Virtual Reality Locomotion Using the HTC Vive and the Effects on Spatial Awareness

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Abstract
With the recently growing phenomenon of Virtual Reality(VR) as a popular form of entertainment, researchers are now placing their efforts in developing ways to use Virtual Reality practically as well as for leisure. VR opens new means through which real activities can be simulated, opening opportunities not only for entertainment but for training and education. In recent years there has been an explosion in the production and design of Virtual Reality software and gaming apparatus, and with any development thorough examination is required. In this research, we present a user study involving the comparison of virtual locomotion to its real world counterpart and show how virtual locomotion used in combination with the HTC Vive can be used to simulate real environments, and compare the accuracy of real movement and memory after experiencing these environments. We then draw conclusions on the reliability and viability of using virtual locomotion in place of real physical movement in a real environment.

Keywords: Virtual Reality, Virtual Locomotion, HTC Vive

1.0 Introduction

pop with the concept of virtual reality. So, it is no wonder that people are excited by it and interested in the market for these devices. It is a field with a wide variety of possible applications and huge potential.

A concern within the field of Virtual Reality is locomotion, or how a person’s avatar moves through whatever virtual environment they’re in. Locomotion in virtual reality is required for virtual spaces that are larger than the room they are in. To travel across a football field, while staying within the confines of a small room, coming up with a different method of movement is imperative. Many different locomotion techniques have been proposed for such movement. The classic movement techniques used in traditional video games are not ideal, as they can cause motion sickness in VR. Teleportation was one of the first options developed, and is one of the more popular options. With this method, the user can point to a location and teleport to that location. This solves the issue of scale and motion sickness.

Comparing virtual and real locomotion is important, because different locomotion techniques can potentially result in different degrees of accuracy and thus have varying degrees of usefulness when performing delicate tasks. The patterns that emerge from our research will help to demonstrate the precision of each locomotion technique and give concrete data on each one's usefulness.

1.1 Concise Literature Reviews

The HTC Vive is the beginning of a fundamental change to the way we compute (Anshel, 2016). Anshel, who is a technical writer, has spent a year to study the VR field, and he found out that HTC Vive is the one which caught his attention the most because of its price and features. In addition, according to Source Virtual Reality Developers Conference, there are more than 50% of Developers indicate that HTC Vive is the most popular VR, AR or MR platform (SOURCE VR Developers Conference, 2017). A study indicates that the advent of inexpensive consumer VR equipment enables many more researchers to study perception with naturally moving observer, and the position and orientation tracking could be suitable for much research, that is currently done with far more expensive systems (Diederick, 2017). While compare to other devices like oculus, HTC Vive's workaround is more elaborate (Newman, 2017).

2.0 Method

Our methodology will involve testing the effects of various locomotion techniques in VR. These techniques include:

- Trackpad movement
- Teleportation
- Reach and Grab
- Arm Swing Movement
- Dash movement

Using each of the locomotion methods, the test subject placed a virtual cube on an X marked in virtual space. They then return to the start and take off the headset. Then, they were tasked to place an object in a room with the same dimensions as the virtual room. We measure the difference between the real world and the virtual world's placement.

2.1 Participants

The goal when selecting our participants is to try and broaden the number of demographics participating as much as possible. Our goal is to have a variety of age groups and levels of technical ability

Unfortunately, due to the nature of the time and facilities allotted to us, our participants are limited to users who are available in the Kennesaw State University Marietta Campus. This group is generally biased towards highly technical users. This includes a high concentration of Computer Science majors that are already familiar to some extent with the hardware presented.

2.2 Apparatus

During our research, we used an HTC Vive in conjunction with handheld controllers to control the Virtual Reality portion of our user study. Program creation was done using Unity and was written in C#. The view of a menu from user's perspective is illustrated in figure 2.2 - 1 and virtual space where X is marked on the floor in software development environment, Unity, is illustrated in figure 2.2 - 2.

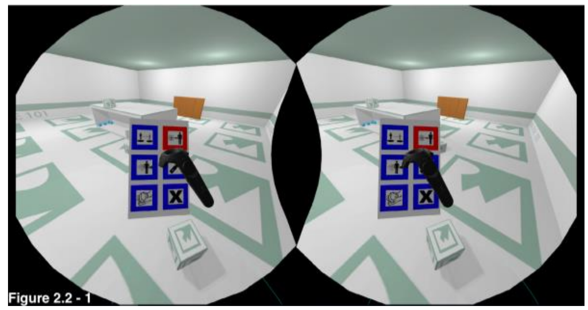


Figure 2.2 - 1

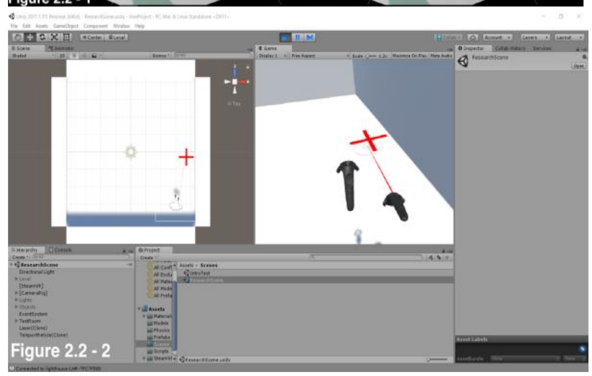


Figure 2.2 - 2

The specifications of the laptop the program was run on are as follows:

- **Operating System**: Windows 10 Home 64-bit
- **Processor**: Intel® Core™ i7-770HQ CPU @ 2.80 GHz (8 CPUs),
- **RAM**: 16 GB
- **Video Card**: GTX 1060

2.3 Procedure

1. Set up Vive system.
2. Identify flag locations in real space relative to virtual space.
3. Test simulation.

4. Connect participant to Vive system.
5. Have participant move through virtual space to identify flag location.
6. Have participant plant a flag in real space where they believe the marker was in virtual space.
7. Record results.
8. Change mode of locomotion.
9. Test again.
10. Repeat steps 4-9 until all forms of locomotion are tested.
11. Repeat procedure with each new test participant.

2.4 Questions

The questionnaire included questions that were administered the participants for the VR system and are as follows:

I. What is your age?
II. How familiar are you with the concept of virtual reality (VR)?
III. Do you have experience with the HTC VIVE - Virtual Reality system or any other VR system?
IV. Do you believe it took you a short amount of time to understand and operate the simulation's interface?
V. Do you believe that the control system required to use VR is overwhelming?
VI. Which industry do you think will be impacted by the VR in the next 5 years?
VII. Do you believe the overall experience with the VR was satisfying?

3.0 Results

Our measurements were divided among four tests, with each test consisting of distance measurements for each of our different locomotion methods. The methods were the Arm Swing Method, Point Teleport (AKA Blink), Sliding, Grab/Pull, and Dash.

Teleport: The user points their controllers at the location they want to move to and press the button to teleport to that location.

Blink: The user will move a set distance forward when the button is pressed.

Sliding: The user controls their movement by pressing the analog button on their controller in the direction they want to go. They will move in that direction at a set speed.

Arm Movement: The user simulates running by moving their arms back and forth in an alternating fashion.

Grab/Pull: The user can grab a location in virtual space by holding down a button on their controller and pull themselves forward.

Test #	Locomotion Method	Target Horizontal Position(cm)	Target Vertical Position(cm)	Actual Horizontal Position (cm)	Actual Vertical Position (cm)	Horizontal Offset (cm)	Vertical Offset (cm)	Offset (cm)
1	Teleport	600	400	730	478	130	78	151.6047493
	Blink	400	600	426	782	26	182	183.8477631
	Slide	300	300	378	396	78	96	123.6931688
	Arm Movement	500	800	732	838	232	38	235.0914716
	World Grab/Pull	200	600	279	299	79	301	311.194473
2	Teleport	600	400	716	452	116	52	127.1219887
	Blink	300	300	304	315	4	15	15.5241747
	Slide	800	500	640	310	160	190	248.394847
	Arm Movement	600	200	427	417	173	217	277.5211704
	World Grab/Pull	800	400	737	173	63	227	235.580135
3	Teleport	400	600	326	524	74	76	106.0754448
	Blink	500	800	614	746	114	54	126.1427762
	Slide	300	300	574	366	274	66	281.8368322
	Arm Movement	400	800	498	792	98	8	98.32598843
	World Grab/Pull	600	600	620	590	20	10	22.36067977
4	Teleport	100	200	117	198	17	2	17.11724277
	Blink	600	500	544	544	56	44	71.21797526
	Slide	700	100	711	102	11	2	11.18033989
	Arm Movement	300	800	340	650	40	150	155.241747
	World Grab/Pull	600	800	584	564	16	236	236.5417511

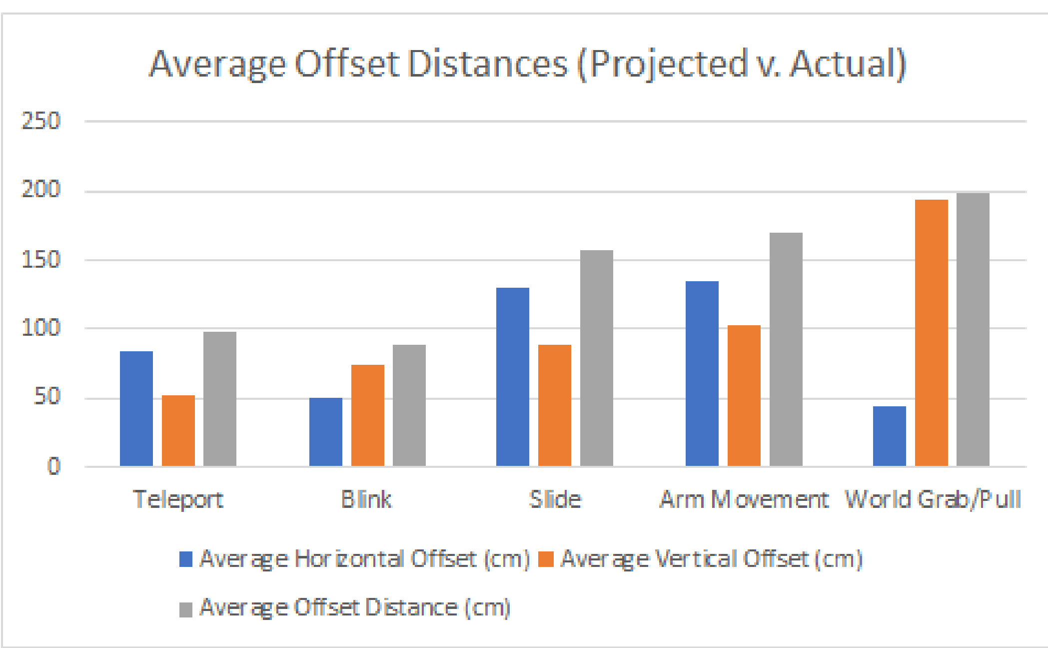
Full Test Results

Below are the full range of test results, including the virtual positions versus the actual positions that testers ended at.

Test #	Arm Swing Average Offset (cm)	Point Teleport Average Offset (cm)	Sliding Average Offset (cm)	Pull Movement Average Offset (cm)	Dash Movement Average Offset (cm)
1	151.60	183.85	123.69	235.09	311.19
2	127.12	15.52	248.39	277.52	235.58
3	106.07	126.14	281.84	98.32	22.36
4	17.12	71.22	11.18	155.24	236.54
Avg	99.01	89.10	157.89	170.55	198.55

Average Offsets

Below are the results regarding the average offset between the target position and the actual position results. This data is the driving factor in determining how accurate and precise a locomotion method is. Note that "Horizontal" and "Vertical" in this scenario refer to the X and Y axis on a two-dimensional plane, the ground in this case.



4.0 Conclusions and Discussions

After many hours of research and much experimentation we have concluded that blink-based locomotion achieves the highest amount accuracy of the available locomotion techniques, though only marginally more accurate than the teleportation method. These two methods seem to allow users the largest degree of accuracy despite being more reliant on the controller and less reliant on the user's movement.

We have also determined the world grab/pull locomotion method is the least accurate of the available techniques, and gives similar results to the arm movement techniques. These two techniques try to most accurately mimic real-world movement by including movement by the user, yet seem to lose a degree of accuracy in doing so.

Our conclusion is that locomotion methods that rely on using the controller's interface (its buttons and the analog controls) are the most accurate choice for moving the user through virtual space. By comparison, the methods that emulate real movement such as arm swinging and the grab/pull technique are perhaps more realistic representations of human movement, but are significantly less accurate as a drawback. For applications that requires precise movement, it is recommended that movement should rely on the controller's interface.

5.0 References

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