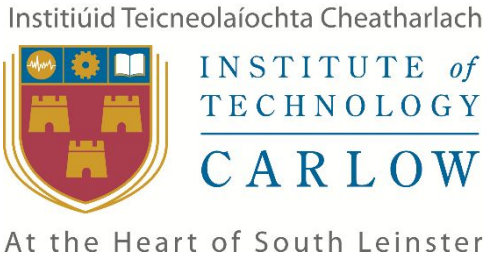

Computer Games Development Project Report Year IV

Aoife Powders
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Interactions in VR

Contents

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Project Abstract

Motivation

We live in a time where technology is evolving at a massive rate and with that several innovations are here to change the world as we know it forever, including artificial intelligence, machine learning, augmented reality and virtual reality.

Many people believe virtual reality is going to make more of an impact than smartphones. It seems like a big claim until you consider the true potential of virtual reality and the ways in which it can be used.With VR , you don't need to dream, you can become, with its vast array of immersive virtual environments. You can explore entire new worlds, experiences and even careers. All of this is made so immersive by the interactions available in VR. Usually you can pick up anything you could in real life and more and use it like normal or not depending on the application.

VR is making a huge surge in games with headsets becoming cheaper and more available to the public. More people than ever before are becoming exposed to VR but it's not just a medium for games. It can be used in the business world, too. Soldiers and military can get real, life-like training, law enforcement can prepare for emergency situations, the possibilities are endless. Even Walmart announced that it is using 17,000 Oculus Go headsets to train its employees. It is likely we will see industries involving work with expensive tools and equipment, or hazardous conditions using VR more and more.

The use of interactions in VR is essential to feeling truly immersed in the environment. This was the main motivation behind this project, as the interactions you have with your surroundings is what makes virtual reality what it is today.

It was this relevance that influenced my study of *Interactions in VR* as I believe that VR has the potential to become even more than it already is. VR is growing bigger and bigger every day with new uses found all the time, its potential is limitless.

Purpose

My aim for this project is a study on *Interactions in VR*, to become more accustomed to developing for VR devices, and expand upon my knowledge of VR. I intend to develop a demo that uses the HTC Vive, and will teach the user about all the different ways in which you can interact with your environment in VR.

Method

I started this study by studying games and gaming in VR. I looked into all the different genres and styles out there. I then focused on specific genres I felt would be feasible to create throughout the year.

I also studied Virtual Reality technology and what it can do, and looked into the different VR headsets and what they are capable of so I could choose the correct one. I inevitably chose the wrong headset (Oculus Quest) and soon swapped to the HTC Vive as I couldn't debug any code using the Quest.

The results of my research gave me some good ideas of games I could develop in VR with the HTC Vive. It didn't take me very long to realise I wanted to change my field of study. The more games I researched the more I saw new and innovative interactions being used. That's when I decided that I wanted to look into just the interactions. But then came the predicament that I still wanted to make something game related. So I came up with the idea of making each interaction into a minigame similar to an arcade.

After this revelation I researched many interactions developers were using in VR and which were most prominent or which could be used to create a game from.

I choose a wide array of different interactions some of which I made minigames surrounding. I felt the decision to explore interactions was the best decision as I can learn about the most important side of feeling immersed in VR environments.

Project Introduction and Research Question

“Interactions in VR”

My objective is to create fun VR interactions in Unity3D and Visual Studios, using mini games. It is intended to be played using the HTC Vive VR headset. Each mini game is designed as a fun way to experience a single interaction. There are four main interactions I concentrated in turning into mini games. They are pushing buttons, using levers to move objects, picking up objects and clipping them into place and hitting an object with another object. There are two parts to some of the minigames. Both are the same game but the interactions used to play differ. This gives users the option of choosing which style of interaction they preferred. The user can move through the environment using a teleporting system. Each interaction minigame has a teleportation waypoint in front of it the user must simply point at the way point and click the trackpad to teleport to that location.

You start with some basic interactions like opening a door or drawer, or picking up and dropping objects. Then you can move to the first set of minigames involving pressing buttons. This minigame has two parts, one is focused on interactions with UI which means that you point and click to interact with the button, the other is “pure VR”, which can also be known as diegetic meaning something that exists in the game world rather than being overlaid onto the game, where you have to actually push the buttons. The objective of these

games is to press the buttons as they light up. The next minigame you come to is a maze-like game, where you use the two levers to maneuver the cube around the maze and find the exit. Next up you will see two more minigames, this is another two part game. Using the picture above them as reference, the user will need to transfer the blocks into the appropriate pattern. On one side the user will move the blocks around using their hands, on the other side the layout of the blocks is there for them, they will have to move the correct block into the correct space and the block will clip itself in place. The final minigame is simple, you have a baseball bat and a ball. All you have to do is try to hit the ball as far as you can with the bat.

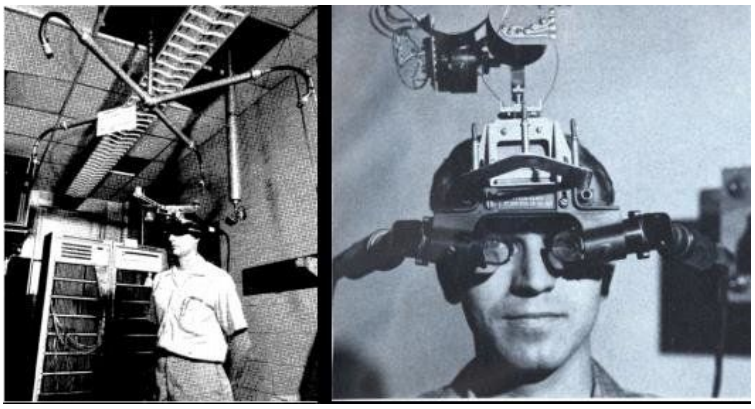
My goal is to create a pleasant and engaging way of interaction with objects in VR.

Background

If we focus more closely on the nature of virtual reality as a way of creating the illusion that we are present somewhere we are not, then the earliest attempt at virtual reality is surely the 360-degree murals from the nineteenth century. The purpose of these paintings was to fill the whole field of view of the viewer, making them feel present at some historical event.

(Panoramic Painting of Battle of Borodino, 1812)

VR dates back to 1838 when Sir Charles Wheatstone was the first to describe stereopsis, explanation of binocular vision. In 1960 the first HMD was released, there was no motion tracking at this point. Headsight was the first motion tracking headset, it was created in 1961. It had built in video screens for each eye. Used in the military. The first HMD was named The Sword of Damocles. The head mount was connected to a computer rather than a camera. But it was too heavy to wear so users were strapped in while it was suspended from the ceiling **[**Anon (2017)**]**.



(The Sword of Damocles)

One of the first companies to attempt to launch a VR headset was Sega, which planned Sega VR as an accessory for the Genesis.Unfortunately it was never released, with one explanation being that Sega worried the virtual effect was too realistic, and people would wind up hurting themselves while immersed **[**Luke Dormehl (November 13, 2017)**]**. In 2010, 18-year-old entrepreneur Palmer Luckey created the first prototype of the Oculus Rift. Showing a 90-degree field of view that hadn't been seen previously in a consumer device, it raised $2.4 million on Kickstarter a couple years later, before the company was purchased by Facebook for $2 billion in 2014.

In 2017 hundreds of companies started working on their own VR headsets.These include market leaders such as HTC (makers of the HTC Vive), but also Google (Google Cardboard), Apple, Amazon, Sony, Samsung, and others.

Technology is always advancing at a rate some people just can't keep up with. With virtual reality and augmented reality rising in popularity and decreasing in price, most households have some form of VR headset, if not a €200 - €400 Oculus then a €10 headset for your phone. With this in mind, this project aims to study *Interactions in VR using HTC Vive.* The overall outcome for this project is to create intuitive interactions for beginners that incorporates the technology of the HTC Vive and VR.

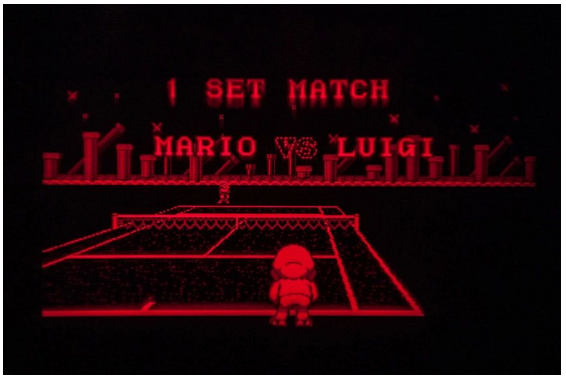
Literature Review

In this section, I aim to explain VR technologies, their uses and how interactions can really make virtual reality feel like reality.

The first VR headset controlled by a computer came in 1968 created by computer scientist Ivan Sutherland. Sutherland worked with student Bob Sproull to create a system that would track the user's head position and render a simple wireframe environment based on their field of view. The device was named "The Sword of Damocles" because it was so heavy that it couldn't be supported by the human neck and had to be hung above the wearer from a mechanical arm **[** K.Thor Jensen (April 4, 2016) **].**

Some of the first VR games were made by sega and nintendo. Segas Master System 3D glasses appeared in the 80s. This headset recreated a unique 3D effect across many games. The headset didn't sell as well as Sega had hoped it would but it was the start of a serge of 3D games.

Nintendo also tried their hand in virtual gaming in 1995 with the Virtual boy. It was on sale for $180. The display was completely in red and black which, rightly so, made some players feel unwell, the Virtual Boy did introduce some cool ideas before it was discontinued.



(The Virtual Boy along with one of the games released on it, Mario Tennis.)

In the 90s, a company called Virtuality Group wanted to introduce players to a new arcade experience. And it did just that, with Virtuality cabinets, they were huge units where players entered and put on a set of virtual goggles and became immersed in a 3D world. This would eventually lead to 1998 when Virtuality Group would try a home model **[**Robert Workman (April 3, 2014) **].**

(Virtuality Cabinets)

All the advancements in VR up to this point had one thing in common. Almost all of them still used a single controller or it was just an environment you could look at, not move around in. It's safe to say that interactions were not at the foreground of research around this time. But fast became the foreground. Research was still being done on 3D interactions that had less to do with VR, especially in games with the likes of PlayStation's EyeToy and Nintendo's Wii. The EyeToy allowed players to control characters using their body by using

motion detection. This was done by taking the video of the player and masking on top of a computer generated background, then each frame was compared to the last to calculate the motion. Then you have the Wii which uses physical props for interaction for example guitars and drum sets for games like guitar hero and rock band. But the most important example of this was the Wii and the Wiimote. The Wiimote revolutionised 3D spatial interaction in gaming.**[**Joseph J. LaViola Jr (Tuesday, July 27, 2010)**]**

By 2014, VR was making headlines again when facebook made a huge leap into VR by purchasing Oculus for $2 billion after it became increasingly popular on Kickstarter. Oculus, along with Valves headset the HTC Vive, are the leading manufacturers of VR headsets today. Both companies are the go to for VR.

When VR started to emerge in the mainstream is after the interactions needed while inside virtual reality were really starting to take off. Oculus and Vive both had similar ideas of how they were going to have users interact with the environment in VR, by giving them 2 controllers, one for each hand. Although Oculus did release a headset with only one controller (Oculus Go) it was sold at a cheaper price, you could only move in 3 degrees of freedom and it had only 1 controller. It was created as an on the go VR HMD as it was a standalone device, meaning it didn't have to be attached to a PC. The HTC Vive was the first to introduce dual-hand controllers, with the Oculus Rift soon following. Using two controllers would seem to make the user feel more immersed in the environment by being able to use both hands to perform a task. Yet research shows that users actually prefer to perform any task using one hand at a time and when faced with a task made for utilising both hands they prefer interaction that does not require both hands.**[**Nanjappan, V., Liang, H., Lu, F.(2018)**]**

To really get interactions right you need to consider the Universal Simulation Principle, meaning “Any interaction mechanism from the real world can be simulated in VR”. For example the user might open a door by turning the knob and pulling. There are 4 main design considerations when developing interactions for VR. Effectiveness, Difficulty, Ease of use and overall comfort **[**Steven M. LaValle (2019) **]**. There are also many different patterns used for interactions.There is no best way to interact in VR. It really depends on the application, goal and intended audience. Each technique or pattern will have its strengths and weaknesses within your application making it important to test many different techniques and pick the one that fits your situation **[**Jason Jerald, Ph.D.(February 1, 2016) **].**

Virtual Reality technology has the highest potential for growth right now. Although Virtual Reality is huge right now, it's still not quite mainstream yet. Many people say 2020 could be the year it finally hits the mainstream **[**Hayden Dingman (January 20, 2020) **].** Fortune Business Insights predicts that the market for virtual reality will continue to grow steadily to $120.5 billion by 2026, from $7.5 billion in 2018 **[**Devindra Hardawar (December 24, 2019) **].**

Basically, there is more than enough evidence that VR isn't slowing down and companies now more than ever have big plans for VR while the technology will continue to advance

more and more. With VR having such a promising future of course I want to get involved and learn more about the technology .

Study

To begin my research topic of Interactions in VR, I began by researching the technology itself and how to increase immersion in a VR environment.

Today most VR systems are powered by a computer. Many systems use HMDs, Head Mounted Displays, to display images to the user. They contain 2 monitors, one for each eye. The images create a stereoscopic effect, giving the illusion of depth. Many systems also use tracking systems to track the position and orientation of the user. Finally input devices are used. These include controllers, electronic gloves, tracking pads, joysticks etc. **[**Jonathan Strickland(29 June, 2007)**]**

A user experiences immersion inside a virtual reality environment, meaning they feel inside or a part of that world. They can also interact with their environment. The combination of a sense of immersion and interactivity is called telepresence **[**Jonathan Strickland(29 June, 2007)**]**. This causes you to become unaware of your real surroundings and focus on the virtual environment. True interactivity also includes being able to interact with the environment.

My original plan was to test my project on other people but because of Covid-19 this was not safe, so I tested on one person, my sister. She has no experience with the HTC Vive but has used the Oculus Quest multiple times before. Because of this I explained what each button did before she started the game. Then I timed how long it took her to figure out how to interact with each object and game. Then I took her heart rate when resting then playing the button game and the blocks game as they were the most strenuous. While resting her heart rate was 72.

She became used to the controls pretty quickly. She figured out how all of the interactions worked without being told. The only interaction she couldn't figure out was the teleporting she saw the ray being drawn from her hand to the squares on the floor but couldn't figure out how to move toward it. Meaning she knew that they were there for her to move towards. When I told her to press the big button in the middle (the trackpad) she replied that she didn't know that it was a button, she assumed it was a trackpad only. She found the interactions themselves to be pretty simple to use and understand.

Next up was the first game, the button game. The game lasts for 10 second and the highest score you can get in 10 seconds is 5. On her first attempt she scored 1, she understood what she had to do and how to do it but didn't know why she only got a score of 1. I explained she had to push the button in fully to score. On her next attempt she scored 5. She then played 2 more games then I took her heart rate. It was now at 117 meaning it had gone up by 45.

Before moving on, I allowed her to rest so her heart rate would return to resting, I then moved her onto the UI version of the button game. She started by trying to physically press the start button. When that didn't work she noticed the line extending from her hand to the canvas and

tried to point and click the trigger button, which was correct. She easily picked up how to play this game and scored 5 every attempt. I then checked her heart rate which was now at 85, it had gone up by only 13.

In conclusion, when comparing the 2 games she thought the UI game was easier but the 3D game was more fun. Her heart rate shows that because she was moving around much more while playing the 3D button game her heart rate rose much more than when she played the UI game.

Next up she played the maze game. She started with the lever and was confused, she tried to move both levers in the same direction at the same time but quickly realised that both levers move in different directions. She then tried to use both the levers to move the block in 2 directions at once. She found this too difficult to use. She found the best way to move the block was to use one lever at a time to move in one direction at a time. I timed her traversing throughout the maze. Using the levers it took her 45 seconds to get to the end.

Then she tried the arrow keys to move back to the beginning of the maze. She noticed it was similar to the previous UI button game and immediately knew how to interact with it. She finished the maze in 10 second with the arrow keys.

She thought the levers were more fun to use but the arrow keys were easier to use. The time it took her to traverse through the maze can conclude that she had more difficulty moving with the levers than with the arrow keys.

She then moved on to the building block game. I asked her to start with the right side and build with the outline first. She understood what to do and started building. She found it difficult to find where each block fit so she looked at the reference picture quite a lot. I timed her during this game and it took her 3 minutes and 30 seconds to finish building.

She then moved on to the left side which had each block already in the correct shape only they were all transparent. Her first instinct was to place the blocks she used for the previous building into the transparent blocks, which was correct. Each block would clip into place if it was placed in the correct position. She didn't need to look at the reference picture at all. She got through this game much faster taking 1 minute and 24 seconds to finish.

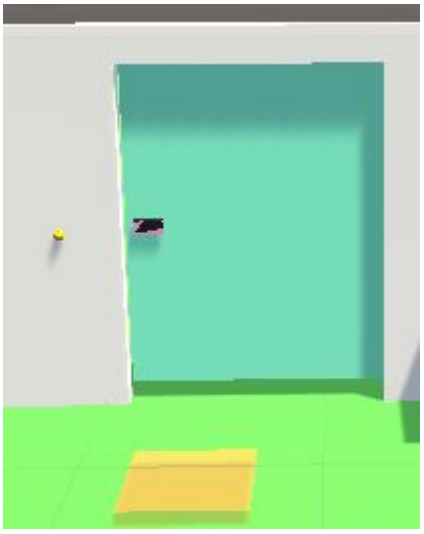
She then moved to the next table where there was a different building. The last building was horizontal so all the blocks were laid on the table, this building was vertical. She tried to build without using the clipping interaction but found it incredibly difficult and frustrating and gave up after 2 minutes. When she moved on to the clipping version she found it much easier and finished the building in 1 minute 48 seconds.

In short, by the end of this game she clearly found the clipping version of both games much easier and more fun to use. She thought the freedom of being able to place the blocks and move them around so they fit comfortably in the correct place was cool but in all was too frustrating to use without the clipping.

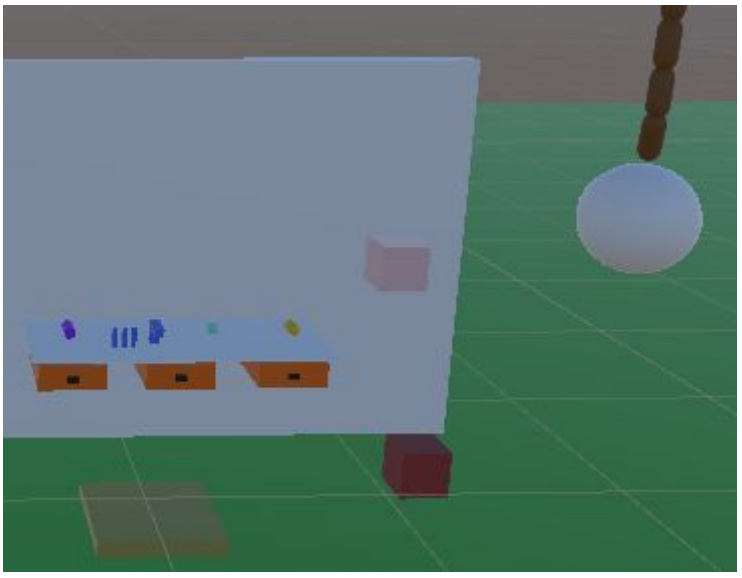
Finally, the last game is the baseball game, she was asked to just have fun and give some feedback. She said it was super fun and easy to hit the ball. She thought it was probably easier to hit the ball here than in real life and it was cool to see it go super far.

Project Description

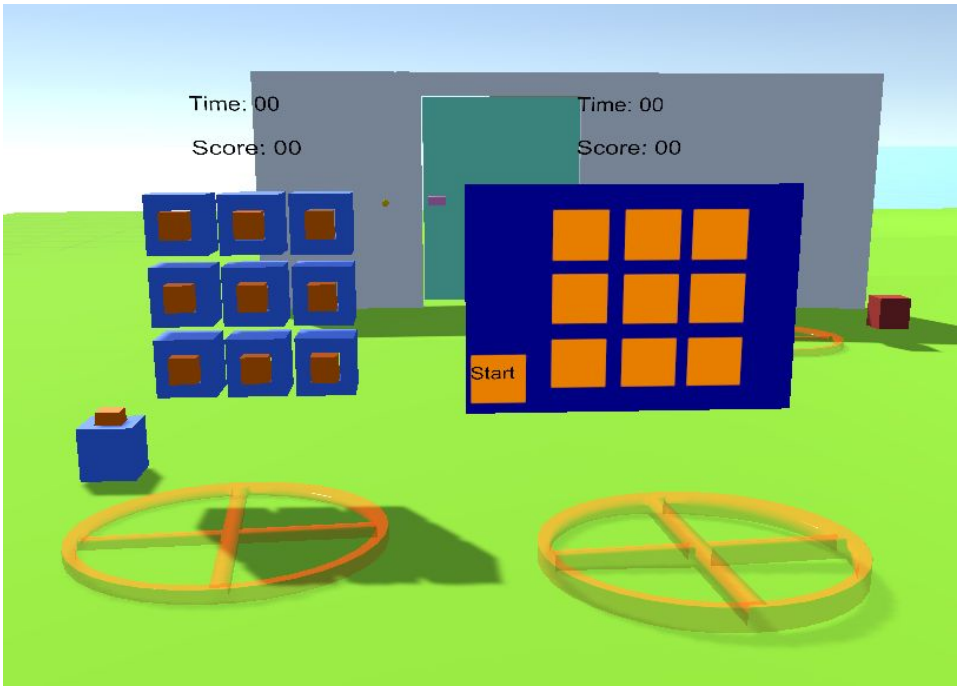
When the user starts the game they will see a small area with some objects they can interact with. In Front of them is a door which they can open. There is a dial on the wall which if rotated will change the lighting.



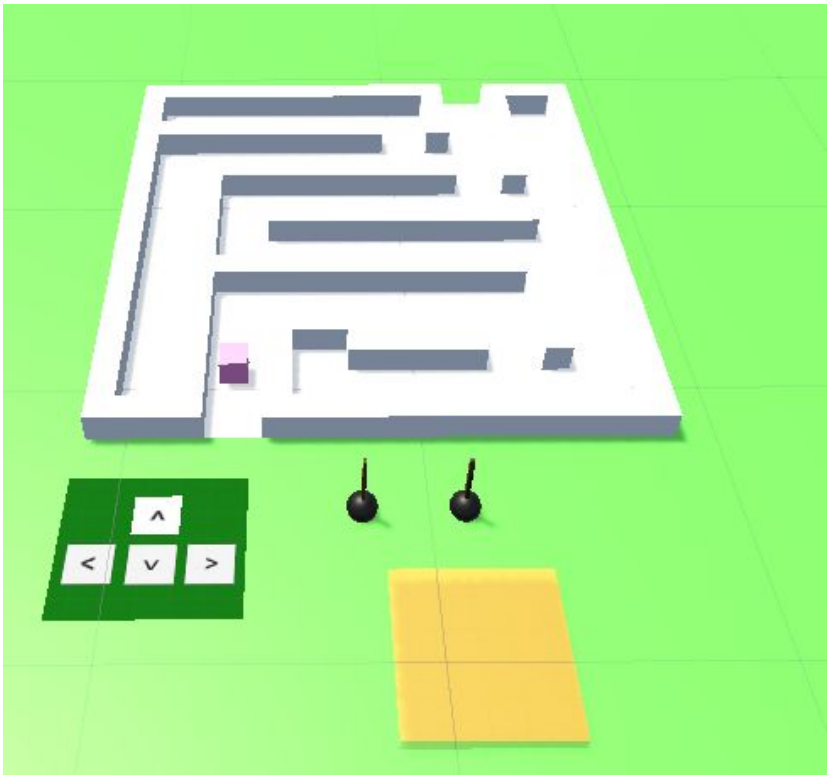
To their right is a table with some objects on it and drawers under it. To get to the table the player will use the teleporting waypoint system, they must point at the waypoint and click the trackpad to teleport. Once there they can open and close the drawers by grabbing the knobs. They can also pick up the objects in front of them without touching them, as if they are using the force. The last object on the table is a toy gun that they can shoot at the targets to their right but they must be careful there are only 3 ammo magazines available.
The last object in this area is a ball hanging from a rope. The user can hit this ball like a punching bag. These were all small interactions to get the user settled and comfortable with how some interactions will work.



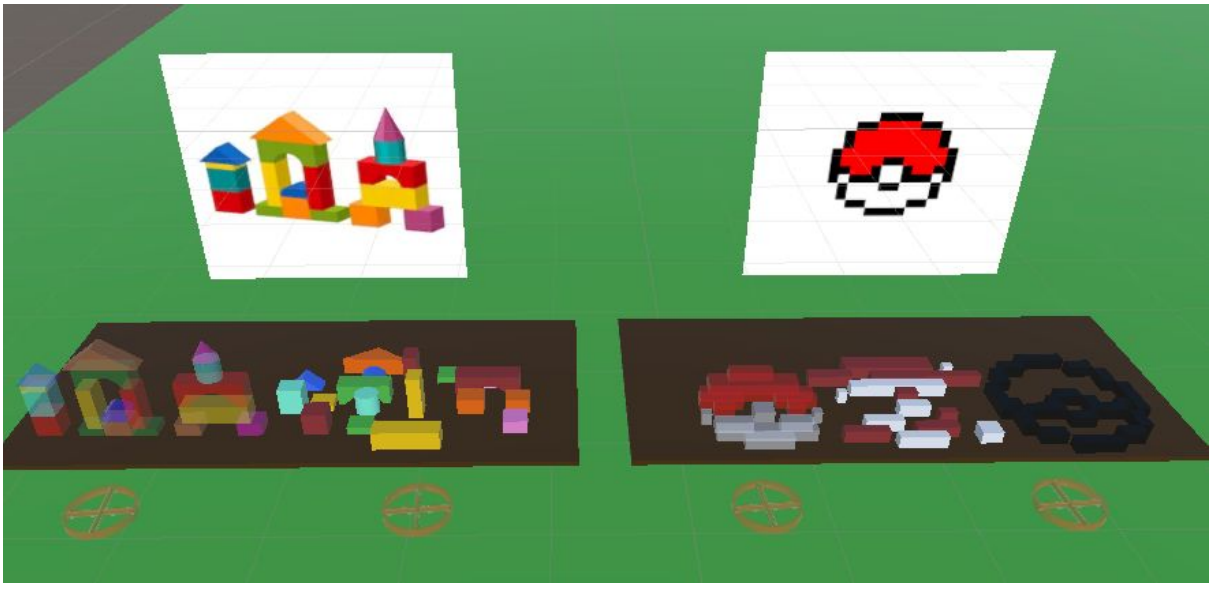
Next they will move onto the first minigame, the button game. They will see a 2D canvas with a start button and orange squares. When the start button is pressed they will notice the orange squares turn blue. If they point at the blue squares and click the trigger button they will increase their score. They will have a limited amount of time to get a high score. After this they will try another version of the same game. This version is 3D and requires the user to push the buttons when they turn blue.



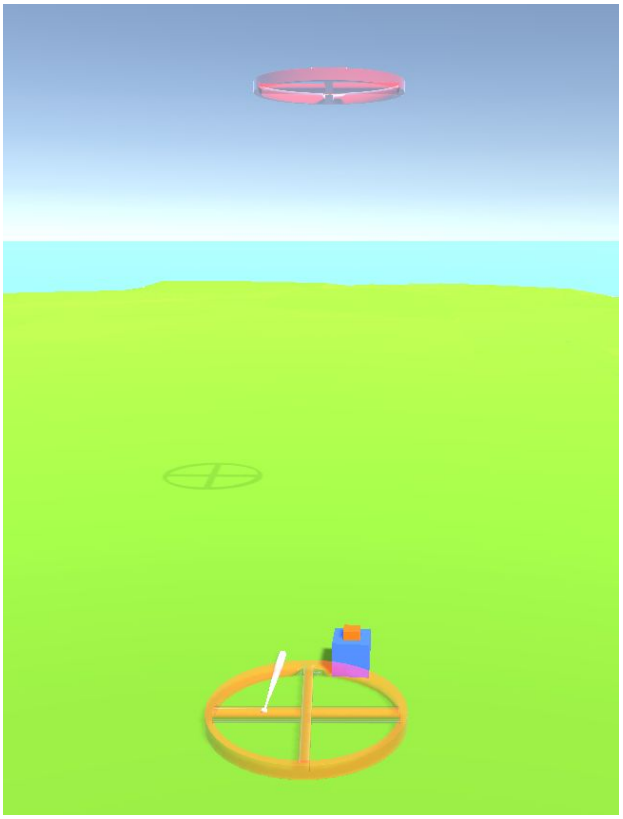
The next game is a maze style game. The user will see a maze, inside it a square, outside it 2 levers. They must use the levers to move the square and traverse through the maze to the finish.



Next we have a building block game. The user can see the picture of what they must build above. They can also see the blocks needed to build it below. Now they can choose to use physics and build themselves on the right or use the outlines and choose the correct block to fit in the correct place on the left. If they put the correct block in the correct place it will clip into place when they release it.



The final minigame baseball. The user can see a baseball bat and a button. The user must pick up the baseball bat and press the button which will release a ball above them. The player is tasked with hitting the ball as far as possible.



All of these interactions being brought together has really deepened my understanding of interactions in VR and VR in general. It gave me a better understanding of what works and what does not work in VR and why. I now have a greater appreciation for how interactions help make the user feel more immersed in the environment.

Project Milestones

October 2019:

Started research and development on the Oculus Quest. Researched into physics in Unity and VR and found multiple toolkits called VRTK and Newton VR. Set up a simple scene using VRTK and ported it to my Oculus Quest for testing. I quickly realised that Unity's physics system isn't the best, so making a believable VR golf game would be difficult if not impossible. Project was then changed to an Interactions Demo, showing off some of the many interactions available in VR. I also changed from using the Oculus Quest to the HTC vive as the Quest is an android device meaning debugging code is practically impossible. Using the Vive now I set up a scene with a baseball bat and a ball using VRTK interactions. You can pick up the ball and hit it with the bat.

November 2019:

Early November I implemented the HMD and Controllers tracking and the ability to pick up and drop objects by pressing and releasing buttons on the controller. I spent a lot of time trying to implement throwing objects into the demo but by the end of the month decided to take a break and try again later on in the year as it was taking up too much of my time. I then moved on to some simple interactions like a dial that controlled the lighting, a door, a drawer and locomotion (moving around the environment).

January 2019:

By January I had the idea of creating an arcade-like demo where some of the interactions I create could be made into minigames for users to test and give feedback on their thoughts of how each interaction felt. I had done some testing and found some bugs with the way I was grabbing objects and decided I would change the way it was implemented to a more effective way. I also developed a rope that had a ball swinging from the end and a lever that moves on one axis. I fixed a lot of major bugs that I had found from previous testing. By the end of the month I was sick of looking at the boring way I had laid out all the objects in the scene so I found an asset pack and decided to make the scene look more pleasing.

February 2019:

By February I decided to add some UI into the demo. I created a canvas with a button that could be pressed if you pointed at the button with the controller and pressed the trigger button on the controller. I revisited the throwing mechanic again and felt I was so close to getting it right but it was just taking up too much of my time so I decided to leave it for now and maybe revisit it again in the future when I have time to spare. I decided to change the locomotion to teleporting to different way points throughout the scene instead of just moving around as it can cause motion sickness. I came up with an idea for my first minigame which I called the button game. It took the button I had made and turned it into a whack a mole type game. I also made the same game but with the UI I made earlier. So I had 2 versions of the same game.

March 2019:

By March I had implemented 2 minigames. The button game and a maze game using the levers to move a block through a maze. I was then onto my third game which was going to be a tangram esque game, you will be given a picture, an outline of the picture and some blocks. The aim is to move the blocks into the outline so they fit and match the picture. I also had the idea of creating a similar game but the blocks would clip into place if they were in the correct slot.

April 2019:

By now the majority of my project was done. All major aspects of the game were implemented. This month was mainly finding and fixing bugs and final polish.

Results and Discussion

The finished project is a demo of some of the many interactions that can be had in VR. The user can teleport throughout the environment and can interact with all the different objects and minigames around the world allowing them to become immersed in the environment. There are some interactions set up without any game that the user can play around with themselves to get a feel for how basic interactions work alone. Then there are 4 mini games to keep them entertained and interested.

The first set of minigames the user will interact with is what I simply call the button game. They are faced with 2 sets of buttons. One set is UI based meaning, the buttons are flat like they're on paper and the user will soon figure out that they can point their controller at the buttons where a line will form from their controller to the button. They will then have to click a button on the controller to press the button in VR. The next set of buttons are 3D buttons to which the user will find to play this version they will have to push the buttons with the controller. Multiple versions of the same game were made to show the user that there is more than one way to use interactions in VR.

The next minigame is a maze like game. The user will see two levers in front of them and a maze with a pink cube inside. The user must use one lever to move the cube up and down and the other lever to move the cube left and right. The user can then navigate throughout the maze to the other side. It's a simple concept but it's effective at showing the use of levers.

Next up is another set of two games. These are building block games. First the user will see a picture of a pixelated pokeball, an outline of the pokeball in black and a bunch of red and white blocks. The objective is to move the blocks into the correct spaces. Whereas on the other side the objective is to do the same thing but with a different picture and if you put the block in the correct space it will clip into the correct position giving the user feedback that their decision was correct.

Finally the last minigame is baseball. The user will see a button and a baseball bat. Press the button and a ball falls from the sky. The aim is to simply hit the ball as far as you can. This was made as a throwback to my original golf game idea and shows it can be tricky to get right as it's difficult to hit the ball far.

This project shows off only a select few out of the vast array of interactions used in VR as to not overwhelm anyone new to VR.

Technical Achievements

My aim of this project was to create a fun and immersive environment for the user. I believe I have done this as the project is centered around the user having to engage physically and mentally with the game through moving around the environment and interacting with all the objects within the environment.

I had never worked with this technology before, meaning almost everything that was done in this project was a technical achievement. Having to script and code interactions with this

technology was completely foreign to me. I had to do a lot of trial and error to find what worked well and what didn't.

I was able to work more with Unity and learn more about the platform. Unitys scripts are written in C#, which is very similar to C++ which made it easier to learn and understand but it was still a new programming language that I have only briefly used before. I was able to use joints which I haven't used before. Also learning how the interactions would work with the UI options in 3D space was new. I learned a lot about what unity had to offer on the side of VR but I also learned about the downsides of Unity such as the physics system isn't very strong, I also found it difficult to implement low coupling. There were many objects connected that shouldn't have been, although I was able to fix them, it took time.

Project Review and Conclusions

I aim to review my project and discuss the development process, what went right and what went wrong, along with what I would have done differently, in this section.

One of the first road blocks I came upon was doing research for my initial project proposition in October. While researching I realised that Unity's physics system is not great so creating a realistic feeling mini golf game would be quite difficult. Because of this I decided to completely change my project to a study of interactions in VR.

During the first month of development I was using the Oculus Quest to develop on. I realised quickly that this was not the best option. The Oculus Quest is an android device and to test work on an android device with unity you have to build and port the project every time which took quite a long time. Another drawback of using an android device is its very hard to debug code so my project supervisor kindly offered me the HTC Vive which is a computer controlled device. This was a much better suit for me as i could now easily debug and test code without having to wait 10 minutes to build and port the project.

My project is based on interactions in VR so I found some VR toolkits that I could run in Unity and used these as inspiration for what interactions I could implement. These toolkits included VRTK and NewtonVR.

During Development in February, I had to abandon my plan to include a throwing mechanic as one of the interactions. This was not an easy decision as throwing is such an important if not one of the most important interactions in VR. However, I had already spent many hours trying different methods with zero result and there were other tasks that needed prioritisation. Although I didn't implement throwing into my project, it was a learning experience as I now have an understanding of how this is achieved and why I was unable to implement it.

Unity is the most accessible and easy to understand programs out there for developing in VR. Although it is easy to understand it is not easy to use or to find information on especially in VR. Unity has a massive community with so many useful forums online and it is constantly being updated with new patches and versions. The problem with this is if you need to make sure that the information you find online is referring to the correct version of unity which can

be difficult. VR however is a whole nother can of worms. If you search anything to do with VR in Unity you will either come across Steam VR or Oculus Integration. Both of these are very useful libraries for developing in VR. Both have a wide array of resources so that you don't have to code almost anything to do with the VR side of games, all you have to do is find the script and drag it onto your gameobject. But for me, I wanted to really understand what was going on behind the scenes so I decided I wanted to code most of the VR side from scratch which led me to Unity XR a plugin for VR/AR development. It's quite hard to find much of what I needed while using this as most people opt for the toolkits mentioned previously.

If I could have done things differently at the beginning, I would have decided what interactions I was going to implement sooner. It took me quite some time to decide on what interactions I would use. I would also spend more time trying out different implementations of the basic grabbing and releasing mechanic as I feel that was my downfall. I stuck to the first implementation I got working and it gave me some trouble later on. I had to fix the way I had implemented this mechanic and it took me some time to figure this out. Even still I see this as useful knowledge for me as I now know that the original implementation was inefficient.

Once the quarantine for Covid-19 set in, everything became much more difficult for development. It was quite hard to find the motivation to do work at home but once you get stuck in you don't feel the time pass. The biggest problem for me with working at home was the space. You need quite a lot of space for VR, which is something I lack in my bedroom. I had a very small area to move around in, maybe a metre wide and two and a half long. This became a huge problem as testing almost anything in my game ended up in me hitting the wall or bumping into my bed. I managed to get by but not without difficulty.

In conclusion, I have an overall sense of satisfaction looking back on the work I did for this project. I believe I achieved everything I set out to do. I created many different interactions and even created minigames centred around some of them Interactions. All of which are fun to play around with. This project also taught me the importance of interactions in vr for combating motion sickness and for the user to feel immersed.

However, I can't look back and not be disappointed with the exclusion of the throwing mechanic. It is definitely a much needed interaction as most people's first reaction to picking anything up in VR is to throw it. I spent a lot of time on this mechanic but in the end it wasn't worth spending more time on one feature when I had many more to do.

These decisions had the best interests of this project in mind, meaning sacrifices had to be made. I am very proud of the end product and all the decisions I have made in the process lead me to create a successful project.

References

Referenced Publication	Citation	Reference
Website	Anon (2017)	Anon. (2017). History of Virtual Reality. [Online]. Virtual Reality Society https://www.vrs.org.uk/virtual-reality/history.html (Accessed April 2020)
Website	Devindra Hardawar (December 24, 2019)	Devindra Hardawar (December 24, 2019) 2020 is VR's Make-Or-Break Year.. EnGadget. https://www.engadget.com/2019-12-24-vr-in-2020-oculus-quest-half-life-alyx.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAFmhgiyP6L7Wxov25rIESPqsteFvcCDJYjwNCW9FAlPrX5Ux3yBM-7wRVvJI-b8hvehg0MSNXkUJ4f0Zvx_cVd1n_6rD6v3-FRQ80YrIw2AtvLGB8W5i_0YH1X9UBabwBODAkH-qJe8smSv7_mplOFwYBLCKkALxqVecvEW1G6FT (Accessed April 2020).
Website	Hayden Dingman (January 20, 2020)	Hayden Dingman (January 20, 2020) Will Virtual Reality Finally Break Out in 2020. PCWorld. https://www.pcworld.com/article/3513794/will-virtual-reality-finally-break-out-in-2020.html (Accessed April 2020).
Website	Jason Jerald, Ph.D.(February 1, 2016)	Jason Jerald, Ph.D.(February 1, 2016) The Best Way to Interact Within VR. UploadVR. https://uploadvr.com/the-best-way-to-interact-within-vr/ (Accessed April 2020).
Website	Jonathan Strickland (29 June, 2007)	Jonathan Strickland (29 June, 2007) How Virtual Reality Works. howstuffworks. https://electronics.howstuffworks.com/gadgets/other-gadgets/virtual-reality.htm (Accessed April 2020).

Report	Joseph J. LaViola Jr (Tuesday, July 27, 2010).	Joseph J. LaViola Jr (Tuesday, July 27, 2010). An Introduction to 3D Spatial Interaction with Video Game Motion Controllers https://drive.google.com/file/d/1-9_-r3zE4r765q4gXOT0edzP5YVIetWE/view (Accessed April 2020).
Website	K.Thor Jensen (April 4, 2016)	K.Thor Jensen (April 4, 2016). The History of Virtual Reality Video Games. geek.com https://www.geek.com/news/the-history-of-virtual-reality-games-1652225/ (Accessed April 2020).
Website	Luke Dormehl (November 13, 2017)	Luke Dormehl (November 13, 2017). 8 Virtual Reality Milestones that took it from Sci-fi to Your Living Room. DigitalTrends. https://www.digitaltrends.com/cool-tech/history-of-virtual-reality/ (Accessed April 2020).
Report	Nanjappan, V., Liang, H., Lu, F. (29 October, 2018)	Nanjappan, V., Liang, H., Lu, F. (29 October, 2018) User-elicited dual-hand interactions for manipulating 3D objects in virtual reality environments. https://link.springer.com/article/10.1186/s13673-018-0154-5 (Accessed April 2020).
Website	Robert Workman (April 3, 2014)	Robert Workman (April 3, 2014). A Brief History of Video Game Virtual Reality, and Why This Time Will be Different. Primagames. https://primagames.com/feature/brief-history-video-game-virtual-reality-and-why-time-will-be-different (Accessed April 2020).
Book	Steven M. LaValle (2019)	Steven M. LaValle (2019). Virtual Reality. Cambridge, UK: Cambridge University Press. http://vr.cs.uiuc.edu/vrch10.pdf (Accessed April 2020).