Comparative Study of Input Devices for a VR Mine Simulation

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Abstract

It has been shown that virtual reality (VR) can be used to train mine workers for safety in critical situations [4]. The National Institute for Occupational Safety and Health (NIOSH) has a virtual reality (VR) laboratory on its Pittsburgh campus. Currently, input devices for the system are an Xbox 360 game pad and an air mouse. Due to the high cost and added complexity of most 3D tracking systems, we wanted to first test to see if the mine safety application could benefit from an upgrade to a 6-DOF tracking system. Thus, we conducted a pilot study at Duke University's six-sided CAVE-type system, and collected performance and questionnaire data for three tasks (selection, navigation, and maneuvering) and three devices (gamepad, air mouse, 6-DOF wand). Results indicate that the wand allows users to complete tasks faster and is preferred by users. However, in certain situations its use led to more errors.

Keywords: Virtual reality, mine safety, device comparison.

Index Terms: H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities.

1 Introduction

In the year 2012, there were 3443 coal mine accidents including 20 fatalities in the United States [6]. To help better prepare miners for future accidents, the National Institute for Occupational Safety and Health (NIOSH) is interested in utilizing virtual reality for training. Previous work has shown the usefulness of virtual reality for training for critical mine situations, such as escape during a fire [4].

NIOSH has a VR laboratory that currently utilizes two input devices: an Xbox 360 game pad (with multiple buttons and axes), and a Gyration Air Mouse Go Plus (which has an inertial system that changes the mouse position when the trigger is held). Our research investigated what the outcomes would be of upgrading the input devices at the NIOSH laboratory. Specifically, we decided to compare the existing devices, with a well known 6-DOF input device: the Intersense IS-900 wand (which has several buttons and 2 axes).

Previous device comparison studies have compared the mouse/keyboard and 6-DOF wand [3]. Work by Teather and Stuerzlinger [5] compared mouse, simulated air mouse, and 3-DOF tracking. However, we feel that it is important to evaluate an actual air mouse, because the errors introduced from the air mouse being an inertial system can cause problems for the user.

We used the Duke Immersive Virtual Environment (DiVE), a fully enclosed six-sided immersive CAVE-type system for our pilot study. The software platform used in the experiment was 3DVIA Virtools. The simulation was a simplified version of a training module currently used by NIOSH. The application consists of a simulation of a coal mine and was modified to allow standardized tasks to be performed.

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2 Method

Three devices were tested in a pilot study for three different tasks: selection, navigation, and maneuvering (Figure 1).

2.1 Tasks

The first task was selection. Users were instructed to point at the target object and press a specific button to select the object. Then a new target object would appear in a location based on ISO 9241-9 standards [2]. We tested 3 sizes of targets, each with a set of 16 trials. The pointing technique for all three input devices was based on ray-casting. To move the ray the subject could directly move the ray (wand), use the joystick axis (gamepad), or do inertial movements while the trigger was held (air mouse). Once selecting the object, a button was pressed on the controller to register the selection. Users operated the gamepad with both hands, and the wand and air mouse with one hand.

The second task was navigation. The participants traveled a path towards a waypoint location, which was represented as a sphere with an arrow that indicated the direction to the next waypoint sphere. Once a participant reached a sphere, it would disappear and the next sphere in the mine would appear. The participant could set the direction of travel by moving the targeting cursor, which was also the flashlight, via direct pointing (wand), right stick (gamepad), or inertial movements (air mouse). In order to move forward, the participant could use the forward axis (wand), the left stick (gamepad), or the left button (air mouse). We did not allow strafing (sidestepping) or backwards movements because those were viewed as dangerous in the context of the mine (movement should always proceed in the direction of the flashlight. Collisions between the user and the walls were recorded.

Finally, the maneuvering task consisted of steering through a set of virtual crates positioned close together in a zigzag fashion, such that constant adjustment of direction was required. The maneuvering controls were the same as the navigation techniques in the navigation task. Collisions with the crates were recorded.

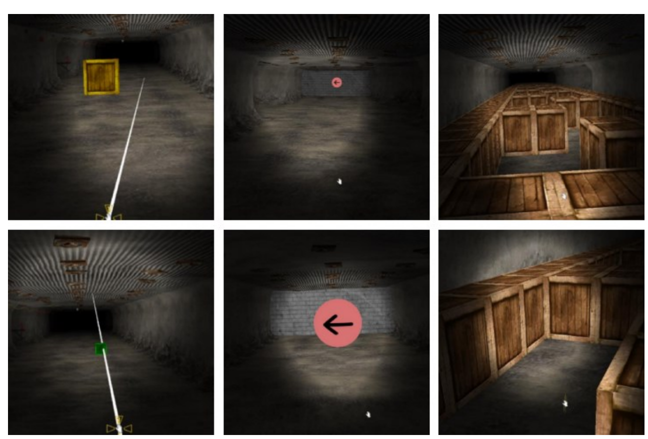

Figure 1: The three tasks. The first column is the selection task. The user must touch the target with the ray and press the trigger. The second column is navigation. The user must follow the signs to navigate the mine. The third column is maneuvering. The user must travel through the mine and avoid hitting crates.

2.2 Pilot Study

We ran a pilot study with 9 volunteers to assess the input devices for performance and usability. We used a within-subjects design. To account for possible ordering effects, the order of presentation of each input device was counterbalanced. The user was assigned a device and then completed the tasks always in the following order: selection, navigation, maneuvering. After testing each device, participants completed presence and usability questionnaires.

3 Results

Performance data was analyzed through Analyses of Variance with Repeated Measures (ANOVA-RM) for all tasks.

3.1 Selection Results

There were main effects on the mean time to select a target for both input device ($p<.005$) and target size ($p<.0001$). Pairwise comparison on individual factors showed that the wand allowed significantly faster selections than gamepad ($p<.05$) and air mouse ($p<.01$). For target sizes, pairwise comparisons showed that the smallest target size resulted in significantly slower selection times than both the medium ($p<.005$) and the large ($p<.005$) ones.

Looking at mean errors per trial, there were also main effects for both input device ($p<.01$) and target size ($p<.05$). Pairwise comparison on individual factors showed that the wand caused significantly more errors than gamepad ($p<.05$).

3.2 Navigation Results

A strong main effect of input device was found ($p<.0001$). Pairwise comparisons showed that the participants were significantly faster when using the wand as compared to the gamepad, and faster (although only marginally significantly) when compared to the air mouse ($p=.073$).

3.3 Maneuvering Results

A significant main effect was found for total task time ($p<.0001$). Pairwise comparisons were performed and showed that the gamepad was significantly slower than the wand ($p<.005$) and borderline slower than the air mouse ($p=.051$). The air mouse was significantly slower than the wand ($p<.05$). Pairwise comparisons showed that collisions took significantly longer on average with the gamepad as compared to the wand ($p<.01$).

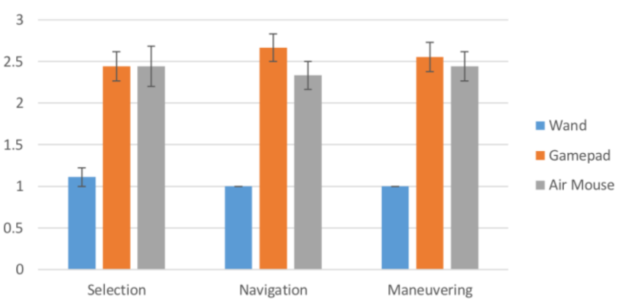

Figure 2: Overall preference by task. Lower scores are better.

3.4 Questionnaire Results

The overall usability score showed a main effect, where the wand was rated significantly better than gamepad and air mouse. In a final preference questionnaire (Figure 2), the wand was preferred by all but one participant (who favored the air mouse for selection) and there was a split between the gamepad and the air mouse for second, with a slight favor towards air mouse. Finally, many users commented that the air mouse was at times frustrating to use, because it did not do the action they were intending to perform.

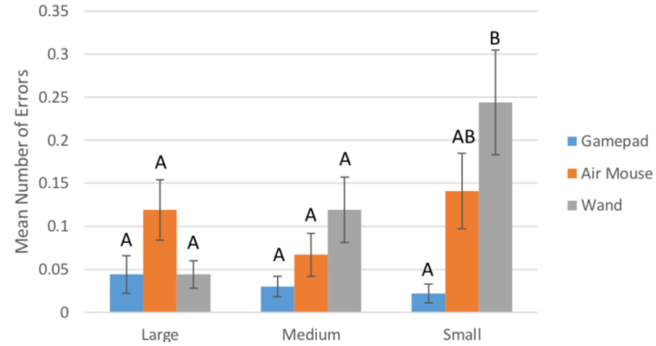

Figure 3: Selection task mean number of errors per trial for each input device per target size. Error bars show standard error. For each target size, levels not connected by the same letter are significantly different.

4 Discussion

For the selection task, the wand had the fastest selection, but it also had high error rates for smaller targets (Figure 3). The gamepad had slower selection times, especially with smaller targets, but the error rate was also lower on average and significantly lower than the wand in the selection of small targets. The air mouse had intermediate performances both in terms of time and in terms of errors. These results evidence an interesting tradeoff. Devices like the wand that have a direct position and orientation mapping are good because they can be controlled rather quickly, through a flick of the wrist. The negative point, though, is that one needs to be aiming the device continuously in order for it to point accurately. The aiming can also be disturbed at the moment of the button press in what has been labeled the “heisenberg effect” [1].

5 Conclusion

A pilot study compared three input devices (two of which are currently used by NIOSH) for speed, accuracy, and usability. Performance and questionnaire data were collected from nine volunteer participants for selection, navigation, and maneuvering with a 6-DOF Intersense wand, an Xbox gamepad, and an air mouse. Results indicate that the wand is faster for task completion and preferred by most users. However, in certain situations, more errors were made while using it.

References

[1] D. Bowman, C. Wingrave, J. Campbell, V. Ly, and C. Rhoton. Novel uses of pinch gloves for virtual environment interaction techniques. Virtual Reality, 6(3):122-129, 2002.

[2] S. A. Douglas, A. E. Kirkpatrick, and I. S. MacKenzie. Testing pointing device performance and user assessment with the ISO 9241, part 9 standard. In Proceedings of the SIGCHI conference on Human factors in computing systems, pages 215-222. ACM, 1999.

[3] R. P. McMahan, D. A. Bowman, D. J. Zielinski, and R. B. Brady. Evaluating display fidelity and interaction fidelity in a virtual reality game. IEEE Transactions on Visualization and Computer Graphics, 18(4):626-633, 2012.

[4] T. Orr, L. Mallet, and K. Margolis. Enhanced fire escape training for mine workers using virtual reality simulation. Mining Engineering, 61(11):41-44, 2009.

[5] R. J. Teather and W. Stuerzlinger. Assessing the effects of orientation and device on (constrained) 3d movement techniques. In Proceedings of IEEE Symposium on 3D User Interfaces, pages 43-50. IEEE, 2008.

[6] Mine Injury and Worktime Report 2012. Retrieved from: http://www.msha.gov/ACCINJ/accinj.htm