<VR Puzzle Game>

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UXCFXK-30-3

Digital Systems Project



# Abstract

**Your Abstract**

# Acknowledgements

**Just want to give credit to friends, family and my supervisor who helped me develop ideas.**

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# Introduction

In this paper I will design and build a VR game that involves puzzles. More specifically the 8 queens puzzle, and other such chess related puzzles. The game will be created using a game engine, in this case unity, the language of choice is c#. The chosen platform is the quest 2 which uses a version of the android operating system. Both the headset and its operating system were developed by Meta formally known as Facebook. To add further complexity, I will develop a website a long side the game to display scores submitted by players. This paper will contain the research for said project, design information, testing and research.

# Literature Review

## Chapter introduction

This chapter of the report contains my research on VR technologies, web technologies and other such things that I will require to design and build my VR game

## Introduction to VR

There have been many representations of VR in the media, in the form of books and films.

### VR in past and present media

The first book, William Gibson’s Virtual light, in summary, is about a pair of glasses which allow a person to view information by feeding it into that person’s optic nerve (Gibson et al., 1993). Ready player one is a dystopian future in which people use virtual reality to escape the tough reality of life. The VR world they go to is called the Oasis (Cline et al., 2011).

### The metaverse

The metaverse can be described as a 3-dimensional virtual universe (Dionisio, III, Gilbert, 2013). This however differs from the concept of cyberspace that represents all of a shared online and virtual space across all dimensions (Dionisio, III, Gilbert, 2013). There are multiple different versions of the metaverse, the first example is an enlarged virtual world, and another is a large network of virtual world (Dionisio, III, Gilbert, 2013). The second example is wanted can be seen in ready player one. The virtual universe is split into multiple virtual worlds (Cline et al., 2011) that players can explore interact with, they are able to travel to other worlds inside the universe.

All of these examples show how virtual reality has been represented over the years, however in reality, today the technology is much more primitive compared the previous given fictional examples.

To illustrate how VR works in reality, one could look to early examples of VR headsets and VR like devices that have previously been developed in the past.

## Early Virtual reality headsets and headmounted displays

### Sensorama

An early example of a VR headset was the Sensorama( [Craig](https://learning.oreilly.com/search/?query=author%3A%22Alan%20B.%20Craig%22&sort=relevance&highlight=true), [R. Sherman](https://learning.oreilly.com/search/?query=author%3A%22William%20R.%20Sherman%22&sort=relevance&highlight=true),  [D. Will](https://learning.oreilly.com/search/?query=author%3A%22Jeffrey%20D.%20Will%22&sort=relevance&highlight=true), 2009). This piece of literature describes early VR technology. “The Sensorama was the brainchild of cinematographer and inventor Morton Heilig” ”( [Craig](https://learning.oreilly.com/search/?query=author%3A%22Alan%20B.%20Craig%22&sort=relevance&highlight=true), [R. Sherman](https://learning.oreilly.com/search/?query=author%3A%22William%20R.%20Sherman%22&sort=relevance&highlight=true),  [D. Will](https://learning.oreilly.com/search/?query=author%3A%22Jeffrey%20D.%20Will%22&sort=relevance&highlight=true), 2009). As described by the writer of this literature the system “was lacking a major component of the modern virtual reality system: response based on user’s actions” ”( [Craig](https://learning.oreilly.com/search/?query=author%3A%22Alan%20B.%20Craig%22&sort=relevance&highlight=true), [R. Sherman](https://learning.oreilly.com/search/?query=author%3A%22William%20R.%20Sherman%22&sort=relevance&highlight=true),  [D. Will](https://learning.oreilly.com/search/?query=author%3A%22Jeffrey%20D.%20Will%22&sort=relevance&highlight=true), 2009). Early headsets were very basic, this simply means that the system did not allow a user’s actions to have any impact on the virtual world unlike modern day headsets that allow a user to interact with the virtual world using controllers or in some cases the users’ hands.

### Myron Krueger’s Videoplace

“Krueger’s artificial reality provided a second-person view of a virtual world in which participants could watch themselves within the world” ”( [Craig](https://learning.oreilly.com/search/?query=author%3A%22Alan%20B.%20Craig%22&sort=relevance&highlight=true), [R. Sherman](https://learning.oreilly.com/search/?query=author%3A%22William%20R.%20Sherman%22&sort=relevance&highlight=true),  [D. Will](https://learning.oreilly.com/search/?query=author%3A%22Jeffrey%20D.%20Will%22&sort=relevance&highlight=true), 2009). [Craig](https://learning.oreilly.com/search/?query=author%3A%22Alan%20B.%20Craig%22&sort=relevance&highlight=true), [R. Sherman](https://learning.oreilly.com/search/?query=author%3A%22William%20R.%20Sherman%22&sort=relevance&highlight=true) literature also talks about another early VR headset such as Myron Krueger’s Video place. This headset gave the user a “second-person point of view” of themselves. No games could be played on this headset and the user did not have any devices or other sensors attached to their body( [Craig](https://learning.oreilly.com/search/?query=author%3A%22Alan%20B.%20Craig%22&sort=relevance&highlight=true), [R. Sherman](https://learning.oreilly.com/search/?query=author%3A%22William%20R.%20Sherman%22&sort=relevance&highlight=true),  [D. Will](https://learning.oreilly.com/search/?query=author%3A%22Jeffrey%20D.%20Will%22&sort=relevance&highlight=true), 2009) unlike some modern-day VR headsets that use full body tracking that require sensors to be placed all over the user’s body including head, legs and arms depending on what degree of tracking you want.

## Key elements of VR in 2003

There are a few key elements of VR that have been identified in the past, this information will help with the creation of the puzzle game and help to mitigate any mistakes that could be made during design.

The paper written by Sherman details four key elements of virtual reality.

A virtual world is the context of a medium(Sherman, [B.Craig](https://learning.oreilly.com/search/?query=author%3A%22Alan%20B.%20Craig%22&sort=relevance&highlight=true), 2003). In this case the case of this project this would refer to the game world. This will also tie into the writers next point regarding immersion. This is because the virtual world, if created correctly helps give a sense of immersion and improves the experience of the player.

It must have immersion, Immersion into a different reality or another point of view(Sherman, [B.Craig](https://learning.oreilly.com/search/?query=author%3A%22Alan%20B.%20Craig%22&sort=relevance&highlight=true), 2003). It must have both Physical and mental immersion, this can be split into two, mental immersion can often be referred to as having a mental presence within the world (Sherman, [B.Craig](https://learning.oreilly.com/search/?query=author%3A%22Alan%20B.%20Craig%22&sort=relevance&highlight=true), 2003) and physical immersion, a body entering into a medium (Sherman, [B.Craig](https://learning.oreilly.com/search/?query=author%3A%22Alan%20B.%20Craig%22&sort=relevance&highlight=true), 2003). Both of these points apply today, If the VR experience will be greatly affected if immersion is broken, so during development I must pay extra attention to this as one of the major causes of braking immersion is frame drops whilst playing a VR game, therefore it is imperative that my code is optimised.

It must have Sensory feedback, “VR allows participants to select their vantage point by positioning their body and to affect events in the virtual world” (Sherman, [B.Craig](https://learning.oreilly.com/search/?query=author%3A%22Alan%20B.%20Craig%22&sort=relevance&highlight=true), 2003). This refers to moving your arm for example in the VR worlds and have it match up with the real world. Technologies to make this more accurate already exist, with the rise of full body tracking for certain headsets. Sensors are placed on the body and tracked by the headset allowing for more accurate tracking of limbs creating the illusion of the player actually being in the virtual world.

The final key element according to the writer is, Interactivity. “For virtual reality to seem authentic, it should respond to user actions, namely, be interactive” (Sherman, [B.Craig](https://learning.oreilly.com/search/?query=author%3A%22Alan%20B.%20Craig%22&sort=relevance&highlight=true), 2003). In the case of current day VR this could be seen to be tied to the act of a user performing an action and getting a reaction. For example, a player pushes a box with there in game hand and the box moves back in response.

## VR Possibilities outside of gaming

### VR in Education

There are many applications for VR outside of gaming for entertainment, there also are applications for VR in the educational sector, for example in the research paper by (Holly, Pirker, Resch, Brettschuh, Gutl, 2021), it goes over how learning environments like Marroon (GameLabGraz), are environments designed to provide an interactive learning environment for students and allows student to perform experiments in a VR environment. The experiment that the researchers performed consisted of testing to test several factors for the game, Immersion, and engagement, learning value from both the teachers and learners’ respective perspectives (Holly, Pirker, Resch, Brettschuh, Gutl, 2021). In summary the response was positive in all areas of study, most students and teachers were happy with the level of immersion and engagement, and on average most students and teachers concluded that is had a high learning value (Holly, Pirker, Resch, Brettschuh, Gutl, 2021).

### VR in medicine

VR also has applications in medicine as out lined in this study by (Pourmand, Davis, Marchak, Whiteside, Sikka, 2018). The study delves into how VR can be used to distract patents from many types of pain, such as acute pain (Pourmand, Davis, Marchak, Whiteside, Sikka, 2018). It concluded that VR have become one important option for helping with pain management and how the evidence in said study shows how VR can be effective at distracting patients from many types of pain including actue and chronic short-term (Pourmand, Davis, Marchak, Whiteside, Sikka, 2018). The study references a paper that goes on to run some experiments on hospitalized patients, it was noted in the study that patents, had a significant drop in pain by around 24% in the VR group of patents compared to the 13% drop in pain in the control group (Tashjian, 2017).

## Game engines

The Wikipedia definition of a game engine is as follows, "A game engine is a software framework primarily designed for the development of video games, and generally includes relevant libraries and support programs. The "engine" terminology is like the term "software engine" used in the software industry."[Game engine 2021].

For further clarification this is what is defined as a game engine in Comparison between Famous Game Engines and Eminent Games journal article. Game engines are sets of tools that allow a programmer to, perform game related tasks like interpretation and physics related tasks and for focusing on the niceties that make the game great([Mishra](https://www.ijimai.org/journal/bibcite/contributor/5998), [Shrawankar](https://www.ijimai.org/journal/bibcite/contributor/5999), 2016).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **ASSESSMENT OF ENGINES ON PERFORMANCE ASPECTS** | | | | | | |
| Game Engine | Platforms | Language Support | AI Engine | Physics Engine | Forward Compatibility | Backward Compatibility |
| CryEngine 3 | Win, X360, PS3, Wii U | C++, Visual Script, Lua | Lua-driven AI | Soft body | No | Yes |
| Hero Engine | Win | Hero Script | AIseek | PhysX | Partial | Yes |
| Source 2 Engine | Win, Mac, Xbox 360, Wii, Linux, Android | C++ | AI Director | Ipion | No | Partial |
| Unity 4 | BlackBerry, Win Phone, Win, OS X, Android, iOS, Apple TV, PS3/4, PS Vita, Xbox 360, Xbox One, Wii U, Wii | C#, JavaScript, Boo | RAIN | PhysX | Partial | yes |
| Unreal 4 Engine | Windows, OS X Linux, Xbox 360/ One, PS3/4, Wii U, Android, iOS, WinRT, PS Vita | C++, C#, GLSL, CG, HLSL | Kynapse | PhysX | Partial | Yes |
| Vision Engine 8 | Windows, Xbox 360, PS3, Wii, Wii U, iOS, Android, Win Phone, PS Vita | C++ | Kynapse | Bullet, ODE, PhysX | No | Partial |

Figure 1 ([Mishra](https://www.ijimai.org/journal/bibcite/contributor/5998), [Shrawankar](https://www.ijimai.org/journal/bibcite/contributor/5999), 2016).

As can be seen from figure one CryEngine, Hero Engine don’t support nearly as many platforms as the other four. Furthermore, Hero engine does not support any of the more popular programming languages like C++ or C#. In addition to this Hero Engine, Unity and unreal only have partial forward compatibility.

Unreal Engine has Blueprint Visual Scripting” (Chu, Zaman, 2021). It was created to support the workflow of designers and artist by giving them access to tools normally only accessible to programmers (Chu, Zaman, 2021). Blueprints is object oriented visual programming system which is used to create gameplay elements (Chu, Zaman, 2021). Other engines also have these capabilities, such as unity. A recent example of plugins that allow unity to obtain this functionality include, FlowCanvas, playmaker, Bolt and Amplify shader editor (Chu, Zaman, 2021).

## Tracking technology

### Xbox Kinect

Oculus uses state of the art tracking technology that developed from a massively successful technology known as the connect Kinect was an early example of SLAM being used, originally developed at Microsoft research Cambridge and then productized within the Xbox team at Microsoft. The Kinect is made up of 3 devices, the first being Depth sensor, the second being an RGB camera and lastly a 4-microphone array, this all gives 3D full body tracking, facial recognition and voice recognition (Zhang, 2012). The Kinect senses depth using its IR camara and IR projector which make up the depth sensor (Zhang, 2012). This works by the IR project projecting dots in an area, then if the dot in said image matches dots in the known dot pattern produced by the projector it is possible to rebuild it using 3D triangulation (Zhang, 2012).

A picture containing text

Description automatically generated

Figure 2. (Zhang, 2012).  
[Here](https://gyazo.com/9f3e31cf8efe38baab1eb00a047b4845) is a depth map produced by the Kinect, the darker the Gray the closer the object (Zhang, 2012).

This can then be used in conjunction with other techniques to track a person's body, this image gives the general outline of this.

A picture containing diagram

Description automatically generated  
Figure 3. (Zhang, 2012).

From the depth image a body part distribution is inferred, this is done per pixel as can be seen from the second part of the image above. ([Shotton](https://ieeexplore.ieee.org/author/37550019800), [Fitzgibbon](https://ieeexplore.ieee.org/author/37282639100), [Cook](https://ieeexplore.ieee.org/author/37951907600), [Sharp](https://ieeexplore.ieee.org/author/37408379000), [Finocchio](https://ieeexplore.ieee.org/author/37944916600), [Moore](https://ieeexplore.ieee.org/author/37950527600), [Kipman](https://ieeexplore.ieee.org/author/37944916100), [Blake](https://ieeexplore.ieee.org/author/37282602200), 2011). Local modes of this are then hypothesized to provide a good quality proposal for the joints in 3 dimensions, this all can also be done for multiple users([Shotton](https://ieeexplore.ieee.org/author/37550019800), [Fitzgibbon](https://ieeexplore.ieee.org/author/37282639100), [Cook](https://ieeexplore.ieee.org/author/37951907600), [Sharp](https://ieeexplore.ieee.org/author/37408379000), [Finocchio](https://ieeexplore.ieee.org/author/37944916600), [Moore](https://ieeexplore.ieee.org/author/37950527600), [Kipman](https://ieeexplore.ieee.org/author/37944916100), [Blake](https://ieeexplore.ieee.org/author/37282602200), 2011).

### SLAM Overview

SLAM stands for Simultaneous localization and mapping (MathWorks). There are many applications for SLAM including, using it with autonomous vehicles to produce maps of environments and pinpoint a vehicle in that map all at the same time (MathWorks). They can allow the vehicle to map environments and avoid obstacles and path find in that environment (MathWorks).

There are many methods of slam, the first is Visual slam, this type of slam utilises images obtained from cameras and other sensors and there are two main types of this version of slam, Spare methods that match features of images at then utilise an algorithm like ORB-SLAM and dense methods that use algorithms like LSD-SLAM (MathWorks).

The second method of SLAM is LiDAR SLAM this version of slam usually uses some form of distance sensor, for example a laser sensor (MathWorks).

Both types of SLAM have advantages and disadvantages, LiDAR is not affected by light level and its angular view is quite large. Unfortunately, however, on a large-scale LiDAR is not as viable in certain situations as it can get very expensive (Huang, Zhao, Liu, 2019). Visual SLAM, however, does not do so well in low light conditions and in low texture environments (Huang, Zhao, Liu, 2019). But visual SLAM can usually be implemented at a much lower price as RGB-D cameras, used to implement it can be obtained quite cheaply (Taketomi, Uchiyama, Ikeda, 2017).

### Offline-SLAM for Map Acquisition a simple example of SLAM

There are many ways to use SLAM, a simple example of SLAM involving robots is as follows; the first phase is map learning phase, as a robot moves through an environment the sensor data obtained, and labels are given such as place names. After this the SLAM algorithm creates a map from the data to robot collected, this data can then be used to plan paths and localization and so on (Frese, Wagner, Rofer, 2010).

### Oculus and SLAM

SLAM tracking technology is a tracking method utilized by the Oculus quest and rift s (Hesch, Kozminski, Linde, 2019). On both these headsets it uses three major types of sensors to work out the VR headset’s location, room aspects like where the floor is and track controllers with reference to a 3d map of the space around it that is generated continuously (Hesch, Kozminski, Linde, 2019).). The 3 sensors include, IMUs that track the headsets orientation and position, cameras to generate a 3d map of the room, and infrared emitters mitigating the controller drift cause by having a lot of the IMU sensors (Hesch, Kozminski, Linde, 2019).

## APIS

APIs are powerful tools that can be used in this project, to break down what an API is, we must first learn what it stands for, its stands for application programming interface([Uzayr](https://learning.oreilly.com/search/?query=author%3A%22Sufyan%20bin%20Uzayr%22&sort=relevance&highlight=true), 2016). Is a way in which you can hide the component specification from the actual implementation or the user of said components (Souza, Redmiles, 2009). One reason for doing this is it separates the modules in to public and private modules the public one being the API and the private one being the implementation of said API, there for any changes made to the private module does not impact the public module (Souza, Redmiles, 2009). Using APIs allows a company to give a developer functionality without said developer needing to know how it works (Souza, Redmiles, 2009).

## Rest API

To give context, using rest is one way we could implement a way to transmit data between a virtual reality head set and a webserver, in this case it would be the transmission of score data etc.

To summarize a rest API is a type of application programming interface that conforms to a set of constraints (Kotstein, Justus, 2021). Rest apis have two aspects, the first is that they are a type of architectural style that can dictate how distributed hypermedia systems are built and used like the world wide web (Kotstein, Justus, 2021). Furthermore, this journal article goes into further detail for example the second aspect it gives is that rest is like a guide that formalizes how web components like urls and http for example should be used when creating new applications that utilize them.

## Web frameworks in python

### Django

Django is a collection of python modules designed for building web applications (Yudin et al., 2020). The Django framework can map URLS to methods, it can also render HTML webpages and it can handle cookies, session and also web security (Yudin et al., 2020). Django can also support things like relational databases using object-relational mapping (Yudin et al., 2020). It has a build in database solution, known as SQLite (Yudin et al., 2020). It also contains tools that allow easy authentication and authorization (Yudin et al., 2020). It is also widely used, namely these websites use it, YouTube, Spotify and also many others (Yudin et al., 2020).

### Flask

Flask is a small framework and is small enough to be called a micro framework (Grinberg eta al., 2018). Flash was designed to be extendable, and you can pick and choose what you need to avoid bloat (Grinberg eta al., 2018). Flash has a few dependencies, including the routing, debugging and web server gateway (Grinberg eta al., 2018). However, it does not have support for accessing databases, validating web forms or authenticating users (Grinberg eta al., 2018). This is an issue for this project as we require a database to store score data from the game, also a way to authenticate users.

Comparing Django’s and Flasks features, Django is the most logical option as it allows the use of an SQLite database and has user authentication and authorization features which is lacking in the Flask framework.

## WebSocket scripting

A WebSocket is a transfer control protocol for web applications. It provides connection in both ways meaning data can be sent too and from a server and client. However instead of connecting to an internet host and a port, it facilitates connections using URLS instead. To establish a connection between a server and client the protocol is changed from HTTP to WebSocket protocol. Once a connection is established messages can be sent back and forth between the client and the server (Lubbers, Albers, Salim,2011). This is one way in which information could be sent between the vr headset and a webserver that stores and displays score data in a database. However, the connection only needs to be in one direction as, no messages are going to be sent to the client from the server.

## Examples of VR games

# Methodology

To produce the VR game, we decided to use an agile development process. Agile methods of software developments use an iterative and incremental approach to software development (Kumar, Bhatia, 2012). The type of Agile method of development we have chosen is called, the scrum method. A scrum consists of sprints which are individual iterations that can last anywhere from 2 to 4 weeks each (Kumar, Bhatia, 2012).

Planning for a sprint starts at the beginning of a sprint and that time is also used to determine what can be delivered in the next one (Hron, Obwegeser, 2021). A review of the sprint is then conducted at the end of the sprint to show the outcome of said sprint to the customer and to obtain feedback for the next sprint, feedback will then be used in the next sprint (Hron, Obwegeser, 2021).

Now knowing the information presented above, we will be conduction 2 weeklong sprints for each stage of development.

Project setup Sprint 0:

This sprint will be 2 days long. In this sprint, basic project setup will be completed. Such as importing all libraries and packages that will be needed include Oculus integrations, creating a very basic prototype application to test all packages are working correctly and everything was setup and imported correctly.

Sprint 1:

Basic game development of the puzzles will be done in this sprint, the two puzzles giving a week to produce each puzzle during the sprint I.E 8 queens puzzle and so forth. This will then be tested according to the requirements of the system.

Sprint 2:

Further game development will be done here, including building the website and making sure the headset and the server can communicate. This will also be tested according to the requirements of the system.

Sprint 3:

Database setup will be performed in this sprint, the website will also be further developed. Testing to make sure data is stored correctly and is sent by the headset will also be done here.

Sprint 4:

User interface will be developed here according to the requirements specification. This will be tested along with the rest of the project to make sure everything is working correctly.

Sprint 5:

This sprint will consist of making sure everything is working correctly and working out any bugs that may have occurred and gone unnoticed during the systems development. Final testing of the system will also be done here, making sure the system properly satisfies all requirements.

# Requirements

This section of the report will contain 40 requirements in total. 20 Functional and 10 non-functional. We will be using this to illustrate the Priority of each of the requirements.

Moscow stands for must have, should have, could have, won’t (Asghar, Bhatti, Tabassum, Shah, 2017, Page 303-313).

Must – The system must have this, and this is the highest priority.

Should – The system should have this, this is mid priority.

Could – This system could have this, however it is not necessary.

Won’t – This could be added in the future, but it won’t have this at this given time.

The Requirements are Identified with a number and the type of requirement in said number. For example:

-VR means a requirement related to the VR game itself.

-WS means a requirement relating to the website.

-VR/WS means it is a requirement that relates to both.

## Functional Requirements:

|  |  |  |  |
| --- | --- | --- | --- |
| Requirement No. | Description | Priority | Requirement |
| FR1-VR | Must use a multitude of input methods for picking up in game items such as chess pieces | Must | The game must allow input from both controllers and hand tracking for picking up items |
| FR2-VR | The game must contain 2 working puzzles | Must | The game must have two puzzles for the user to play, 8 Queens etc |
| FR3-VR | The game must know when a user has solved a problem | Must | Must have an algorithm or algorithms that can detect when a puzzle is solved when a button is pushed |
| FR4-VR | If a user makes to many mistakes or for some reason require to reset a given level, this must be allowed | Must | The user must be able to reset the level by pushing a reset button |
| FR5-VR | The tutorial level will include controls instructions and a description of the puzzles you can play. | Must | The user must be able to play through a tutorial level. |
| FR6-VR | Be able to move around the world when using the controllers | Must | The controllers should be able to provide movement to the player |
| FR7-VR | There must be a save option | Must | The game must save past puzzle solutions onto the headset solved by the user |
| FR8- WS/VR | Users need a way to identify themselves on the leader board. | Must | Allow users to attach a name to the high scores when they are sent to the website |
| FR9- WS | The home page button will take users to the main page of the website, which includes information about the game and information on how to play | Must | Have a home page button for the website |
| FR10-WS | Leader board button should take the user to the leader board page that displays players high scored in order of best to worse | Must | Should have a button that take users to a leader board page |
| FR11-WS | There must be a website to save high scores to | Must | Push high scores to a website |
| FR12-VR | Help could be provided if the user is struggling to sole a specific problem | Should | The game will provide a hint if a user does not make a move within a given time frame |
| FR13-WS | Allow a user to click a link to download the game | Should | When the user clicks a link they are taken to a place where they can download the game to play. |
| FR14-VR | Be able to move around the world using hand tracking | Could | The user should be able to make a hand gesture and move around the world freely |
| FR15-VR | Data on the headset should be backed up to a server at the push of a button | Could | Store games save data on dedicated server and pull data when game is loaded |
| FR16-WS | A login system that allows a user to enter the website | Could | Allow users to login to the website |
| FR17-WS | Users can edit and delete their high scores if necessary once they are logged in | Could | Allow users to manage their leader board data, I.E delete, change their name etc |
| FR18-VR/WS | The user should be able to view their high score data within the headset | Won’t | The user can pull their high score data from the website and view it |
| FR19-VR | Allow full body tracking, allowing the user to use all limbs when playing the game | Won’t | Allow full body tracking for input |
| FR20-VR | Multiplayer allowing multiple users to join a session and solve puzzles with each other | Won’t | Allow multiplayer – Allow users to join other user to solve the puzzles. |

## Non-functional Requirements:

|  |  |  |  |
| --- | --- | --- | --- |
| Requirement No. | Description | Priority | Requirement |
| N-FR1 | A User interface is necessary to allow users to select different puzzles | Must | The game must have a way to select between different puzzles in the form of a UI |
| N-FR2 | The game must be maintainable enough to allow for the addition of new puzzles | Must | Allow for the addition of new puzzles |
| N-FR3 | The game must be able to run at a reasonable frame rate on the quest 2 | Must | Must run on the Oculus Quest 2 |
| N-FR4 | Good maintainability is necessary to allow updates to the system. | Must | Must be simple to maintain both quest 2 app and website. Splitting programs into Classes and functions etc must be observed to prevent the code from being hard to maintain |
| N-FR5 | The game should be able to check the validity of a solution without any lag. | Must | Be able to check a puzzle solution within 1 second |
| N-FR6 | Multiple users are going to need to access the website at one time, the website should be robust enough for this to be allowed | Must | Multiple users must be able to use website at the same time |
| N-FR7 | There should be minimal delay when sending a message from the headset to the webserver | Should | Be able to send data to the website from the headset and update it within 1 second |
| N-FR8 | The game should also be available for headsets that require to be connected to a desktop machine | Could | Run on the Oculus rift s |
| N-FR9 | If a user of the website does not have the game, they have no reason to access the website and make changes to scores | Could | Users who do not own the game should not be able to access the website |
| N-FR10 | The website must not be down for long periods of time | Wont | The website would not be down for more than 5 minutes during a fault |

# Design

# Implementation

# Project Evaluation

# Further Work and Conclusions

# Glossary

# Table of Abbreviations

# References / Bibliography

Green = peer reviewed

Purple = books

Blue = trusted websites

Orange = unsure if peer reviewed

Red = Not peer reviewed

Yellow = Video games

Brown = Unused/Not finished with

**Temp Colour coding**

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# Appendix A: First Appendix