Navigation in virtual reality

Niels Andreas Østman - nies@itu.dk

There are many different approaches to handling navigation on virtual reality. All of them comes down to a trade-off between virtual reality sickness, immersion and design constraints. First this chapter will give a brief introduction to virtual reality sickness, then immersion in virtual reality, followed by examples of typical and experimental approaches to handling navigation in VR and what compromises they each make. Finally the solution developed for this project will be presented along with the advantages and disadvantages.

Virtual reality sickness

When putting on a virtual reality headset, all visual input given to the player is from a virtual environment seen through a set of lenses inside the headset as seen in figure 1.

Figure 1. Lenses in HTC Vive

Discrepancies or ambiguities between visual, vestibular and proprioceptive cues can lead to a reaction similar to motion sickness. This includes loss of balance, dizziness, nausea and even vomiting. A prominent theory of simulator sickness in virtual environments labels the issue as ‘cue conflict’[11]. Incongruence between what the player sees and what the proprioceptors senses is a cue conflict that can contribute to simulator sickness. For example if the player’s hand is somewhere in the virtual world where the player’s physical hand is not. The most prominent cause of cue conflict is when when the player’s visual system senses motion, but the vestibular system, that is in charge of sensing balance and spatial rotation, senses no movement.
For example riding a roller coaster in vr with no movement of players body can lead to loss of balance as seen in figure 2.

Figure 2. Jacob tries the Oculus Rift (roller coaster)[13]

In figure 3 a father can be seen who has cleverly found a way of stimulating both visual and vestibular sensory systems of his daughter in a pretend roller coaster. He does so by having placed her in a box and moving her around to fit the video of a roller coaster which is playing on the TV in front of her. For her there is no cue conflict and she does not lose her balance. The idea is used on a larger scale in the Tivoli ride The Demon in VR, see figure 4. It is an interesting case where there the vestibular senses are actually experiencing the same movements that the visual senses are seeing.

Figure 3. Dad and Daughter Pretend Roller Coaster[12]

Figure 4. The Demon roller coaster in Tivoli

Immersion

Spatial immersion or telepresence is the subjective sensation of being someplace else. According to Abrash[14] a number of technical conditions have to be satisfied to achieve *presence*. These technical demands should be met by modern VR headsets such as HTC Vive and Oculus Rift. The power of VR allows the player to visit virtual worlds and think that they are actually there. Cue conflicts and VR sickness has a harmful effect on the player's telepresence. To maintain immersion it is important to diminish these effects.

Moving in VR

The physical play area for VR is limited. According to Valve the minimum required space to set up and HTC Vive headset is 2m x 1.5m[15]. This means that when designing games for VR, restricted physical play space has to be taken into consideration. The big design question is how is the player going to move around in the virtual world with the real world size constraints that apply. The following section will look at some different approaches that have been employed for moving in VR.

Small virtual space.
Owlchemy Labs designed their game Job Simulator as a small virtual space that adjusts in size to the physical play area[16]. That way they ensure that the player has one-to-one movement translating from physical space to virtual space. This means that the only movement the player will experience is what they physically perform themselves. With this approach VR sickness can be minimised and

Figure 5. Job Simulator [10]

immersion is high. It is however a big design constraint that all virtual rooms have to fit within the physical play area.

Movement in vehicle

Figure 6. Project cars 2 VR [9]

A common approach is to have the player move inside a vehicle that can provide a static frame of reference. Often seen in racing games and space flight simulators, the cockpit, steering wheel etc., functions as a frame frame of reference that helps reduce VR sickness. Holding on to a physical steering wheel can help further the immersion in the game since it will match the steering wheel seen in the game. However the game does not know if you raise your hand from the wheel and the virtual hand will not follow. The mismatch between physical and virtual hand can hurt the immersion. Basing movement in a VR to be vehicular is also a constraint, as the game has to take place inside a vehicle.

Virtual movement

Lucky's Tale is a game that was developed as launch title for the Oculus Rift [8]. The Rift originally did not ship with motion controllers and instead it shipped with an Xbox controller. That means that the game was developed with a gamepad as an input device. Like in a traditional 3D platformer game, the thumbstick is used for moving the character around. This virtual movement has a high risk of inducing VR sickness since there is visual movement but no vestibular input. It also deprives the player of using their body in the game and the telepresence most likely diminishes the sensation of being in the world, and it will be more like looking into the world. On the other hand this approach for a lot of freedom in the game design since no spatial restrictions apply.

Smooth movement

A variation of virtual movement is smooth movement. It is used in Skyrim VR [7] where the player points their motion controller in the direction they want to move and pull the trigger on the controller. The player is then transported smoothly towards the direction they are pointing. This solution also offers no restrictions on the virtual world size and it incorporates motion control in a way that can result in a more immersive experience. The movement itself however may still prove to give the player VR sickness.

Teleportation

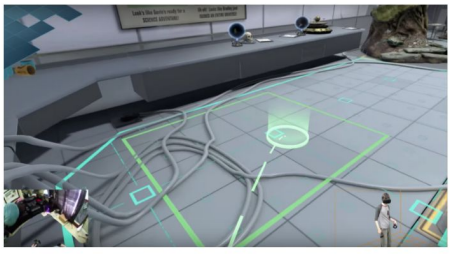

Figure 7. The Lab [3]

Teleportation is a popular method of moving in VR. The player can point their motion controller in the direction they want to teleport and an animated arc will show the player where they will go, an example can be seen in figure 7. The use of it does not constrain the size of the virtual world. It introduces no cue conflicts since the player does not actually move in the virtual space but rather they teleport instantaneously,

which means that no vestibular input should be expected. However, the use of teleportation can distract from the experience the game is trying to create. It can feel like an extradiegetic game mechanic that will remind you that you are not actually there and that it is only a game. An exception to this would be in the case where the teleportation is a part of the story in the game.

Dash and jump

Sairento VR makes use of variations of teleporting with dashing and jumping. These seem to be an attempt at making the mechanics for moving better fit within the world. Dashing is like a compromise between smooth movement and teleporting. Like teleporting, the player get an arc to point where they want to move. Like smooth movement there is a smooth animation taking the player to the target location. Jumping does the same thing but instead of animating in a straight line, the animation will move the player along the curve of the arc. Curved movement such as jumping introduces the risk of VR sickness[1] and there is clearly going to be a cue conflict for the player.

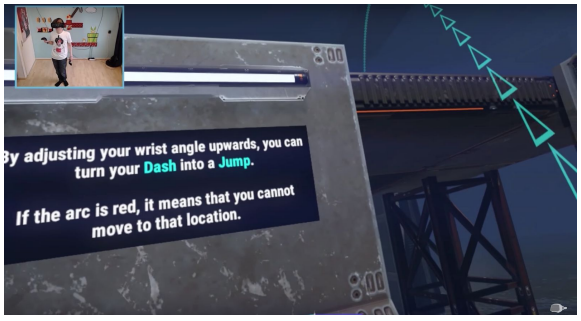

Figure 8. Sairento VR [2]

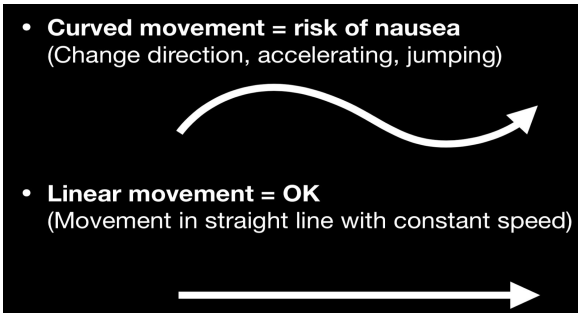

Figure 9. Curved vs linear movement[1]

Fringe movement systems

Some more experimental approaches try to give the player fitting vestibular input while they stay in place to increase immersion. Examples include the player swinging their arms to move forward, walking in place and sliding feet around while seated. While these solutions may have a good coherence between what you see and what you do, it requires some rather involved setups and they may become self-aware of what they are doing, causing them to lose their immersion in the game. The mechanic for moving in the virtual world also seems to require some practice to get right.

Figure 10. ArmSwinger VR Locomotion System[6]

Figure 11. Walking in place with Virtuix Omni[5]

Figure 12. Walking in place, seated with Cybershoes[4]

Free movement by level design

Eye of the Temple is an upcoming game being developed by Rune Johansen that employs clever level design to achieve one-to-one movement in a large virtual world. This is made possible by having moving platforms that moves the player forwards, backwards, left or right. By meticulously designing the level it can be guaranteed that the player will return to the center of the play space before taking another step. It is simple to learn since the player simply has to move onto the moving platform to get transported. The movement while on the platform is similar to that of vehicle movement since the player has the platform underneath them as a static frame of reference. Depending on the player this may still lead to discomfort. The system constrains the game design to make use of moving platforms for this to work.

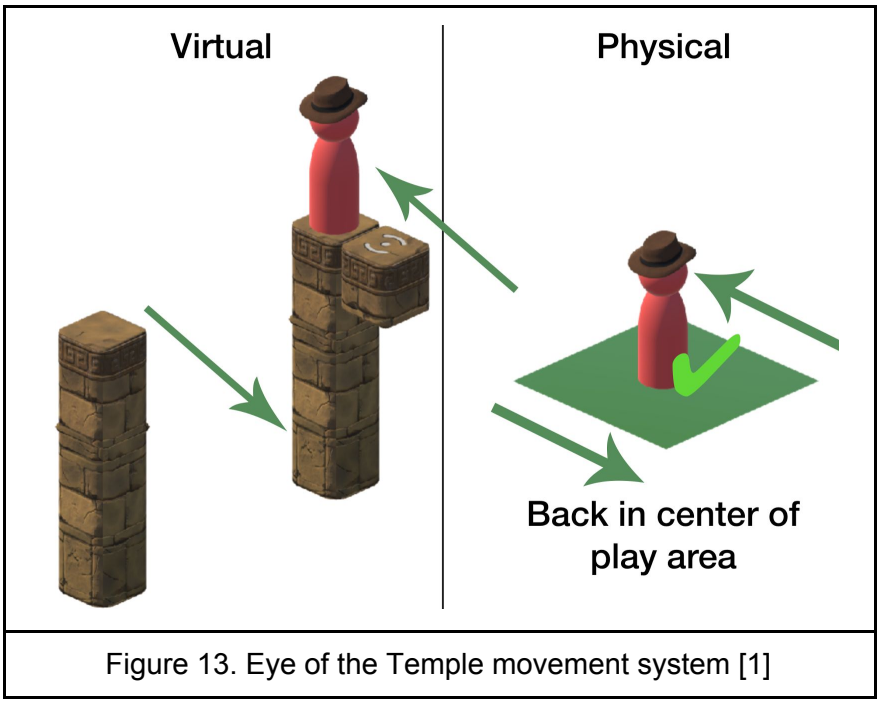

Figure 13. Eye of the Temple movement system [1]

Movement in Memoirs

We developed a number of small virtual spaces that each allow one-to-one movement. In the main room the player has a selection of photos hanging on a pinboard that each represents a room that can be visited. To visit a room the player picks up the photo and moves it close to their face. The game fades to black and the selected room will appear. The player is able to freely explore and move around in the room they have entered, and when they want to go back to the main room, they can pick up and put on a detective hat. The room will again fade to black and the main room will appear.

This means that there is no virtual movement in the game, only the movement the player themselves make in the physical world. The player does not move as the scenery gets swapped out and the fade to black between scenes makes the change less abrupt. The only two modes of movement is one-to-one movement and changing scene, this limits cue conflicts and immersion is preserved.

Moving back to the main room with the hat turned out to work well. It is something that invites the player to pick it up and try it on. They will not know what will happen, and they are just trying out things. But something does happen, which leaves a great impression on the player, leading them to remember what the hat does. Putting on the detective hat also fits

within the fiction of the game, and it can help the player immerse themselves in the narrative of the game. They will feel that they are the detective making deductions and solving the murder. It is only natural that they should put on their hat before they leave a scene. Transporting the players to new rooms with images did not work as self-explanatory as the hat did. The pictures do not present the same immediate affordance as the hat does. The player instinctively knows that a hat is something that can be put on and be worn. In preliminary playtests it was necessary to explicitly tell the player how to use the pictures. In later versions of the game, a board with instructions for interactions in the game was introduced. It is certainly a problem that one of the core interactions for moving in the game is not self-explanatory, but the interaction is very similar to that of the hat and when people have tried it, they understand.

An interesting observation made is that the placement of the photos in the main room impacts where the player will be positioned when they enter another room. In the case of Memoirs it reveals that the design of the main room could be improved. As it is, the pinboard containing all the photos are hanging on a wall by the edge of the virtual and the real world. That means whenever a player goes to pick up and enter a photo, they will be facing the wall with their back turned to the center of the room, see figure 14. This is a problem because the player will not be facing the content of the new scene when it is loaded. A solution would be to place the pinboard in the center of the room. That way the player will always be centered in the room when they enter a new scene.

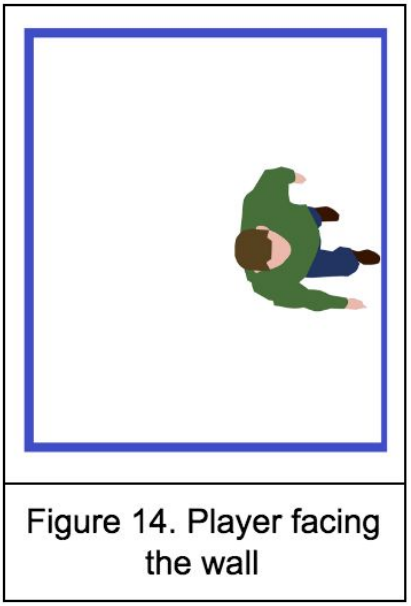

Figure 14. Player facing the wall

Realizing that the placement of the objects that take the player somewhere else can control where the player will be positioned, can be used as a tool. For instance the hat can be placed such that the the player puts on the hat in a room, the will appear in front of the desk in the main room in terms case where we want them to find something specific there. This gives the level designer control over where the player will be at certain times in the game.

All the different approaches that have been described each have their own strengths and weaknesses. It would seem that is necessary to assess what are the needs for the specific game being developed and choose the approach that suits the needs of the game.

The solution chosen for navigating in Memoirs works well for the specific type of game where it makes sense to move from place to place through objects, but it is of course a design constraint. Throughout the testing there was no issue with players getting VR sickness and it seems that the approach works well in that regard. While there are some issues with learning the interface for navigating through the game, it seems to be an interaction design or usability challenge that probably could be solved and maybe a tutorial would alleviate the learning curve.

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