Evaluation of a 3D UI with Different Input Technologies

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ABSTRACT

We present two studies of navigation and object manipulation in a virtual supermarket. The first study compared a mouse and keyboard setup to a game hardware setup using a *Wii Remote*, *Wii Balance Board* and a *dancemat*. The second study used more game-like software interfaces for both conditions and used only the *Wii Remote* and *Nunchuk* in the game-hardware setup. The mouse setup was around 36% faster in both studies. In the first study the mouse setup was 98% more accurate; no difference in accuracy was found in the second study.

KEYWORDS: manipulation, navigation, gaming input devices

INDEX TERMS: H.5.2 [User Interfaces]: Graphical User Interfaces (GUI), Input devices and strategies

1 INTRODUCTION

A major obstacle preventing widespread use of 3DUIs remains hardware cost [2][10]. Recently, game consoles have included multiple degree-of-freedom input devices that can be used in 3D UIs. These are attractive alternatives to traditional tracking systems for are use in 3D UI research. An example is the award winning system by Bacim et al. [2] which employed six such devices: a *Wii Remote (Wiimote)*, a *Wii Sensor Bar*, a *Wii MotionPlus*, a *Wii Nunchuk*, a *Wii Balance Board*, and a *dancemat*. This was used for navigation and item manipulation in a supermarket scene.

LaViola [3] argues that such devices will remain popular for some time. Consequently, research on the usability of these devices within 3D UIs is fruitful [4][9][10]. On the other hand, these devices do not match the capabilities of specialized tracking hardware [2][10]. McArthur et al. [5] evaluated pointing with the *Wii Remote* in a Fitts' law pointing experiment, and found that it afforded pointing throughput of around 3 bits per second, with error rates of 5%. While this is significantly lower than mouse pointing throughput reported in the literature (typically 4–4.5 bits per second), it is still reasonable.

We present an evaluation of a system similar to Bacim's [2] compared to a mouse-based 3D UI. Our second study evaluated an improved version of the system which used only the *Wii Remote* and *Nunchuk*.

2 USER STUDY I METHODOLOGY

Our first user study compared a mouse-based 3D UI to the interface proposed by Bacim et al. [2], which uses the *Wiimote*, a *Nunchuk*, a *Balance Board* and a *dancemat*. Twelve paid participants (mean age 24.7, six females) were recruited. Eight were non-gamers and two were occasional gamers.

The *Wiimote* was used for object selection/translation, and the *MotionPlus* gyro add-on rotated objects. The *Nunchuk* joystick rotated the view. The *Balance Board* and dancemat were used for navigation. Participants held the *Nunchuk* in the left hand and the *Wiimote* in the right hand. The display was a 50" DLP TV and the "sensor bar" was mounted at its top edge.

The task was based on the 2010 3D UI Grand Prize competition [2], see Figure 1. Participants started at location "AS" and navigated the supermarket to find objects in a specific order. Once collected, items had to be placed on table at location "BS". Finally, participants rotated each object to match the orientation of the corresponding reference item. Participants repeated this task five times for each condition.

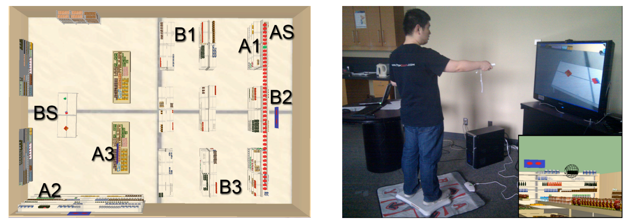

Figure 1. (Left)Top view of the supermarket scene showing positions of objects in both studies. "AS" was the starting location for User Study I, "BS" for Study II. The item locations are: A1, A2, A3 in User Study I, and B1, B2, and B3 in User Study II. (Right) Participant performing the task, and insert selection sphere.

The task required selecting each object and moving it from its initial location to a target location. Both conditions employed a previously developed surface-sliding algorithm [7][8] that automatically computes object depth and uses a contact constraint. Collision detection prevents object interpenetration.

In the *Wii* condition, pointing the *Wiimote* at the screen controls a wireframe sphere to specify a set of selection candidates. Pressing the A button then activates a quad menu [2] that displays all the selected candidate objects distributed among four quadrants on the screen. This allows the user to disambiguate their selection with repeated selections. Selected items were put in the "shopping cart", an off-screen inventory which is activated with the B button. The shopping cart uses the same selection menu interface as the selection step. After selecting an object, participants then position it in the scene by pointing the *Wiimote* at the desired location. The *Wii MotionPlus* gyro add-on was used to control object rotation following positioning. A 1:1 (isotonic) mapping was used.

The mouse condition used the movement method of the multi-scale 3D navigation technique of McCrae et al. [6]. It used the aforementioned surface-sliding algorithm to move objects selected via ray-casting. Mouse rotation used a "two-axis valuator" [1].

The study employed a 2 × 5 repeated measures design (2 input methods and 5 repetitions). The two tested input methods were Mouse and *Wii*. To counterbalance learning effects half of the participants did the mouse condition first.

3 USER STUDY I RESULTS

A significant main effect on total task completion time for input method was found ($F_{1,11} = 27.46$, $p < .0001$). The mouse condition (mean 159 s) was faster than the *Wii* condition (216 s) on all trials. There was a significant main effect for input method on manipulation time ($F_{1,11} = 19.49$, $p < .005$). See Figure 2.

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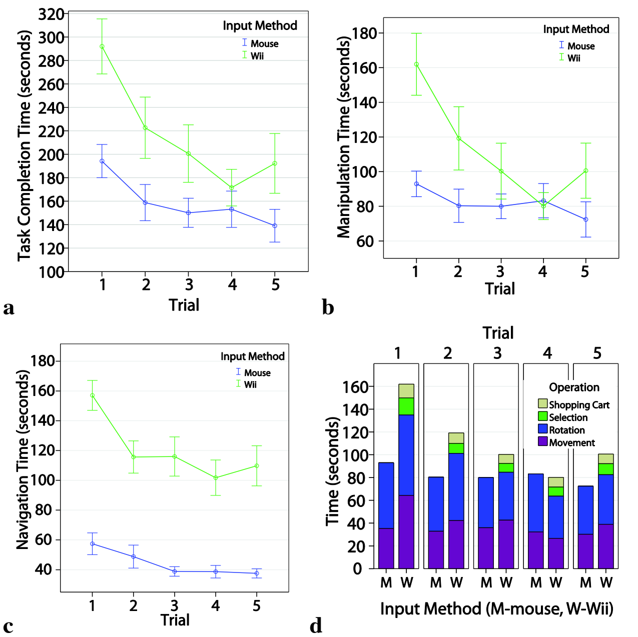

Figure 2. User Study I (a) total, (b) manipulation and (c) navigation time. (d) Manipulation time breakdown. Error bars: ±1 SE;

4 User Study II Methodology

Our second study focused more on the selection menu and shopping cart. Based on user feedback, both interfaces were made more game-like. In the mouse condition, the WASD keys controlled camera movement while the mouse controlled viewpoint rotation. The *Wiimote* was used for camera turning and selection, and the *Nunchuk* analog stick moved the camera.

Sixteen paid participants (four female, mean age 24.3) were recruited. Participants were screened to have at least of one hour of weekly gaming. This study used only the *Wiimote* and *Nunchuk* in the *Wii* condition. The task was similar to the first study, except that the target objects were in different locations. In Figure 1 the locations are designated with "B1", "B2" and "B3". The positions were changed to encourage more navigation.

We used a $2 \times 2 \times 2 \times 4$ repeated measures design (2 input methods: mouse/keyboard and *Wii*; selection menu: on or off; shopping cart: on or off; 4 repetitions). Half of the participants used the mouse condition first. The remaining factors were counterbalanced according to a balanced Latin square.

5 User Study II Results

There was a significant main effect for input method ($F_{1,15} = 36.1, p < .0001$). The mouse (79 s) was faster than the *Wii* condition (125 s). There was also a significant main effect for the shopping cart ($F_{1,15} = 12.69, p < .0005$), which improved time. Trial had a significant main effect ($F_{3,15} = 17.22, p < .0001$) and an interaction with device ($F_{3,45} = 2.83, p < .05$), all mouse trials were faster than all *Wii* trials.

There was a significant main effect for input method ($F_{1,15} = 24.51, p < .0005$). Manipulation with the mouse (48 s) was faster than with the *Wii* (79 s). Finally, navigation was also significantly faster with the mouse (21 s) than the *Wii* (38 s) ($F_{1,15} = 48.26, p < .0001$). See Figure 3.

6 Discussion and Conclusions

By the final repetition in each study, the *Wii* and mouse conditions had similar manipulation times. By comparison, the navigation components were quite different in both studies. Thus, we suggest that devices like the *Wiimote* are best used for object selection and manipulation tasks. This may be because of the ease of using the essentially 2DOF remote pointing mode for the *Wiimote* and the natural rotation method used.

Navigation times were relatively shorter in the second study. This is likely due to the facts that the participants were gamers, and the interfaces were both more familiar and easier to use. With more repetitions, we believe the performance of the second study *Wii* setup could eventually match that of the mouse setup.

We believe that the shopping cart is beneficial to both input methods as it reduces navigation time. Besides improving selection times, the selection menu also improved navigation time. This is likely because it afforded the ability to select multiple objects at once and there was no limit on how far the selection could "reach", thus limiting the need for navigation.

Average rotation times were longer in the second study with the *Wii* than with the mouse. We attribute this to the isometric rotation mapping used in the second study which proved to be inferior. In the future, we want to investigate the effect of interface on orientation accuracy.

Overall, the mouse conditions performed better than the *Wii* conditions. However, we speculate that with training, performance in the two conditions may eventually match.

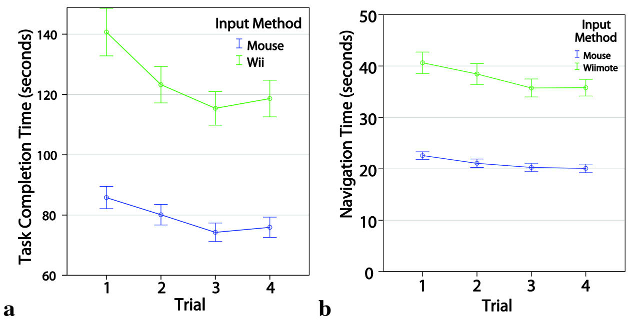

Figure 3. User Study II: (a) total, and (b) navigation times. Error bars: ±1 SE

References

[1] R. Bade, F. Ritter, and B. Preim, "Usability Comparison of Mouse-Based Interaction Techniques for Predictable 3D Rotation," *Smart Graphics 2005*, pp. 138–150.

[2] P. Figueroa et al.,"3DUI 2010 contest grand prize winners," *IEEE CG&A* 30(6), 86–96, 2010.

[3] J. J. LaViola Jr., "Bringing VR and spatial 3D interaction to the masses through video games," *IEEE CG&A* 28(5), 10–15, 2008.

[4] J. C. Lee, "Hacking the nintendo Wii remote," *IEEE Pervasive Computing* 7(3), 39–45, 2008.

[5] V. McArthur, S. J. Castellucci, and I. S. MacKenzie, "An empirical comparison of 'Wiimote' gun attachments for pointing tasks," in *ACM Engineering Interactive Computing Systems 2009*, 203–208.

[6] J. McCrae, I. Mordatch, M. Glueck, and A. Khan, "Multiscale 3D navigation," in *Interactive 3D graphics and games 2009*, 7–14.

[7] J.-Y. Oh and W. Stuerzlinger, "Moving objects with 2D input devices in CAD systems and desktop virtual environments," *Graphics Interface 2005*, 195–202.

[8] J.-Y. Oh, W. Stuerzlinger, and J. Danahy, "SESAME: towards better 3D conceptual design systems," *ACM DIS 2006*, 80–89

[9] A. Shirai, E. Geslin, and S. Richir, "WiiMedia: motion analysis methods and applications using a consumer video game controller," in *ACM SIGGRAPH symposium on Video games 2007*, 133–140.

[10] C. Wingrave et al., "The Wiimote and beyond: Spatially convenient devices for 3D user interfaces," *IEEE CG&A* 30(2), 71–85, 2010.