**Virtual Reality Art Museum**

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**Improving the usability of a Virtual Reality Art Museum for multiple virtual reality headsets using SteamVR2**

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**Abstract**

Virtual reality is a new emerging technology that is only now beginning to branch out into the mainstream. This projects goal is to port an existing project and improve the user interface to work with multiple virtual reality headsets. I hope to combine the emerging technology of virtual reality and combine it with the traditional academic field. Creating such an experience requires the use of technology and history to create something brand new to peak the interests of future generations.

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**Acknowledgment**

I would like to extend my sincere thanks to all my family, and those who have helped me throughout my entire degree. I would also like to thank my supervisor Dr. Hubert Cecotti for all his support and guidance throughout the semester; the assistance he has provided has been invaluable to my learning experience at Fresno State.

# Introduction

## Aims and objectives

The main aim of this project is to update the previous Art Museum virtual reality project to work with more VR headsets and changing VRTK out for SteamVR.

To achieve this, the new project needed to be rebuilt from the ground up. This new project will be built in a newer version of Unity (2019.14.8f1). I needed to create a virtual environment that can house paintings to show the user a life like version of these works of art. Included with each painting must be a questionnaire to find out each user’s understanding.

This project is important because virtual reality is growing in popularity and accessibility every day. This project can increase the amount of people that have access to fine art, without the need to travel great distances to witness these works of art.

The expected results of the projects are an immersive museum environment created in a virtual environment with life size paintings that can be examined from any angle the user feels necessary to appreciate the work of the artist.

## Outline

The remaining sections of this report are organized as follows: The state of the art technology related to virtual reality is described in Section [2.](#_bookmark3) The analysis of the project is detailed in Section [3.](#_bookmark5) The methods are given in Section [4](#_bookmark14) and the information related to their implementation is detailed in Section [5.](#_bookmark17) The results are presented in Section [6](#_bookmark18) and discussed in Section [7.](#_bookmark19) Finally, the main contributions and results of the project are summarized in Section [8.](#_bookmark22)

# Related works

Virtual reality is currently a popular growing field. There are new technological improvements coming out regularly and an increasing number of creators are trying their hand at VR games and applications. Once example of new hardware improvements would be the Oculus Quest 2. Let us compare the new oculus quest 2 and the HTC Vive that I am currently using to develop this project. The HTC Vive requires two four-inch cube sensors be plugged in at two opposite corners of the room to be able to use the wireless controllers. The Vive also requires the headset be plugged in to power and to a high-end PC. The Quest 2 does not require any of these things. The Quest 2 can be used with or without a PC, this headset does not need sensors to be able to track the controllers in the room. Each of these headsets cost drastically different amounts of money with the HTC Vive originally coming in between $500 - $700 and the Oculus Quest 2 coming in at $299 or $399. The HTC Vives video quality is just under 1080p for each eye, while the newer Oculus quest 2 has a video quality of just over 1080p for each eye. These two VR headsets are just one example of some of the improvements that are being made in the world of virtual reality.

Technology has advanced enough to shrink the size of all the components used in the VR headsets, increase the quality, and bring the price down to a more accessible price for most people. Virtual reality is currently in a critical state for the professional world, there are different companies attempting to integrate VR into their business to increase their ability to train and solve problems. One developer has attempted to assist with surgical training by creating a VR for Surgical simulation training called “Osso” that allows people in the medical field to train on virtual patients. The application Osso is discussed in an article [3] that goes over how it works and how the medical field plans on implementing it for the training of future surgeons. This is one example of how virtual reality can be used in a professional setting.

# Analysis

## Problem Statement

## The previous VR Art Museum project only worked with one VR headset and did not work with SteamVR2. This new version of the project needs to work with multiple headsets and SteamVR2.

## Proposed solution

## To create a virtual reality art museum, that will create the immersive experience of visiting a real-life museum. Traveling is not always possible, or available to everyone. In todays day and age, most people have access to a personal computer and most have one or more in their own home.

## Requirements

### Functional requirements

### Multiple paintings.

### Rooms must scale with the size of the paintings

### Paintings must be observable from all available angles.

### Most VR headsets should work with this project.

### Paintings and questions must be editable by non-technical user.

### Program must run at a frame rate of 45+ frames per second to maintain quality of experience.

### Non-Functional requirements

### Virtual reality must maintain high visual quality throughout experience.

### Virtual reality must be consistent in textures, sounds, and quality throughout.

### Movements must be smooth and easy to use.

### Movements must not induce motion sickness or abrupt visual changes.

### Software requirements

### Steam VR

### Unity 2019.4.8f1

### Hardware requirements

### A Virtual Reality Headset

### A graphics card that supports VR.

### Nvidia GTX 960 4GB/ Radeon R9 290 or greater.

## Project management

The project has been organized following the timeline depicted in T[able.1.](#_bookmark4)

Table 1: Timeline for the CSci198 project.

|  |  |  |
| --- | --- | --- |
| **Week** | **Objective** | **Comments** |
| 0 | Familiarize with Project | Study Layout, learn Unity. |
| 1 | Project Doesn't Run, Start Rebuild | Project only runs in specific Unity version. Does not run on my PC. Rebuild entire project in current Unity. |
| 2 | Recreate Museum Room | Recreate the main Museum Room. |
| 3 | Recreate painting import and quizzes | Create the functions required to import JSON files and display information on screen |
| 4 | Troubleshooting | Paintings loading incorrectly and frame sizing/ textures are off. |
| 5 | Implement general controls | Implement movements and game controls in SteamVR which supports many different VR hardware devices. |
| 6 | Implement Teleporting | Implement teleporting to navigate environment |
| 7 | Troubleshooting | Fixing quiz moving with player, bugs with quiz going outside the room |
| 8 | Texture fine tuning | The textures for the room and painting frame need to be exchanged for better suited materials. |
| 9 | Fine tune quiz and lighting | Adjust quiz to encompass all texts, adjust lighting to equally light painting and rooms. |
| 10 | Adjust Room wall & floor textures | Room wall and floor textures were not scaling with room. |
| 11 | Change Teleporting implementation | Teleporting was previously to designated places in the room. Has been updated to anywhere in the room. |
| 12 | Troubleshooting | Adjusted JSON files, added dev modes, buttons updated to look better. |
| Spring Break | Code Refactor | Clean up unused items in code and in file structure. |
| 14 | Adjust painting frame and plaque | painting frame texture changed, adjusted scale for different size paintings. Added plaque to hold description. |
| 15 | Finalize Details | Finalize painting frames, painting size, bugs. |

# Methods

Detailed Description of the algorithms and methods...

This Project required certain criteria to be met to ensure its success. The criteria was as follows, quality, realism, accessibility, usability. This project was previously implemented on an older version of Unity and with different visual stylings.

Functions and Data structures:

Loader:

* + - * SetButton(bool b, GameObject go)
        1. This sets the size of the buttons.
      * HideButton(GameObject go)
        1. This will hide the button that is passed to it.
      * ShowButton(GameObject go)
        1. This will show the button passed to it.
      * PositionQuiz()
        1. This positions the quiz relative to the player’s position. It loads the quiz on the left side of the player anytime they move.
      * LoadImage()
        1. Reads in the JSON file, gets the file path, and loads the image. Then it places the image in the room, handles the lighting and frame.
      * UpdateAnswer(int idx)
        1. This updates the answers from the file to the button. Calls SetAnswers().
      * SetAnswers()
        1. This updates the answers that are displayed on the buttons within the quiz.
      * DisplayQuestion()
        1. Loads and displays the questions on the top of the quiz.
      * QuizProc()
        1. This decides which JSON file is loaded for the quizzes.
      * CheckAnswer()
        1. This is where we check the answer to see if the user selected answer matches the correct answer in the JSON files. Calls DisplayQuestions().
      * SetPainting(int p)
        1. This sets up the painting in the world. Calls DisplayQuestions().
      * NextprevPainting(int delta)
        1. This is how the Next and Prev Painting buttons are working. Calls DisplayQuestions().
      * NextprevQuestions(int delta)
        1. This is how the Next and Prev Question buttons are working. Calls DisplayQuestions().
      * SetQuestion(int q)
        1. This is where the questions are setup in the quiz. Calls DisplayQuestions().
      * InitAQ()
        1. This counts how many paintings, questions and answers are in the JSON file that is getting loaded.
      * Awake()
        1. When the program loads it will call QuizProc() so that the quiz is loaded before its needed.
      * Start()
        1. This is called before the first frame updates.
      * Update()
        1. This is called once per frame. PositionQuiz() is called.

RoomSizeController

* + - * CalculateRoomPosition(Vector3 dimensions)
        1. Calculate the position of the room based on the size of the painting
      * CalculatePlayerPosition(Vector3 dimensions, float pw)
        1. Calculate the player position so that the painting is in full view.
      * CalculateRoomDimensions(float ph, float pw)
        1. Calculate the size of the room based off the picture height (ph) and picture width (pw)
        2. Calls OptimalPlayerDistance(float pw)
      * OptimalPlayerDistance(float pw)
        1. Calculate the optimal player distance given the picture width.
      * ResizeFrame(Transform paintingTransform, float xval, float yval)
        1. Adjust the size of the frame so that it fits around the painting.

SaveAnswers:

* + - * SaveFile()
        1. This is what writes the selected answers back to a file at VRArtMusuem\_2019.4.8f1\_2020\Assets\StreamingAssets\JSON\Responses\response.json

Data Structures:

* Answer Painting
  + List of Answers
* Answer Quiz
  + List of Answer Paintings
* Answers
  + public float PositionX;
  + public float PositionY;
  + public float PositionZ;
  + public int AnswerNumber;
  + public string SelectedAnswer;
  + public int TimeToAnswer;
* CollectionPainting
  + List of Painting
* Painting
  + public string filename;
  + public string title;
  + public string author;
  + public string date;
  + public string description;
  + public double size\_y;
  + public double size\_x;
  + public List<QuestionAnswer> Questionnaire = new
  + List of QuestionAnswer
* QuestionAnswer
  + Public QuesitionInfo Question;
  + List of Response
* QuestionInfo
  + public string Text;
  + public bool TrueFalse;
* Response
  + public string AnswerText;
  + public bool Correct;

Music

* MusicManager
  + This ties all the music functions together.
* UIPlayMusic
  + This controls the music playing.
* UISelectorMusic
  + This controls the buttons that change the music.
* UIVolumeMusic
  + This controls the volume and volume buttons on screen.

UI

* ButtonColorScheme
  + This controls the color of the background on the button, canvas and quiz.
* ButtonPrevNextPainting
  + This controls the previous and next buttons to move between paintings.
* ButtonPrevNextQuestion
  + This controls the previous and next buttons to move between questions.
* ButtonSave
  + This controls the save button, which is currently under development.
* ButtonSelector
  + This is what controls if a button is selected.
* ButtonSetPainting
  + This shows the number of paintings in the JSON file on the Painting Button.
* ButtonSetQuestion
  + This shows the number of questions in the JSON file on the Question Button.
* ButtonSubmit
  + This controls the Submit button that saves the selected answer to a Response.JSON file in streaming assets.
* ColorScheme
  + This controls which color scheme is currently active.
* ColorSchemeList
  + This lists all the available color schemes that can be displayed.
* GUIColor
  + This controls the color displayed for the general user interface.

# Implementation

# 5.1 Quality

# Quality of the user experience was a focus from start to finish. The final product has been pieced together with high quality textures and materials that can be used consistently across a plethora of virtual reality headset. The program runs smoothly on minimal computer setups to ensure that regardless of hardware the user experience is consistently the highest quality available to them.

# 5.2 Realism

# Needed to include real paintings at scale. These paintings needed to be high quality and consistent across each painting. High quality textures were chosen, to help bring the immersive experience to life and bring the virtual environment closer to real life. Figure 1. Shows the overview of the room looks and the textures used. The wood flooring used is very detailed showing the grain. The wall texture shows the how rough the concrete is. Figure 2. Displays the painting, frame, and placard.

# 

# Figure 1: Overview of the Room with Quiz and Picture.

# 

# Figure 2: Example of painting and description.

# 5.3 Accessibility

# The focus of this re-implementation of the project was to change the control scheme from the previous VRTK to SteamVR. The reason for this change being that VRTK only supported a couple of virtual reality headsets on the market. SteamVR has support for most headsets which greatly increases the accessibility of the program. The hardware in each headset on the market varies greatly. Some headsets contain sensors, headset, controllers, and treadmills while others may only include a headset and controllers. Each controller was designed differently, with different layouts and buttons. SteamVR works around this by creating a general layout and then assigning them to the controller that the user has chosen to enjoy the program with. These settings are handled through steam using their GUI to assign each controller actions. These actions are stored in a JSON file that the programmer has access to while creating the VR application in Unity. Figure 7. Provides an example of how the JSON files are name for the controller setup. Figure 8. Shows the structure of the JSON file for one of the controller files.

# 

# Figure 7: Example of JSON files for controller Bindings

# 

# Figure 8: JSON Controller Assignment Example

# 5.4 Usability

# The program needed to be simple and easy to use. The program needed to be easily understood by a non-technical person. Each set of paintings and questions have their own JSON files that can be edited as plain text by a standard user. Figure 3. Shows how the quiz is structured relative to the painting. This will allow users to expand upon what art pieces are included in the program after implementation. Figure 4. Shows a closer visual of the quiz layout. Figure 5. Shows how the buttons can be selected from the quiz. Finally Figure 6. Shows the layout of the JSON file that contains all of the settings for the quiz.

# The players location was taken into consideration. Depending on the size of the painting that is specified in the JSON file, the players location, size of the room, lighting and textures will all change to ensure that the player gets the best experience.

# Each JSON file is laid out as follows:

# Picture:

# FileName: Path to the file, should start with StreamingAssets/ (String)

# Title: This is the title of the painting (String)

# Author: this is the authors name (String)

# Date: Date that it was originally created (String)

# Description: This is the description that will show up below the painting. (String)

# Size\_y: This is the Y size of the painting in meters (Int)

# Size\_x: This is the X size of the painting in meters (Int)

# Quiz

# Question

# Text: Question goes here (String)

# TrueFalse: True or false (Bool)

# Answers

# Answer: Correct phrase or word (String)

# Correct: True or False (Bool)

# A picture containing text, picture frame Description automatically generated

# Figure 3: Example of Quiz and Painting.Text, letter Description automatically generated

# Figure 4: Example of Quiz.Timeline Description automatically generated

# Figure 5: Example of selecting Answer.

# 

# Figure 6: Example of JSON file.

# Results and evaluation

Due to the current circumstances regarding a worldwide pandemic, minimal testing has been performed on the current implementation of the project. There has been a small user group testing that was completed using close family. These tests consisted of people unfamiliar with VR and minimal experience with digital gaming. The results of small user group testing were consistent and positive. The experience is smooth, intuitive, and visually appealing. Each user enjoyed the movement mechanisms that were implemented. They appreciated being able to teleport around the room whimsically to view the paintings from their desired point of views. The quiz questions were difficult for the user to answer correctly without previous knowledge of each painting.

Based on this feedback I believe it will be successful once fully implemented and made public. It would greatly increase the success rate to expand the single room to an entire navigational museum. If the user had more mobility, with a large environment to explore, I believe the user experience would be greatly increased to imitate the museum goers experience more closely without the fatigue of all the walking.

# Discussion

## Future developments

## There is a lot that can be improved on with this project. This project could be expanded from a single room to an entire museum with different rooms and floors that could allow the user to explore freely while they viewed the available art. There is already teleporting and turning 90 degrees left and right implemented. More pictures and questions can be added to increase the value of the project very easily by updated the JSON files. The outside skybox can be updated to follow the time of the day, so based on what time the user is interacting with the project it will reflect their current outside lighting. By changing the lighting outside the room to match the user’s physical environment, it would greatly increase the immersion factor.

## Personal reflection

This project was a learning experience, with no prior knowledge of any of the tools required to implement this project I believe that I put my best foot forward and made sizable strides towards the goals of this project. This project was initially presented as a finished project, that required the user controls to be replaced with a newer more robust system. This requirement was met along with reimplementing much of the previous project. This was a great experience to work on a virtual reality project with a lot of frustrations and learning along the way. I had never worked with Unity, C#, or 3D designing. All these things were challenging and interesting to learn. I am grateful for the experience and pleased with the outcome of the work put in.

# Conclusion

# Virtual reality is quickly growing in popularity, technology, and accessibility. New use cases are being discovered daily; such uses include the medical field to train new surgeons. This project has attempted to seek out another use case for virtual reality to include it in academia and push it into the future. The VR Art Museum hoped to bring the experience of a museum to the user without them needing to travel for such an experience. The user would then be able to view and learn about historical art with minimal effort.

# While working on this project many iterations of textures, controls, and environment were experimented with to give the best user experience. Based on the minimal user group testing that was completed, alongside the testing from myself and the professor throughout working on this project. The public launch of this project will have a positive and successful response.

# During the implementation of this project, a lot was learned while working with Unity, C# and a 3D workspace. Unity is picky with which version a project was created, C# is not that bad, and I do not like 3D environments. Overall, the experience was positive, and I am pleasantly thankful for the opportunity to get to work on such a unique project with a very helpful professor.

# References

[1] YouTube.com:

<https://www.youtube.com/watch?v=DAAOtAJ6YE8&ab_channel=FusedVR>

<https://www.youtube.com/watch?v=bn8eMxBcI70&ab_channel=VRwithAndrew>

<https://www.youtube.com/watch?v=5C6zr4Q5AlA&t=532s>

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[2] Sarthak Ghosh: <https://sarthakghosh.medium.com/a-complete-guide-to-the-steamvr-2-0-input-system-in-unity-380e3b1b3311>

[3] Jasoren (VR Surgery Training): <https://jasoren.com/using-virtual-reality-for-surgical-simulation-trainings/#:~:text=What%20is%20VR%20surgery%3F,clear%20feedback%20for%20their%20actions>.