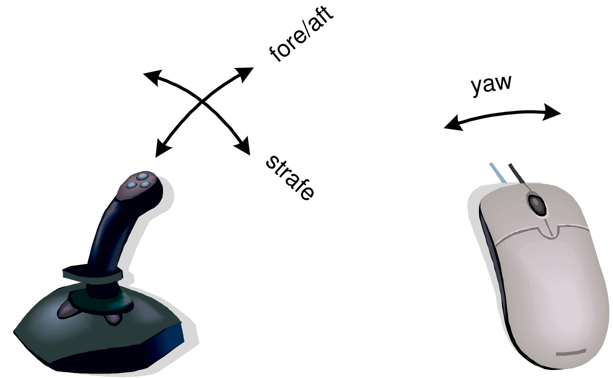

Figure 4. 3-DOF interface

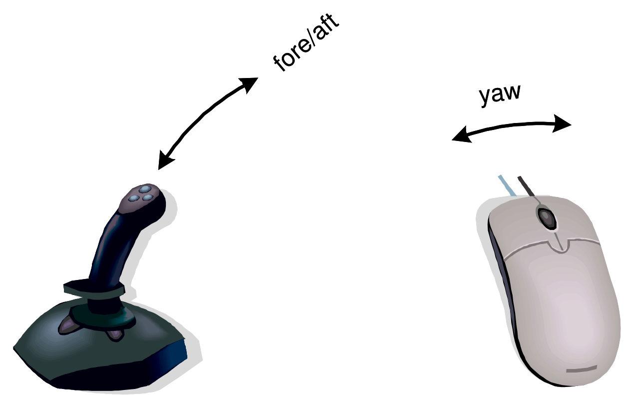

Figure 5. 2-DOF interface

The joystick uses velocity control and the mouse uses position control, which is the typical mapping used for these devices [18]. For the joystick, both translations and rotations were controlled with a linear function gain. The maximum speed was 5 m/s for translations. The mouse used a linear function gain of 25°/cm (with mouse acceleration disabled) to change the viewpoint's yaw and pitch. The speed values and function gains used here were found, in a pilot study, to optimize the user's performance.

E. *Design*

The independent variables were the three travel techniques described earlier and the dependent variables were the task completion time and the total traveled distance. We used a within-subject design and a counterbalanced order to minimize skill transfer effects. For each interface, the participants had right to a demo by the experimenter, followed by a practice and 5 trials. From the pilot study, that number of trials appeared sufficient to give the participants the chance to adapt to the interface and stabilize their performance.

F. *Procedure.*

Participants read the instructions and completed a consent form along with a background questionnaire. They were then seated in front of the system and told to begin the experiment.

The instructions were displayed on-screen before each trial. A 3-second audio countdown preceded each trial. The trials ended automatically when the participants reached the end point. Once the trials completed for all interfaces, each participant was invited to rate each interface on the ease-of-use, fatigue, accuracy, speed and preference.

III. RESULTS

A. Quantitative results.

Figure 4 provides valuable information to determine the number of trials required to warm-up the participants enough to obtain a relatively stable performance. This is important to make sure that further analysis will not be biased by unstable performance data.

An analysis of the effect of practice on the completion time lead us to determine that only the performance of the two last trials of the participants would be analyzed to determine significant differences between each interface. This is because the effect of practice is largely minimized for the 4th and 5th trials as seen on Figure 6.

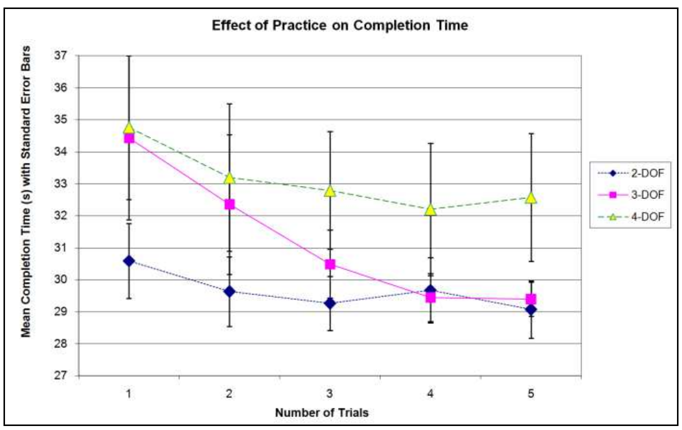

Figure 6. Effect of practice on mean completion time

Figure 7 illustrates the results for the three interfaces for the completion time (average of the last two trials). An analysis of variance (ANOVA) with the pseudo-F test was significant, $F(2,22) = 2.478$, $p = 0.034$.A Duncan' multiple range test [19] reveals that the 4-DOF interface significantly differs from both the 2-DOF and 3-DOF interfaces. Using Cohen's method [20], we found that the effect size on travel time was equal to 0.56 between the 4-DOF and 2-DOF interfaces and to 0.58 between the 4-DOF and 3-DOF interfaces. The practical implication here is that travel time is about 10% longer when using the 4-DOF interface compared to either the 2-DOF or 3-DOF interface.

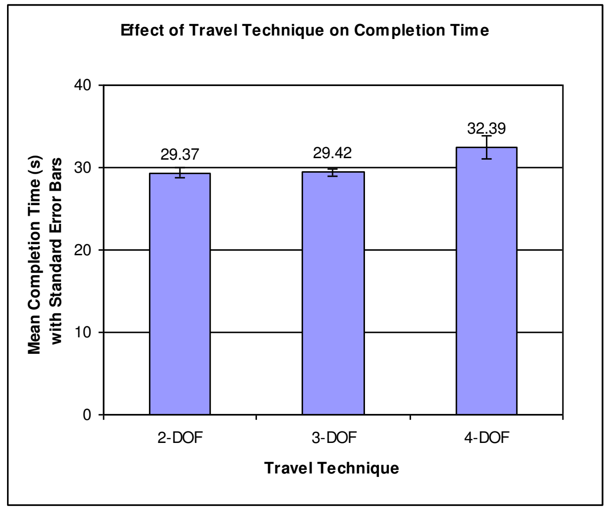

Figure 7. Mean completion time

The ANOVA on the traveled distance was not significant, $F(2,22)=3.155$, $p=0.062$. The results are reported in Figure 8.

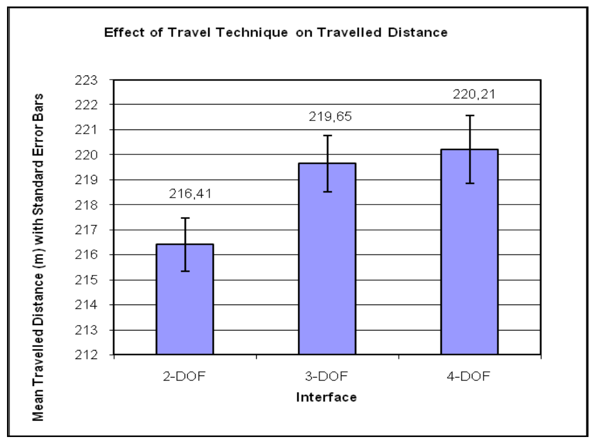

Figure 8. Mean travelled distance

B. Qualitative Results.

Figure 9 reports the subjective ratings on a scale from 1 to 5, a higher score meaning a better score.

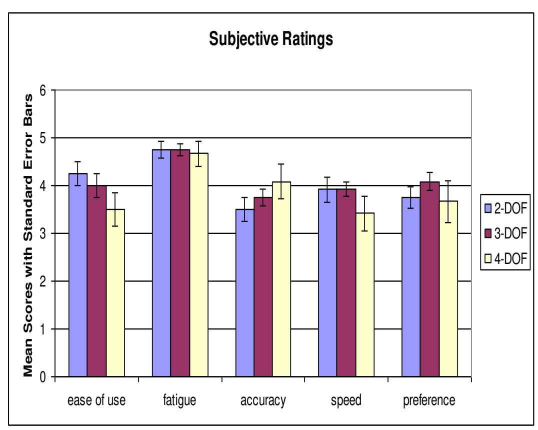

Figure 9. Subjective ratings

The subjective ratings indicate that the ease of use decreases with the number of DOF and the accuracy increases with the number of DOF. Overall, participants seemed to prefer the 3-DOF interface for this specific virtual environment. Finally, fatigue was not an issue on any of the interface.

IV. Discussion

The results of this experiment indicate that, for this specific virtual environment, using the 4-DOF technique (which adds pitch control) slightly but significantly increases travel time when compared to 2-DOF and 3-DOF travel techniques, with an effect size of about 0.6. We did not find any significant difference in performance by adding strafe control. This can be explained by the fact that we used a gaze-directed steering metaphor and strafe movement is not coupled to steering while pitch movement is.

The results reported here are limited to one example of virtual environment and one particular set of users. For more comprehensive results, additional experiments should be conducted, by using tasks and virtual environments of different complexities with different set of users. For example, tasks involving walkthroughs on several different environments such as a straight line (1D), a plane (2D), or space (3D) could help show which DOF of the control interfaces are well suited to specific types of movement.

One important contribution of this paper is to report not only the results of this particular experiment, but also the evaluation method that was used and that could reused for further experiments. This is important in order to allow reproducing the experiment and thus verifying the results. We took care of describing every aspect of the method.

In fact, standard testing methods do not exist in the field and more work in that direction would be needed in order to make systematic progress on improving the interaction techniques.

In conclusion, a 4-DOF walkthrough technique allows more complex movements and full visual exploration of the scene. The results of this experiment indicate that this can be done at a slight expense of performance and with a possible reduction of user's satisfaction. Further experimentation in different virtual settings is however required to confirm that this holds true for every desktop virtual walkthrough setup for specific set of users. Unless task completion time is critical, we think that the cost is worth the gains made in terms of quality of user's experience.

Acknowledgment

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