Exploring Methods for Two-Handed Object Interaction in VR Using 6-DOF Controllers

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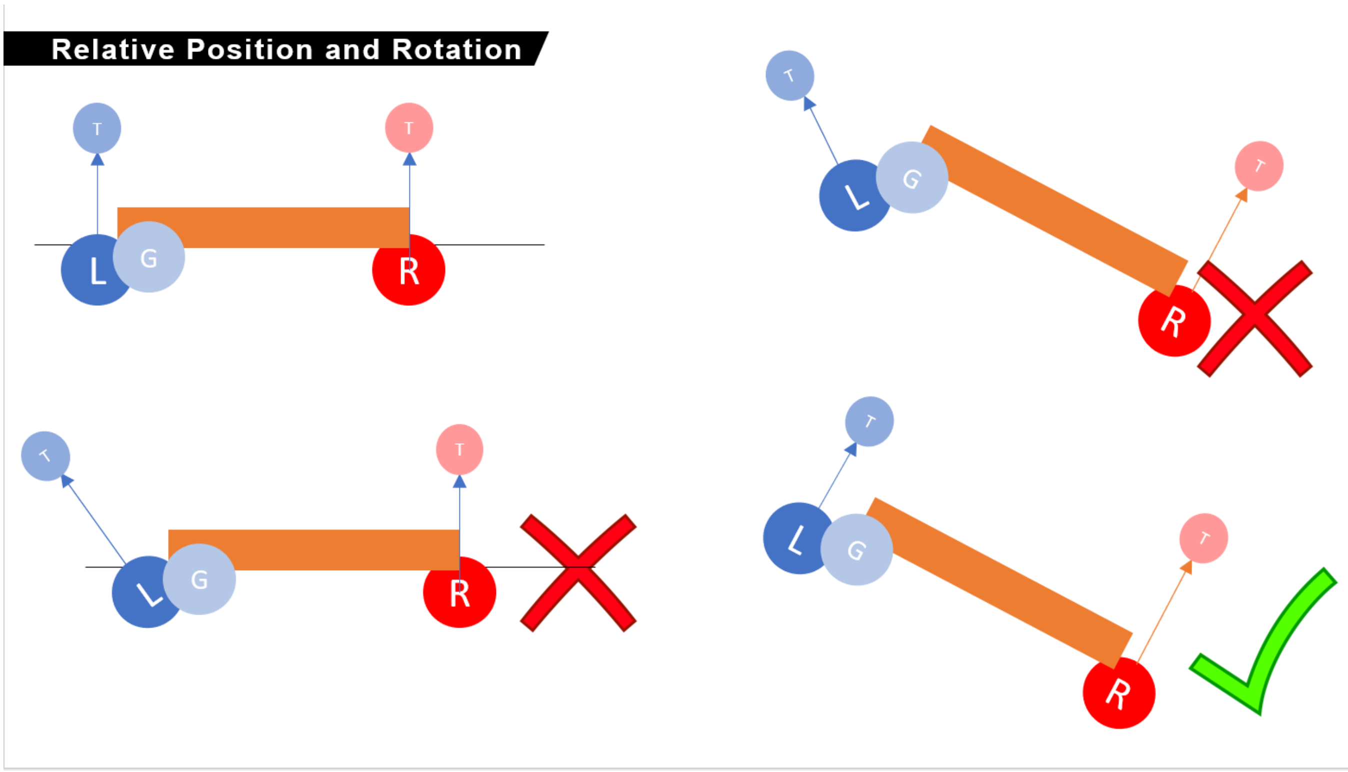

Fig. 1. Using common 6-DOF controllers, researchers explored multiple models of forced two-handed interaction. A target shooting scenario was presented to a multi-user study cohort, in which they were asked to hit all targets using each of the four interaction models. The scenario was designed and built in Unity game engine and was demoed on Oculus Quest.

With the increasing availability of virtual reality headsets for entertainment and enterprise uses, the desire for more accurate virtual simulation is ever increasing. While there exist many applications that allow the user to interact with an object using both hands, many of them break realism by allowing interaction when the player is not in contact with the object. The focus of this project is to find an interaction method that best replicates a two-handed interaction with a real object. The goal is to present a user a target shooting scenario that they must complete by interacting with a virtual rifle using multiple models of two-handed object interaction. This scenario will be implemented in Unity for Oculus Quest and will log the ability of the player to complete the task. The long term goal of this project is to conduct a large scale user study.

1 INTRODUCTION

Current methods of utilizing two-handed objects in VR has posed a challenge for those attempting to maintain a sense of realism within a virtual scenario.In the physical world when manipulating objects with two hands, the grasped object determines the position and orientation of the hands based on its own position and orientation. If one hand attempts to manipulate the position of the grasped object, the other hand must adjust accordingly to allow the object to reach the desired state. In VR, the lack of a physical object to guide our hand movements poses a challenge when attempting to manipulate two-handed objects, as now each hand can move independently.

More realistic methods such as haptic gloves are emerging but are still very much in development. They range drastically in quality and to get a very realistic experience one would have to spend a fair amount to aquire a high-end pair. Despite VR headsets becoming more widely available, it is still rather expensive and finding a a solution without the use of extra hardware is important to have.

If we can attempt to mimic the limitations of motion presented by physical objects, we can achieve a more realistic and comfortable result. Previous studies have shown that VR can cause the mind to disassociate from our regular hand eye coordination, and using a

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Fig. 2. A mechanical device used to constrain controller movement and mimic the use of a rifle in VR.

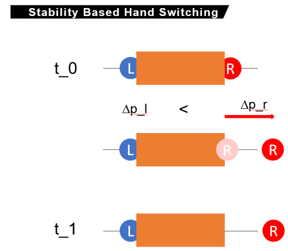

Fig. 3. Diagram explaining the Stability Based Hand Switching

design solution to exploit this may be a path to an ironically more believable simulation.

Another potential benefit from this could be to more realistically interact with objects that require the use of a non-standard grip or one that does not involve the closing of the fingers. Picking up a heavy box for instance usually requires one to place pressure on both sides of the box and use the force of friction and counter pressure to keep the box from falling.

The goal of the project is to find a model for two-handed interaction with an object that could comfortably be used to complete a task of target shooting. Due to its relatively lenient nature, the expectation is that the Relative Position model will perform best. The Stability Based Hand Switching employs the most unconventional method, which will most likely result in the worst performance.

1.1 Contributions

- We introduce the Stability Based Hand Switching, Motion Based Hand Switching, Relative Position, and Relative Position and Rotation interaction models that strictly require the use of both hands for two-handed object interaction.
- We will present the results of a user study concerning the effectiveness and realism of these two-handed interaction methods within a controlled test environment.

2 RELATED WORK

Special controller accessories have been introduced as ways to fix this problem, by providing a physical guide that restricts the degrees of freedom that controllers may move. However high quality accessories for this purpose tend to be rather expensive, and now the user must buy a separate piece of hardware. Despite the increased presence of VR in the home entertainment sphere, the price point still remains relatively high, making the need for a design solution without using additional hardware much more important.

The simplest solution that is commonly presented in VR gun games such as Pavlov VR is to parent the gun to the trigger hand so that the object moves relative to the trigger hand's position and orientation. The second hand may snap to the foregrip when close enough to the gun to simulate realism, but when it is moved far enough away it detaches from the gun. In this case the hand on the forward grip does not effect the aiming of the gun at all. This method essentially treats the object as a one handed weapon.

Another solution is to again use the trigger hand as the primary pivot point, but instead aims the weapon based off of the position of the forward grip hand. This method allows for actual two-handed manipulation, but eliminates the rotational degrees of freedom provided by the touch controllers. This is can be seen in the Oculus first steps demo.

A better method of solving the rifle problem employed in Boneworks VR, introduced a third contact point on the shoulder as the primary pivot, limiting the aiming angle by moving the trigger hand in relation to the shoulder, however this still essentially eliminates the use of grip hand, except for reducing simulated weapon sway. While more realistic, its use of the third pivot on the shoulder disqualifies it as a true two-handed interaction.

3 METHOD

For this study, four methods of two handed interaction were tested. The model for an interaction is based on how the interaction is perceived by each of its actors.

3.1 Stability Driven Hand Switching

When moving an object with two hands both have to cooperate in order to move the object. Therefore an object may not move if one hand doesn't allow it. For this model, when both hands are placed on the object the change in position of each hand since the previous frame is sampled every frame. In this stability based model, the object is dynamically parented to the hand that has moved the least since the previous frame. This essentially does not allow the object to move unless both hands are in contact and moving at a similar rate. 3

3.2 Motion Driven Hand Switching

Conversely, a two handed interaction can be thought of as an action by one hand and a reaction by the other. Therefore, in the Motion Driven model we dynamically parent the object to the hand that has moved the most since the previous frame. In this case it is the job of the more stationary hand to follow the active hand at a similar rate, otherwise it is detached.

3.3 Relative Position

Using this method, the left hand must stay in the same position relative to the right hand as when it was first grasped with both hands. When both hands are attached to the object, the object is parented to the right hand such that it moves with the position and rotation of the right hand. The grip section of the object has a collider that detects the left hand's presence. If the left hand comes off of the grip collider, the object is detached from the right hand and the left hand and must be grabbed again by both hands to be moved again. This is to force the user to move both hands relative to each other simultaneously, to simulate them holding the actual object.

3.4 Relative Position and Rotation

This model uses the same principal as the relative position model, but also takes it a step further by requiring that their same relative rotation be maintained as well. When the object is grasped by 2 hands, we create two empty points that we will refer to as rotation markers, one for each hand. These are placed exactly one unit above their respective hands in the world-space up direction. This is done in the world space up direction to create a common orientation between the two hands, because their current world rotations may not be equivalent. We then parent each of these rotation markers to their respective hand so that they will move relative to their hand's position and orientation.

On every frame we then sample the vector from each hand to their respective rotation marker. We then take the dot product of the two vectors, the left and the right. Because exact orientation matching is unrealistic, we designate a threshold value that will give the user some tolerance for mismatching. If the dot product between the left and right is above the threshold, and the conditions outlined in the previous subsection for relative position are met, then the object will be moved according to the right hand. If not the object will be detached from both hands. 1

4 IMPLEMENTATION DETAILS

Using Unity and the Oculus Integration package, a scene was created with a model gun and a target using Unity's built in primitives. We attached colliders to the gun and added a raycasting system to allow it to shoot. When the user pulls the trigger the gun cast as ray in the direction it is pointing and if it hits the target it logs it to a JSON file. Every time a shot hits its position relative to the center of the target is registered as well as the time since the start of the simulation. The logger also keeps track of the number of times that the gun was dropped or rendered inert due to breaking the offset requirements.

When a target is hit it moves to a new location, forcing the user to adjust their aim. After the target is hit 10 times, the scene is reloaded with a different interaction method. The player will repeat the scenario 4 times using a different interaction method each time.

To asses the results, the player's speed between each of the targets will be compared. Their accuracy will be calculated for each target as the distance from the bulls eye as well as the number of shots it took to hit the target. These metrics will be compared over across all four interaction methods, and the data will be aggregated over all user results.

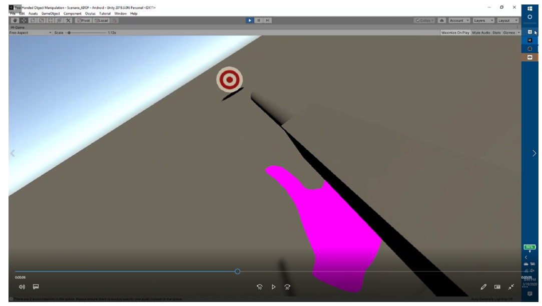

Fig. 4. The target shooting scenario presented to the user-study cohort.

5 EVALUATION OF RESULTS

Unfortunately due to the Coronavirus Quarantine at the time of this paper, the full user test was unable to be completed. The logging interface was only for the local machines so distributing the project it digitally would not be possible as there is no way to retrieve the data reliably. By the time of the quarantine announcement, there was not enough time to write a web based logger.

Based on very few-in person results, there preference seems to be relative positional based, which was expected. It provides a slightly more lenient approach with more tolerance. One subject thought the relative position and rotation model to be somewhat uncomfortable as aiming at targets at lower angles placed their wrist in an awkward position.

6 DISCUSSION OF BENEFITS AND LIMITATIONS

One of the limitations of these models is that they just stop working if the user breaks the conditions. A lot of our movement is subconscious so bringing how you move in VR into your consciousness may be a difficult step for the player to make. A more comfortable design would probably include the ability for a hand to break away from the object and still allow one handed manipulation, but that would go against the point of the study.

Another limitation is the way objects are parented in Unity. In order for the gun to be picked up directly by the hand, we have to make the gun a kinematic rigidbody. By making it kinematic, it does not interact with forces like gravity, so with these models we cannot properly simulate the weight of the gun. Adding gravity or drag could make it more stable and feel cleaner. The weightlessness also causes for instability when aiming, as any small movement of the wrist in the relative models causes the entire gun to move without emulating the rotational inertia that the gun would have from that point.

One thing that was limited due to time was fleshed out graphics. In a scenario that seeks to present a more realistic experience, improved graphics could definitely play a role on the viability of a method. However the current simplicity could also work to our benefit because the focus is solely on the experience and not the graphics.

7 FUTURE WORK

Once the quarantine is lifted, I definitely plan to conduct the user study on my own time and present the results.

Currently the Hand Switching models that have been presented are not completely stable, so it would be beneficial to reduce jitter and conduct the user study. As mentioned earlier, interactions with objects that require non standard grips seem to be lacking in realism in many VR applications. Often times objects can be picked up by pinching a flat and rigid surface with one hand and effortlessly twirled around. While this may work for intentionally unrealistic experiences, it would be interesting to see more realistic interactions in more realistically targeted experiences. This definitely could lead to the ability to convey weight in an object, requiring two hands, or a specific counter-pressure, and adding in ideas like friction to make objects harder to move.

8 CONCLUSION

Replicating realistic two-handed object interactions remains a challenge in the VR community. New methods that require the player to use both hands may provide a more realistic experience, but their comfortability and practicality remains uncertain. While rifles are probably the most common two-handed object used in the VR entertainment sphere, it is important to find more generalized methods of interaction that could be used on any arbitrary object in VR. Particularly concerning realistic physics and weight, it will be interesting to see what users will tolerate for a more accurate simulation.

ACKNOWLEDGMENTS

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