University of Nevada, Reno
Computer Science and Engineering

Virtual Reality Physics Lab

Team 10:
Nicholas Bolling
Christopher Lewis
Andrew Munoz
Willem Zandbergen

Instructors
Sergiu Dascalu & Devrin Lee

External Advisors
Eelke Folmer & Benjamin Brown

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1 Table of Contents

2 Introduction

On the forefront of interactive games hardware are virtual reality headsets and their controllers. Products such as HTC's Vive, Oculus Rift, and Playstation VR provide immersive experiences that outperform what computer monitors can provide. It is with these virtual experiences that Team 10 will build an educational environment that can effectively use all forms of learning.

The commonly used forms of learning are shortened into the acronym "VARK" which stands for "Visual, Aural, Read/write, Kinematic." The typical classroom environment can at best address two of the four forms of learning. Classroom lectures are spoken to students who listen for important details while reading what a teacher has written on the subject and recording the details in notes for later use. Labs that are associated with classroom lectures address the remaining two forms of VARK learning. Students are given the opportunity to see what was being described in their lecture while interacting with the lecture material. Team 10's Virtual Reality Physics Lab will address all four forms of learning using a personalized experience in HTC Vive.

As mentioned, Team 10's Virtual Reality Physics Lab will incorporate all of the forms of learning usually restricted to two environments into one environment. This environment will be in the form of a "sandbox" environment. "Sandbox" environments encourage freedom of movement, where a user is left to their own devices to interact with various objects in the environment. Each object in the Virtual Reality Physics Lab will have information associated with the object that relays physics data relevant to the student's education. With the combination of an immersive "sandbox" experience and the information necessary to learning physics, students will leave the simulation having enjoyed learning about physics.

3 Stakeholders Interviews

During the development of a project it is important to have stakeholder interviews. In short a stakeholder interview is an interview about your project with potential users, advisors, and could even be a member of your development team. I had a total of 13 questions among 4 individuals. The individuals I interviewed are Benjamin Brown, Connor Scully-Allison, Vinh Le, and Patricia Loeblein. Their questions and a brief overview of their answers are below.

1) **Ben** - Based of your previous work. Have you thought about using VR and what would a VR game look like to you?

   The response I received is that standards have not been set yet with VR so that leads to options. Since there is many options that can lead to project complexity and the use of being anywhere in a virtual context is beneficial.

2) **Ben** - Can you give me the strengths of Educational Software vs Weaknesses

   Ben responded with some pros and cons of educational software. He mentioned some positive traits of educational software is that educational software increases engagement levels which can lead to more participation. Though some drawbacks is that audiences can fluctuate depending on the game.

3) **Ben** - What are some key factors that can help influence a child's learning in educational software.

   There are many traits that will influence the learning when in this context according to Ben. He responded with two which are accurate data and art style. This is because specific art styles will cater to a younger audiences and accuracy for learning.

4) **Ben** - When you develop Educational Software, How would you present the information that program is trying feed to the students?

   Ben followed with a response that links with my previous question. He mentioned art style and gameplay. Gameplay was elaborated to scoring and achievements. Both will encourage to know more to do better. For our project messing with velocity and angle will impact the score.

5) **Ben** - In our emails I mentioned PhET Colorado's projectile motion application.. This is what we are looking for… Do you have any idea on what we could do to make something similar to this and make it engaging and memorable?

   Ben circled back to his previous answer with manipulating the velocity and angle. Using that combined with achievements and score will make the game engaging.

6) **Ben** - Can you tell me why educational games aren't as popular as opposed to non-educational games?

   Currently students revolt when they are introduced to school related concepts. Ben mentioned breadth versus depth. Non-educational games stay on the same breadth whereas educational games will take things deep which can lead to overwhelming circumstances. Ben also said we could mask our educational game with a game that feels less educational to help the audience to feel less overwhelmed and dive into the game.

7) **Ben** - Other than you… would it be smart to talk to one of your students?

The response was to try to find any students on campus. Interviewing students in high school or before will involve more problems for the project. Ben suggested to stick with friends, colleagues, stakeholders, and family.

8) **Connor / Vinh -** In our recent conversations you mentioned some things that suggest you know a decent amount about how someone thinks.. Based on your previous studies if you were to make an educational physics game, what would that look like to you?

Connor viewed an educational game as one that is tiered. By tiered he mentioned a distinct lesson plan where you have numbered lessons from a navigable menu.

Vinh mentioned that it depends how you want to cater toward the children. He believes that the students need to passively taught which is more indirect. If a student doesn't know it is a game but learns at the same time will be important.

9) **Connor / Vinh -** What would you consider to be the most efficient way to have someone learn a concept and engrave it into long term memory vs short term memory?

Connor and Vinh believe that if you lead people to bridge connections that will lead to a better result. If you take a student and without interruption let them guide themselves to the desired goal and will be able to recall information better than if guided. I was invited to look up scaffolding.

10) **Connor / Vinh -** Using past experience.. What would you consider to be the best market for this application? High School, Middle School, College/University?

Connor believes that Middle School is the best but is also the hardest to get the best data for. So the next best would be high school.

Vinh mentioned a "hit them while they are young" approach that meant that if you introduce concepts to a student early they are more likely to be involved in that later in life.

11) **Connor / Vinh -** If you were to develop a game in this genre… What would you add to this project (Besides VR Headset and motion controls) to make this game as engaging as possible?

Connor thinks the best process for engagement is to develop a functional game first and then integrate education into so the “mask” is very well set.

Vinh mentioned a few things. To get a kids educated and feel engaged the best way to do is to have rewards for challenges. Another way to help toward a more immersive game is add sound. Vinh then ended in a remark to try to avoid which is VR sickness. VR sickness is the violation of a sense so having a stationary field is one of the best ways to avoid it.

For the following two questions, Patricia linked a document in my email which is their approach to guided inquiry. Below are questions asked. The answers I received are part of [this](#) document. (Creating PhET Interactive Simulations Activities, 2015).

12) **Patricia -** For simulations on the PhET website, like Projectile Motion, besides key functionality, which would be having projectile motion i.e. having objects projecting on screening during the simulation. What strategy do you, being the K-12 specialist, take for presenting the educational information to another individual and having them absorb that information?

When developing a simulation the best way have them absorb the information is to give minimal instruction on the simulation use. This can lead them to find out what works best toward a solution.

13) **Patricia -** When aiding in developing educational simulations, how do you and your team make sure the overall simulation is engaging to the students given they can range from K-12?

For educational simulations it is best to connect and make sense of real world experiences. This is if they can see that science is relevant in everyday life, students can feel what they are doing is more engaging.

4 High Level Business Requirements

These are the requirements of Team 10's VR Lab Project:

1. Establish an intuitive and immersive learning environment within virtual reality.
2. Provide an educational experience that incorporates all forms of learning.
    a. The student will see the interactions of kinematic objects.
    b. The student will hear explanations of kinematic object interaction.
    c. The student will read and understand physics equations.
    d. The student will associate their actions with object reactions.
3. The student will exit a simulation with a better understanding of kinematic physics.

5 Technical Requirements Specification

Tier One Functional Requirements

Requirement	Description
FR1.1	The application will enable to user to be able to interact with objects in the environment.
FR1.2	The application will have an accurate physics system.
FR1.3	The system will have the ability to track the player's position using the headset.
FR1.4	The system will allow the user to teleport to a selected destination.
FR1.5	The system will enable the user to point at an intended destination with a curved ray.
FR1.6	The application will have the ability to let the player freely move around in a small space without teleportation.
FR1.7	The program will have a splash screen with the game title.
FR1.8	The program will have an interactable start button that will initiate the simulation.

Tier Two Functional Requirements

Requirement	Description
FR2.1	The system will allow the player to shoot a projectile from an object.
FR2.2	The system will allow for data about the objects to be displayed on an in-game canvas.
FR2.3	The system will have the ability to save user profiles.
FR2.4	The system will enable the ability to load the user's profile.
FR2.5	The program will have a line of motion for the intended projectile.

FR2.6	The program will allow the user to be able to spawn objects in the environment.
FR2.7	The application will allow the player to choose separate environments.
FR2.8	The application will have intended targets for the player to hit.
FR2.9	The application will have an interactable options screen.

Tier Three Functional Requirements

Requirement	Description
FR3.1	The system will allow the user to toggle a color-blind mode.
FR3.2	The system will allow for the user to load their last session from where they ended.
FR3.3	The program will have achievements for the player.
FR3.4	The program will have an experience points system.
FR3.5	The program will have a scoring system.
FR3.6	The program will enable the player to be able to interact with an in-game scoreboard.
FR3.7	The application will have air resistance as part of the simulation.
FR3.8	The application will enable to ability to toggle air resistance.

Non Functional Requirements

Requirement	Description
NFR1	The program will be interfaced with the HTC-Vive.
NFR2	The program will be programmed using C#.
NFR3	The program will have sound through a wired headset.
NFR4	The system have version control through Git.
NFR5	The system will be interlaced with motion controllers.
NFR6	The application will be developed using Unity.
NFR7	The application will tested using Steam VR.

6 Use Case Modeling

Use Case Diagram:

The use case diagram, labeled Fig. 0, below represents the VR Physics Sandbox game. It shows the system boundary, the use cases internal to the system, and the actors which are external.

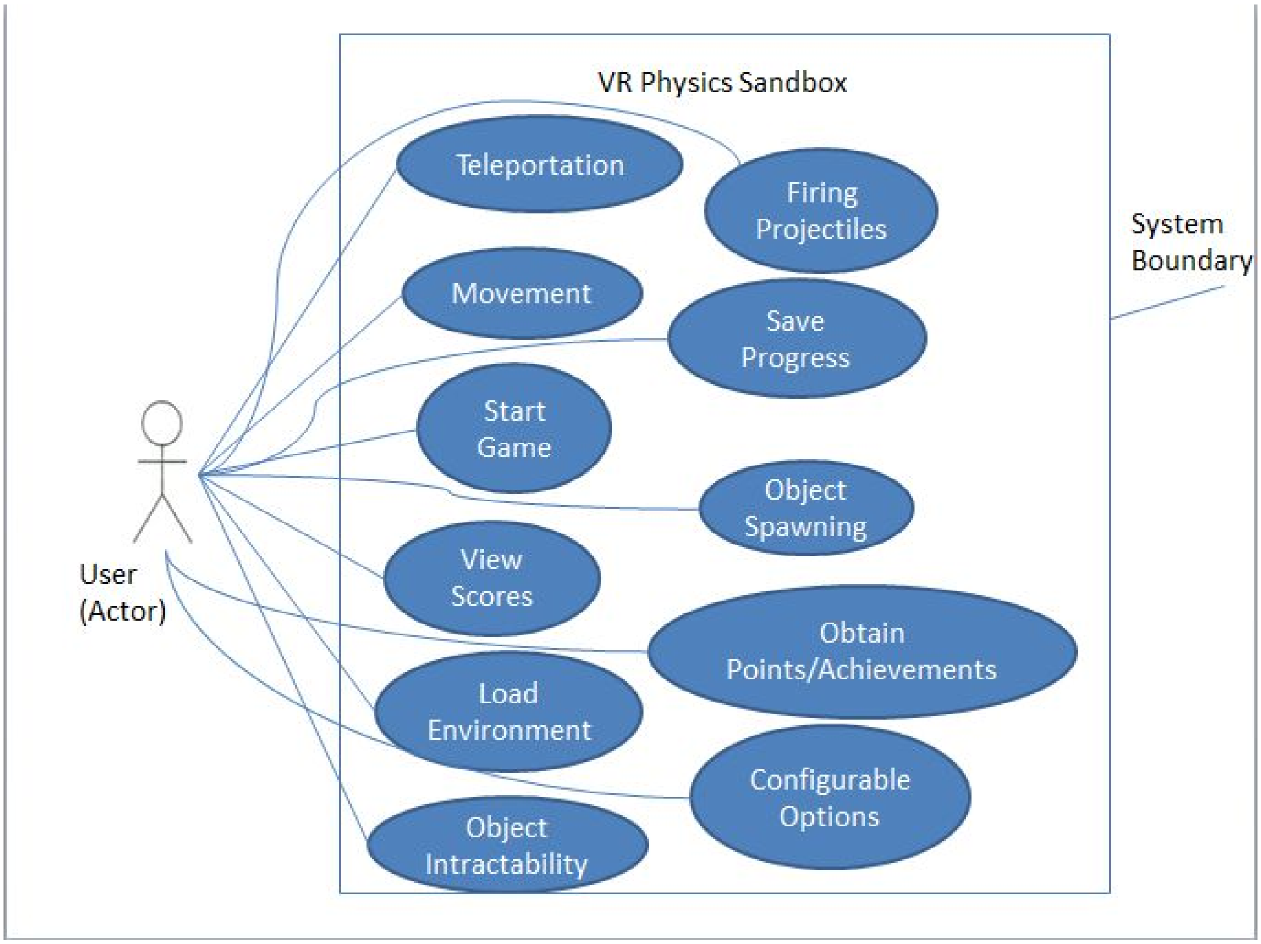

Fig. 0: The use case diagram shows the different use cases that relate to the VR Physics Sandbox game.

Detailed Use Cases:

Number	Name	Description
UC01	Teleportation	The user will be able to teleport to an intended destination. This will be done by pointing at the destination, pulling the trigger on the controller, and then teleporting to the intended destination.
UC02	Movement	The user will move within a fixed space without teleportation. This will be done by tracking the player's movement throughout the space/environment.
UC03	Start Game	From a splash screen a user will be able to access a specific simulation. Before the user starts the simulation a user can load their intended profile, check specific options for their simulation, and click on a start button to start the game. If the user's profile is not there the user can make a new profile.
UC04	View Scores	The user can view their scores to different activities in the game. For example, they will be able to see how much force they applied to certain object, such as a ball, and try to increase the amount of force applied to allow it to travel a farther distance and the user will receive a score.
UC05	Load Environment	The user will be able to load an environment with their profile. If the profile does not exist the user can create a new profile. The environment will be a catered toward a specific task or goal for the user to overcome.
UC06	Object Intractability	The user will be able to interact with placed objects in the environment, including shooting a projectile or interacting with a scoreboard. From there physics will be accurately represented on a canvas for the user to see.
UC07	Firing Projectiles	The user will be able to fire a projectile from a manipulable object toward an intended target. The data for that projectile will be processed and the projectiles line of motion will be displayed in real-time.
UC08	Save Progress	The user will be able to save their scores and progress on the different activities available. Saving will start once the player selects the save option and will then be followed by a screen that shows different users save files and asks the user which file they wish to save their game to.
UC09	Object Spawning	While in the simulation the user will be able to spawn given objects at will and place them in the environment. From there the user will be able to interact with those objects and display data about them on an in-game canvas.
UC10	Obtain Points and Achievements	During the simulation the user will be able to obtain points for specific actions. The points can be a score or experience toward further actions in the game. From there the user may obtain an achievement for their actions in the specific simulation.
UC11	Configurable options	From an in game options screen the user will be able to toggle specific enhancements. The enhancements will be toggling air resistance in the

		simulation and colorblind modes. Colorblind modes available will be: Protanopia, Deuteranopia, and Tritanopia.

Detailed Templates:

Use Case: Movement
ID: 2
Brief Description: The user will move within a fixed space without teleportation
Primary actors: User
Secondary actors: None
Preconditions: 1. Environment must exist for user to interact in.
Main flow 1. The use case starts once the user begins an activity. 2. The user controls the character and moves around the environment. 3. If a model is interacted with in the game 3.1 The model will react realistically based on real physics.
Post conditions: None.
Alternative flows: None.

Use Case: ViewScores
ID: 4
Brief Description: The user can view their scores to different activities in the game.
Primary actors: User
Secondary actors: None
Preconditions: 1. User must complete an activity to see score.
Main flow 1. The use case starts when the User begins an activity. 2. The User completes an activity. 2.1 Score is then displayed on screen. 3. If User views score from menu 3.1 Menu option shows user scores for each activity.
Post conditions: None.
Alternative flows: None.

Use Case: SaveProgress
ID: 8
Brief Description: The player saves their progress in the game to a file.
Primary actors: User
Secondary actors: None
Preconditions: 1. User must begin a new game before saving.
Main flow 1. The use case starts when the Player selects the save option from the menu. 2. The system displays a screen with different save options. 3. If the Player selects a save option 3.1 The system creates a save file that contains the Player's progress.
Post conditions: None.
Alternative flows: None.

7 Requirement Traceability Matrix

	UC01	UC02	UC03	UC04	UC05	UC06	UC07	UC08	UC09	UC10	UC11
FR1.1				X		X	X		X		
FR1.2				X		X	X		X		
FR1.3		X							X		
FR1.4	X										
FR1.5	X										
FR1.6		X							X		
FR1.7			X								
FR1.8			X		X						
FR2.1				X			X				
FR2.2						X			X		
FR2.3			X		X			X			
FR2.4			X		X			X			
FR2.5							X				
FR2.6									X		
FR2.7			X		X			X		X	
FR2.8							X				
FR2.9			X								X
FR3.1											X
FR3.2					X			X			
FR3.3				X						X	
FR3.4				X						X	
FR3.5				X						X	
FR3.6				X		X					
FR3.7											X
FR3.8											X

8 Initial Snapshots

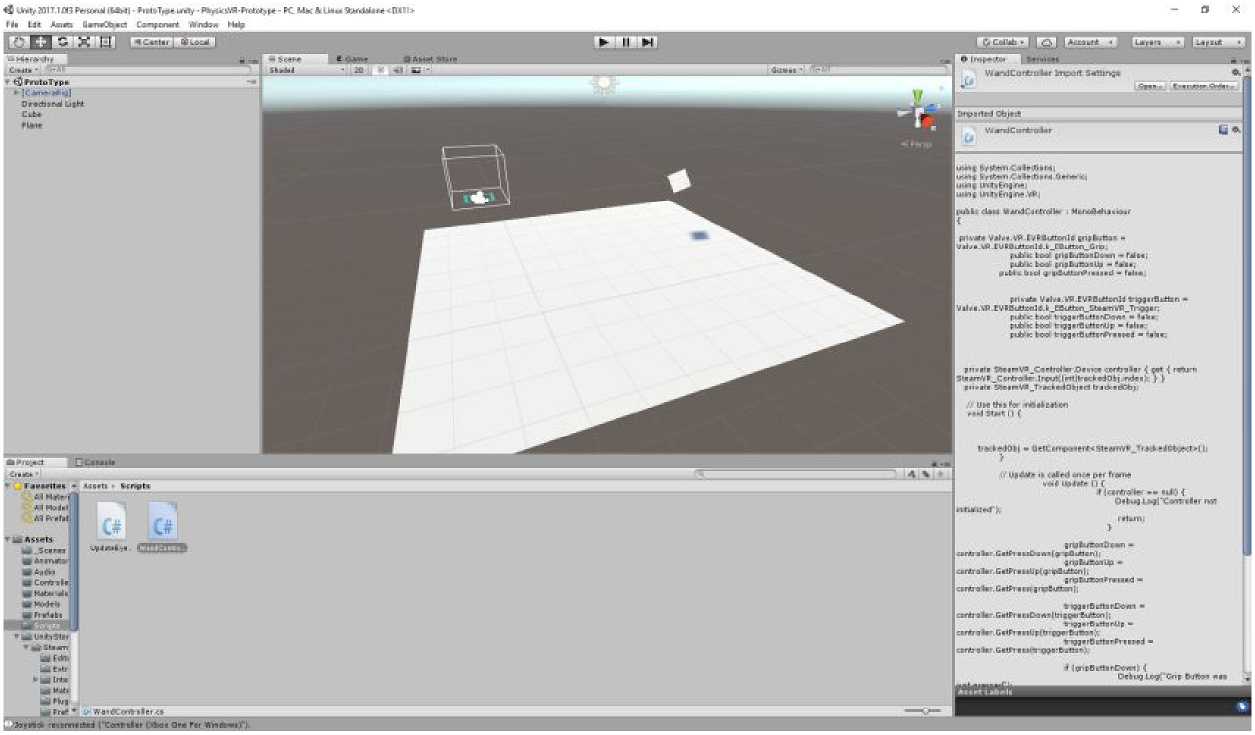

Figure 1 (above) - Prototype Unity 3D space for VR (our initial world)

This will be the playspace for our project, where the physics game/learning will be done.

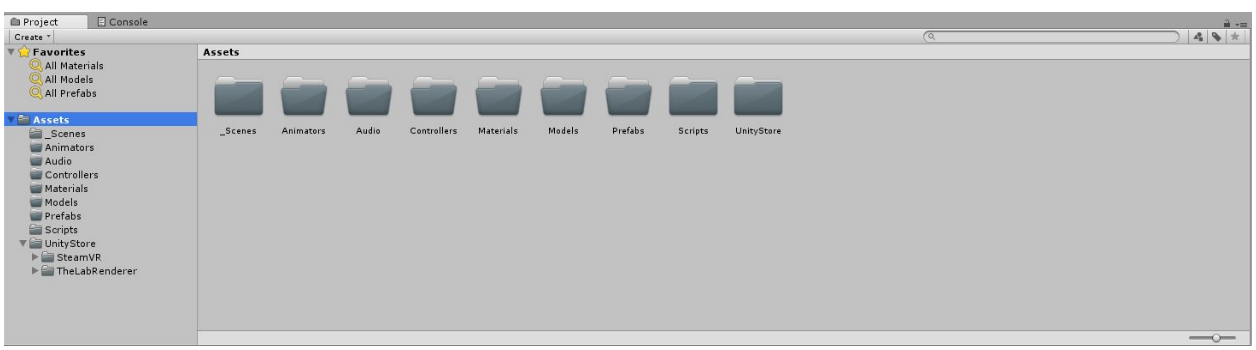

Figure 2 - Current assets and Imported Steam VR Assets and Renders

Steam VR and Lab Renders are free and great resources to allow for easy configuration of VR for the HTC Vive headset.

Figure 3 - HTC Vive Headset (center) with Controllers (front left and right) and Head Trackers (back left and right) for Interfacing and VR interaction.

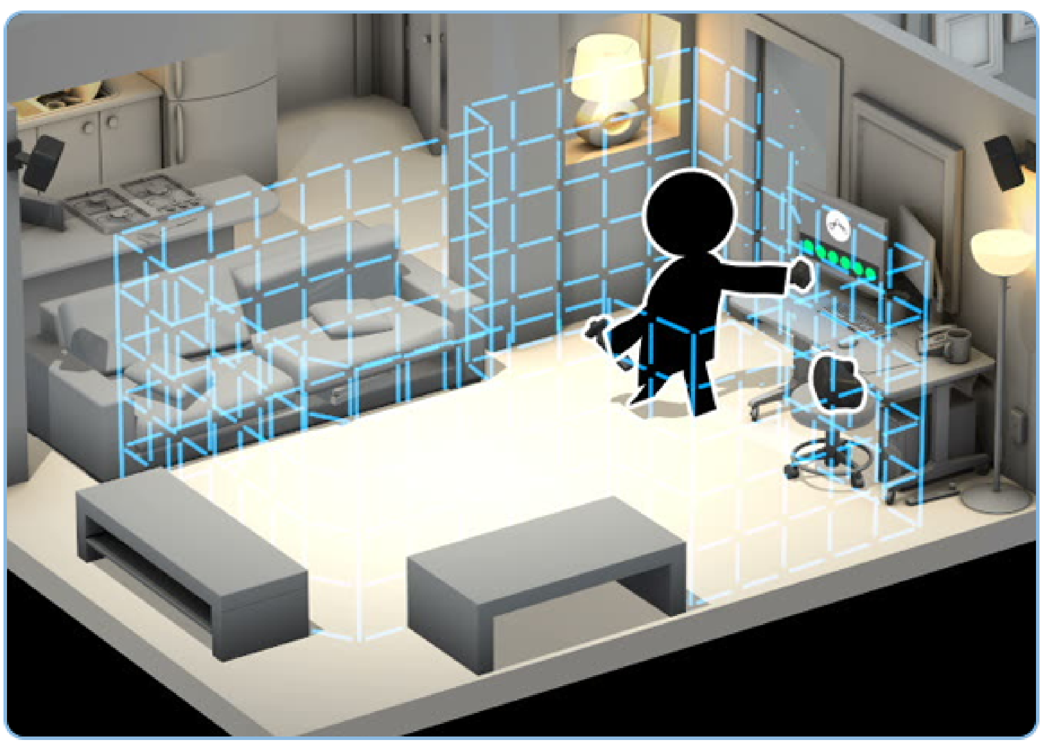

Figure 4 - Configuring the playspace (Courtesy of HTC setup)

Users will have to configure the available playspace around current furniture and object in the environment for boundaries to be displayed in VR.

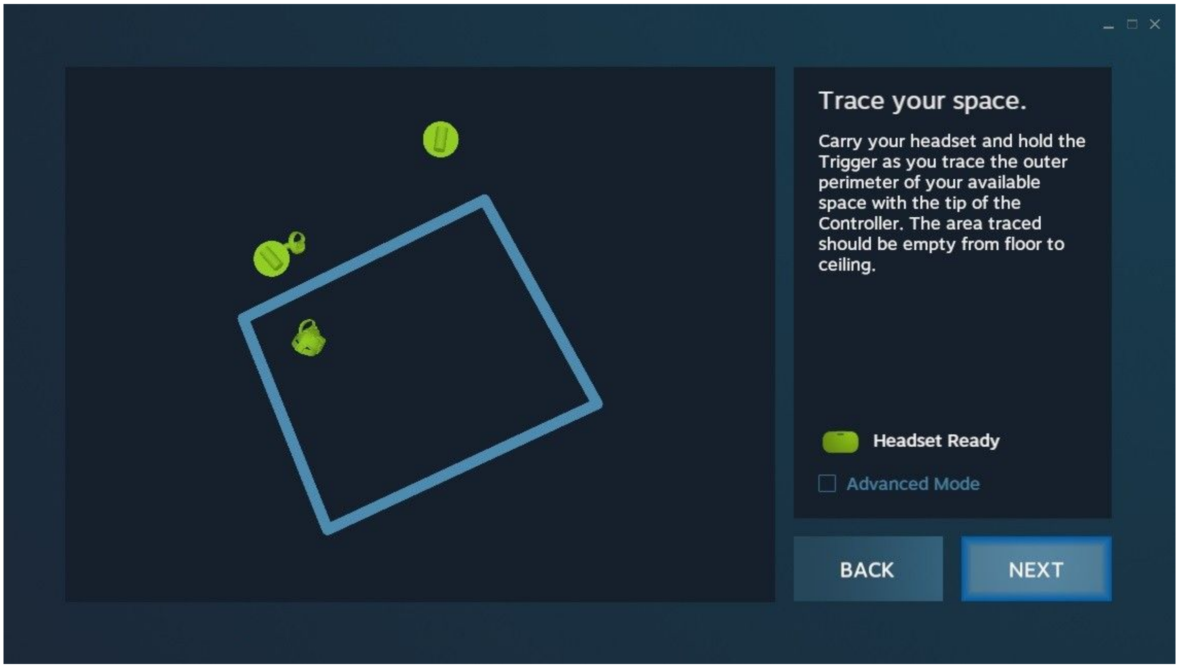

Figure 5 - Configuring the playspace in SteamVR

This shows the current playspace, headset, and headset trackers as viewed by the computer, this will be what is used in spatial calculations for the playspace.

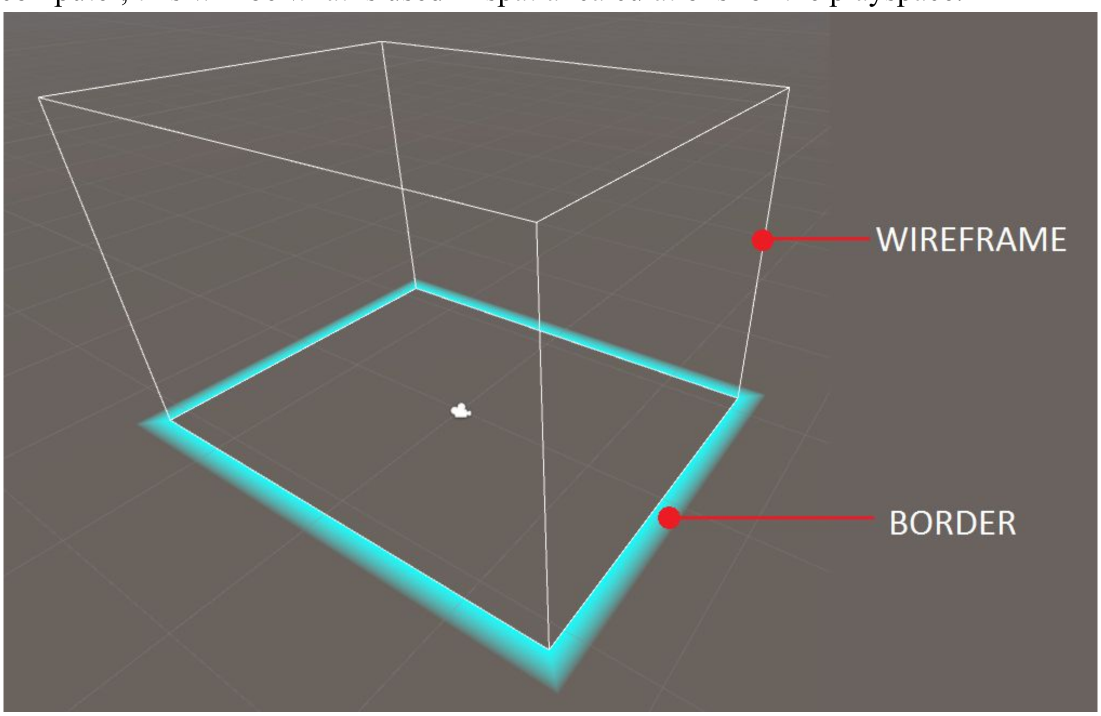

Figure 6 - Generic representation of the VR Playspace

There is a border on the ground with wireframe walls to form a sort of “box house” where the user is contained - the playspace.

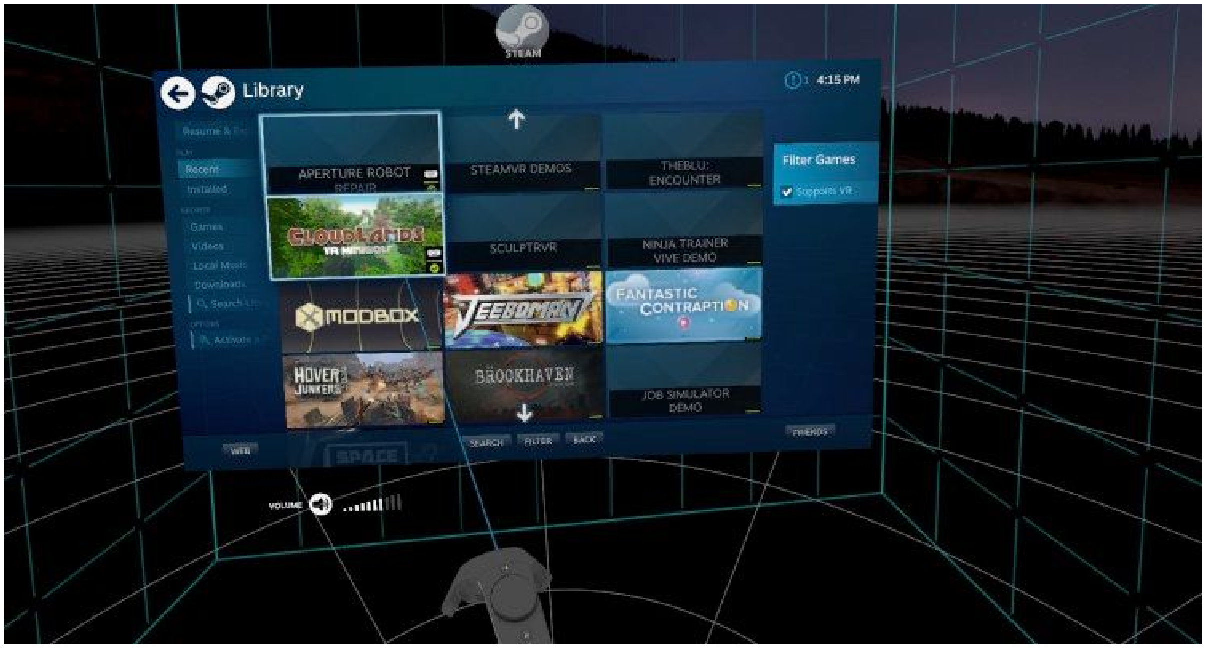

Figure 7 - HTC Vive controller UI interfacing

This is a great example of how we will interface using the HTC Vive controllers. There is a laser (shown coming from the top of the VR controller) that is used to select move UI elements.

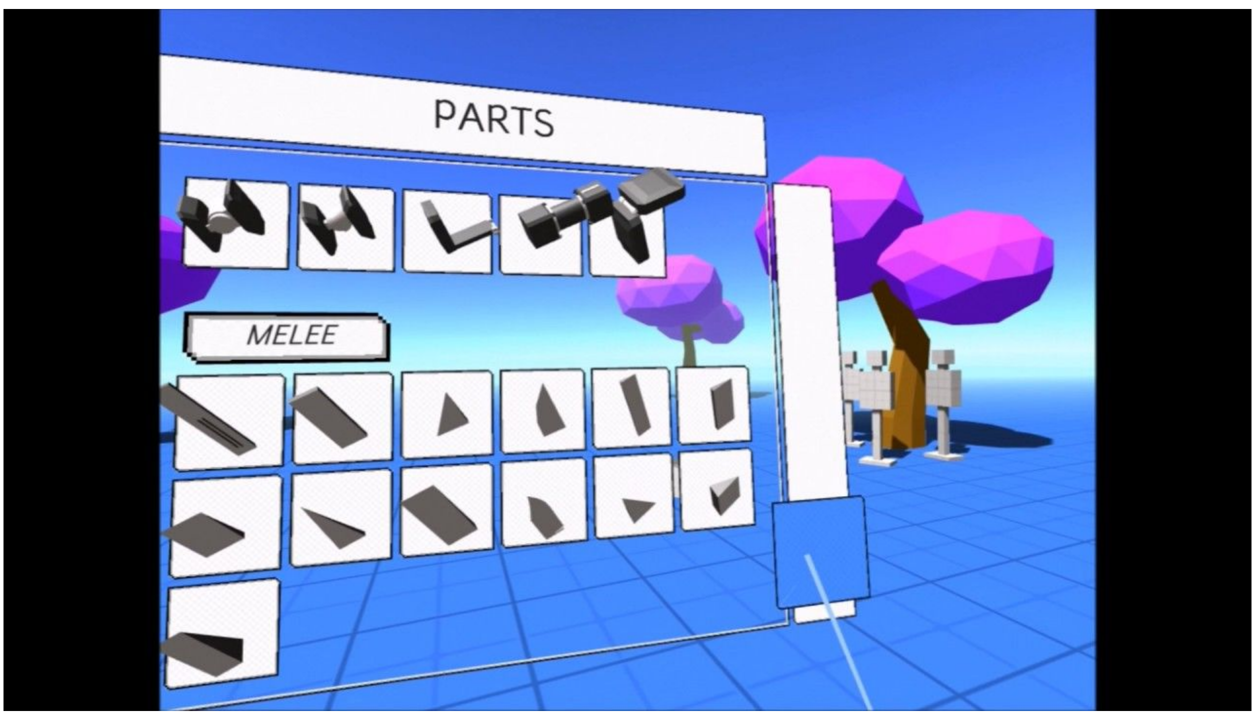

Figure 8 - Simplistic Game specific UI

This is a game UI from ShotForge and is great illustration of how the application/game UI will look in our project, simple and overlayed like Figure 7's Steam VR but separate and used for configuration of the actual game application.

9 Glossary of Terms

- Augmented Reality - The natural world is overlaid with a layer of digital content, typically through glass.
- Avatar (Actor) - The Virtual representation of the player/controller in the VR environment.
- Controller - An interface device similar to a mouse or keyboard that allows for buttons, typically joysticks, and toggles to interface with the computer.
- Cyberspace - A computer synthesized reality. Often a computer synthesized 3-D space. See also: virtual reality.
- Feedback - An output device that transmits pressure, force or vibrations to provide the VR participant with the sense of resisting force, typically to weight or inertia. This is in contrast to tactile feedback, which simulates sensation applied to the skin.
- Field of View - The angle in degrees of the visual field displayed to the user.
- Game Engine - The underlying framework and software behind a computer game or video game.
- Haptics - Physical feedback from interacting with an object, usually integrated into the controller
- Head Mounted Display (VR Headset) - A helmet or set of goggles that have small screens in front of each eye to generate images in three-dimensional space. This is typically combined with a Head Tracker to accurately display the view of the object.
- Head Tracking - Monitoring the position and orientation of the head through specialized devices called Head Trackers.
- Heads-up Display - A display device or interface that allows for graphics to be superimposed on the users view of the world.
- Immersion - The perception of being physically present in a virtual or non-present world.
- Kinethesis - Sensations derived from muscles, tendons and joints and stimulated by movement and tension.
- Latency - A delay between user input and system response, typically user motion and tracker system response in Virtual Reality Environments. Delayed response time.
- Position Sensor - A tracking device that provides information about its location and/or orientation.
- Sandbox game - A game type where there are no rules or objectives, the user can create and destroy at will, similar to a sandbox in real life.
- Simulator Sickness (VR Sickness) - An unpleasant feeling that can include disorientation, nausea, and headaches when using a simulator or Virtual Reality. Similar to generic Motion Sickness.
- Spatial Navigation - Self-orientation and locomotion in virtual worlds.
- Tactile Feedback - Simulates touch and feel of objects in virtual reality.
- Virtual Reality - A computer system that creates an artificial world in which a user has the ability to navigate through and interact with objects similar to the natural world.
- Virtual Reality Environment - The whole space inside the Virtual Reality, essentially the “world” in which you are in while using Virtual Reality.

10 List of References

- **<u>"Problem-domain" book</u>**
  - **The VR Book, Human-Centered Design for Virtual Reality.**
    by Jason Jerarld, Ph.D.
    - This book provides an in-depth look at the human element of virtual reality and the main principles of creating the best VR experiences rather than just a technical implementation.
  - **Unity Virtual Reality Projects**
    by Jonathan Linowes
    - This book helps readers to build their own VR games or applications. It provides step by step instructions for creating virtual reality environments and games.
  - **Learning Virtual Reality:**
    Developing Immersive Experiences and Applications for Desktop, Web, and Mobile
    By Tony Parisi
    - This book helps you to get a better understanding of UI design, 3D graphics and Unity 3D. It also provides valuable information for building apps for Oculus or Samsung Gear VR, as well as browser based applications using WebVR and WebGL.

- **<u>Project reference articles</u>**
  - **The NICE project: Narrative, Immersive, Constructionist/Collaborative Environments for Learning in Virtual Reality**
    https://www.evl.uic.edu/tile/NICE/NICE/PAPERS/EDMEDIA/edmedia.paper.html
    - This paper describes and discusses the NICE project, an immersive learning environment for children implemented in the CAVE and related multi-user virtual reality technologies. The NICE project provides an engaging setting where children construct and cultivate simple virtual ecosystems, collaborate via networks with other remotely-located children, and create stories from their interactions in the real and virtual world.
  - **Learning in Virtual Reality** https://eric.ed.gov/?id=ED359950
    - The essence of the computer revolution is yet to come, for computers are essentially generators of realities. Virtual reality (VR) is the next step in the evolutionary path; the user is placed inside the image and becomes a participant within the computational space.
  - **A Conceptual Basis for Educational Applications of Virtual Reality**
    http://www.hitl.washington.edu/research/education/winn/winn-paper.html~
    - This paper discusses the potential value of VR to education. It does so in the light of research conducted at the Human Interface Technology Laboratory at the University of Washington and on the basis of recent

        - developments in cognitive theory that are relevant to human learning.The case is made that immersive VR offers very different kinds of experience than those students normally encounter in school. The psychological processes that become active in immersive VR are very similar to the psychological processes that operate when people construct knowledge through interaction with objects and events in the real world.
    - **Virtual Reality Simulations in Physics Education :** http://imej.wfu.edu/articles/2001/2/02/index.asp?referer=www.clickfind.com.au
        - A virtual reality physics simulation (VRPS) is an educational tool using a virtual reality interface that brings together a 3D model of real apparatus and a virtual visualization of physical situations in an interactive manner. VRPS enhances students' understanding by providing a degree of reality unattainable in a traditional two-dimensional interface, creating a sensory-rich interactive learning environment. In this paper, we present a computer-based virtual reality simulation that helps students to learn physics concepts such as wave propagation, ray optics, relative velocity, electric machines, etc. at the level of high school or college physics.

- **Project related websites with useful resources**
    - **Lynda.com** - AMAZING resource that we already pay for in our tuition, and we as a university have a subscription to. Has a ton of Unity related courses, and even courses in general programming (C, C++, C#, ect) that will be really useful.
    - **Unity 3d Asset Store** (https://www.assetstore.unity3d.com/en/) - Easily the most helpful website other than Lynda, here we can purchase already made and professionally (and community) developed assets like objects, models, scripts, etc. This will be useful for the initial prototype to ensure everything is working on time, as well as providing high-quality and accurate objects/models in-game.

11 Contributions of Team Members

Listed below are the total working hours each team member contributed to this project as assessed by the team's project lead. Listed below these hours are the specific parts each member worked on for this project specification. Included in these times is the time spent as a group editing and formatting the final iteration of this paper.

Working hours:

Andrew: 4.5 hrs.
Use case modelling and traceability matrix

Chris: 9 hrs.
Interviews and technical requirements

Nick: 3.5 hrs.
Initial snapshots, glossary, and list of references

Will: 3.5 hrs.
Cover page, table of contents, introduction, business requirements, and contributions of team members

12 Other Outside Resources/References

PhET Professional Development Team. 2015. Creating PhET Interactive Simulations Activities: PhET's Approach to Guided Inquiry. (2015). Retrieved Nov 1, 2017.