Virtual Reality Art Museum

Zachary
Day-Scott Fall
2019

Department of Computer
Science College of Science and
Mathematics Fresno State

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Day-Scott Fall
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Department of Computer
Science California State
University, Fresno Fresno, CA
93740

Project Advisor: Dr Hubert Cecotti Submitted
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Abstract

As an emerging commercial technology, the applications of virtual reality programs are still being explored. While many speculate the use of virtual reality in academic settings will be a positive, the effects of the medium are still being discovered. This project seeks to put precise metrics to the difference in student learning in relation to the medium in which the subject was taught. To do this, the project must utilize the most influential aspects of VR to demonstrate its potential as a learning medium.

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Acknowledgment

I would like to extend my sincere thanks to all my family, friends, and those who have helped me throughout my entire degree. You'll never walk alone. I would also like to thank my supervisor Dr. Cecotti for all of his support and guidance throughout the semester; the assistance he has provided has been invaluable to my learning experience at Fresno State.

1 Introduction

1.1 Aims and objectives

The main aim of this project is to find if there is a difference between student learning in virtual reality versus traditional mediums.

In order to achieve this aim, it is needed to create a three stage experiment system that will test students retention of information learned from a virtual reality learning medium and two control traditional mediums. The two traditional mediums being textbooks and a classic first person video game.

This project is important because virtual reality is a rapidly progressing field. Its appli- cations range from video games to training software for engineering firms to architectural demonstrations. More applications of virtual reality are being discovered almost daily, therefore exploring in an academic context is a worthwhile endeavor.

The expected results of the projects are that the immersive qualities of virtual reality will have a positive affect on students retention and therefore will be an effective learning medium.

1.2 Outline

The remaining sections of this report are organized as follows: The analysis of the project is detailed in Section 3. The methods are given in Section 4 and the information related to their implementation is detailed in Section 5. The results are presented in Section 6 and discussed in Section 7. Finally, the main contributions and results of the project are summarized in Section 8.

2 Related works

In [2], they explore the use of VR in increasing empathy for others by placing the subject in specific environments. It was found in [3] that virtual reality has an increased ability for subjects to reach a ”flow” state (meaning they are at a more productive state). [1] examines the use of VR in a language learning classroom environment.

3 Analysis

3.1 Problem Statement

What affect, if any, does virtual reality have on the learning of students in the context of Art History?

3.2 Proposed solution

To create an experiment that tests students learning across three different learning medi- ums. These mediums will be VR, computer screen and textbook.

3.3 Requirements

3.3.1 Functional requirements

1. Static set of paintings that are divisible evenly across the learning mediums

2. Painting - learning medium combinations that can be randomly chosen

3. Similar observation time between the mediums

4. Screen learning medium must be able to operate within the same environment as the

   VR learning medium

5. Paintings and Questions must be easily accessible and edited for a non-programmer.

   The target audience for this file will be art history professors

6. Mesh, texture and lighting data must be optimized to strike the highest possible

   balance between fidelity and performance.

7. Program must run at 90+ frames per second to maintain immersion.

3.3.2 Non-Functional requirements

1. VR learning medium must utilize immersive

properties.

2. VR graphics settings must be maximized to improve chances of immersion.

3. Movement within the VR learning medium must be intuitive enough to be universally accessible

4. Movement within the VR learning medium must contain measures to counteract motion sickness within players

5. Players must feel safe to explore the virtual space while being disincentivized to move outside of the space

3.3.3 Software requirements

1. Steam VR

2. Unity 2018.3

3. Probuilder

4. Photoshop

5. VRTK

3.3.4 Hardware requirements

1. HTC Vive Index headset

2. RTX 2080 Super Graphics card

3. HTC Vive base controllers

4. At least a 7’ by 7’ space for room scale

3.4 Project management

Weekly meetings with the project advisor, Dr. Cecotti, were manditory to maintain positive productive velocity. I also maintained a detailed development log and Trello board set up in an agile format. The project has been organized following the timeline depicted in Table.1.

Table 1: Timeline for the CSci198 project. Week Objectives 0 Project planning 1 Requirements and review of current build 2 Locomotion: Walking 3 Quiz system and dev tools 4 Modeling, json parsing and class diagrams 5 Painting loading and report output 6 Static rooms and transitions 7 New quiz features 8 Full team demo, bug fixes and Index controller testing 9 Dynamic rooms 10 Dynamic rooms and player spawning 11 Locomotion: teleport 12 Testing 13 Controls rework Thanksgiving Break Testing 14 Quiz system optimization 15 Dynamic frame system and music

4 Methods

For the virtual art museum to work well, special focus had to be applied to a couple key areas of development. These areas include technical efficiency, realism, modularity, loco- motion and usability. Many of the design choices were made in development were made with these areas in mind.

4.1 Technical Efficiency

When designing the initial prototypes for this project, some issues became apparent with the design that needed to be addressed. We wanted to maximize the Vive's graphical ca- pabilities. To do so we decided on a small singular room design with simple meshes and textures to save the rendering costs for extremely high resolution painting textures. This simple design also later helped with the modularity of the system as well. The goal of keeping low rendering costs for everything except the painting was a major factor in many of the decisions for the project.

Figure 1: Outside perspective of generic room from

scene view.

4.2 Realism

To maximize the effects of virtual reality on learning, a major focus for development was on the realism within the VR system. The two fields of realism I focused on were interac- tion and aesthetics.

To make the VR application feel as real as possible I had to make the controls intuitive enough so that players who are not familiar with VR can use the application and with minimal training execute actions without having to stop and think about the controller in- terface. With this goal in mind the design of the control layout had to be minimal. The movement within the virtual environment was also designed to maximize immersion time (I will go into more detail in the next section).

For the aesthetics I designed a simple room with minimal details to focus the attention on the painting. The walls and floor have a simple texture that utilize normal mapping shaders to give the illusion of depth and feel. The frame is a set of simple 3d meshes that scale to fit the painting. The painting textures are displayed on a flat mesh. I experimented with bump mapping for the paintings to give them a more realistic feel, but was unable to

achieve a satisfactory result. I think that given more attention a subtle shader applied to the paintings could help the overall immersion. To further explore the aesthetic properties of VR I added background music playing softly in the scene. Before adding this feature, I found that players would more easily be pulled out of their immersive states if they heard a noise outside of the virtual environment. I found that if I was taking notes or typing the player would immediately be self conscious of their actions and be removed from their immersion. Background music has seemed to mitigate that, though further testing would be nice to confirm it.

4.3 Modularity

One of the main goals for this project was modularity within all of the systems. Every part of the experience needed to be instantiated or modified at runtime to allow for anyone in the future to run their own version of the experiment. In a way, we built a small scale museum sandbox. The three main systems that were affected by this goal where the room generation, painting instancing and quiz systems.

The first system to run in the dynamic initialization stack was the painting initialization. The painting texture file would be loaded onto the painting prefab and scaled appropriately. Then the frame would dynamically adjust their scale and position to fit the painting inside. The current system handles any size of painting, however the frame will always be a rectangle. At this time the painting's metadata would be loaded to their appro- priate locations. These included the information panel and the narration system that would both display and dictate information about the painting.

Room generation and alteration was a major component in making the experience feel real. We had to design a room that would feel as though it could realistically be hosting its painting. We developed a simple algorithm that adjusted the scale of the room based on the size of the painting that it was hosting. The painting would act as the starting point and the rest of the room would scale to fit while leaving a predetermined buffer around the painting as to not feel claustrophobic. After the room scaled, the texture tiling of the floor, walls and ceiling would have to dynamically scale to avoid stretching. Finally the ideal place for the player to start would be generated based on an algorithm that was initialized by the painting.

Finally the quiz system gets instantiated. Each question and answer group pairing is read in and a question object is created. This object is how the question metadata is stored

and manipulated within the app.

Figure 2: Quiz in action.

4.4 Locomotion

One of the largest hurdles for VR at the moment is locomotion. There isn't a "right" or universally comfortable mode of locomotion designed yet for VR, there are a few pretty good options at the moment but they do come with their own drawbacks. The two main modes of locomotion we focused on were teleportation and in game slide style "walking".

Teleportation in the app is activated by pressing the touchpad on your dominant hand while in teleport mode and selecting with the trigger. When activated the teleporter dis- plays a curved beam from the controller with a box and circle cursor that represents the size of the play area and the players physical location within the play area. This pointer and cursor style where chosen to lead the player to using the teleporter on the ground with in the virtual room as intended. The circle in the box cursor is also helpful for re-orienting the player within their physical play space. Some of the largest issues with the teleport feature in VR spaces were the player using it to leave the intended virtual playspace and the player losing their orientation in the real world after several rapid teleports.

Figure 3: Teleport pointer and cursor.

The walking feature is intended for small adjustments to the play area’s location within the virtual space. Walking in VR is complicated because it can be extremely disorienting for certain players. It also can cause severe motion sickness. To combat this I chose to slow the speed of the walking to a slow speed that caters to the players more prone to motion sickness. I found in testing that players that were susceptible to motion sickness started to lean in the opposite direction of their in-game avatar. I further noticed a direct correlation between the speed of the in game walking and the severity of the angle of lean that occured in players who were susceptible to motion sickness. Slowing the in-game walking speed reduced players motion sickness and increased the use of the feature significantly.

For each real world action the program had to produce a functionally similar action to the VR space. For example, the right hand is used for both the teleportation feature and menu interaction. These two mechanics are fundamentally different, but the actions the player performs to complete the action is physically similar. For both actions first the player activates the laser pointer with the touchpad, then to submit the action the player

must pull the trigger.

Figure 5: Right controller in teleport mode.

To emphasize the difference between each action a unique pointer and cursor was

Figure 4: Right controller in interact mode.

used. This feature served double duty as the shape or the pointers were designed so that the player would subconsciously be taught the use of the feature upon seeing the pointer. The teleport pointer is only to be used to teleport the player to a new location on the ground, therefore the pointer is an arch that always points to the ground. We found that new players used the teleport feature as intended much faster and more consistently after the pointer was implemented. At the base of the pointer there is a box that auto scales to the size of the users play area. Inside the box there is a circle to represent the players location within the play area. After some AB testing, the players who used the teleport with the box/circle cursor not only used the teleport more controlled, but they also moved around the play area more freely.

4.5 Usability

One of the main goals of the project was for it to be highly customizable. This goal was achieved through a detailed json structure that contained the file locations of the paintings displayed, the meta data for the paintings, and the quiz data associated with each paint- ing.The json structure needed to be robust enough to enable interesting experiences for the player while being simple enough for the exam holders (intended for art history profes- sors) to program and edit.

The superstructure of the json is an array of picture objects. Each picture object con- tains a painting object and a quiz object. The painting object contains the file location for the painting texture and the metadata.

1
3

Figure 6: High level structure of input json.

5 Implementation

5.1 Technical Efficiency

To maintain maximum efficiency, all high resolution textures are dynamically loaded and unloaded at runtime. This means that both the base memory allocation is low and that there is only ever one high resolution texture loaded at a time. This keeps the frame rate at over 100 frames per second (average of 120 fps).

Figure 7: Frame rate tool within the 1.4 build.

5.2 Realism

With the room scaling to different sizes with each new painting, a script had to be written to adjust the scaling and tiling of the textures as to not distort them. This was achieved through seamless modular tiling textures and a script that was called upon the room size being changed.

Figure 8: Part of the texture scaling method.

5.3 Modularity

To maintain optimal modularity, every component is instantiated at runtime. To do this, every component within the quiz system had a separate constructor that took in a json and constructed the object based on its data. The json object would be broken up and distributed to the lower objects until finally all of the data had been read and implemented.

Figure 9: The question class with an expanded view of the json based constructor.

This also allowed the ability to only utilize the features that were needed for any indi- vidual object. This was most useful in the Question objects as it made scaling to accom- modate new types of questions very easy, usually only 3 lines of code.

1
6

Figure 10: Expanded view of the optional parameters method within the

question class

5.4 Locomotion

One of the major challenges we found early on was that players had a hard time switching between the teleportation mode and the UI interaction mode on the right controller. This was addressed by developing an automatic switching mechanic. This feature would detect if the player was pointing toward the quiz UI and swap the pointers for them. We found that this lead players to not only use both features more frequently, but they also understand how to use the menu pointer faster by associating the quiz UI with that pointer more directly.

Figure 11: A section of the PointerSwapper component.

5.5 Usability

With the target audience expected to not have a strong programming background, it was important to maintain simplicity within the parts of the project that they would be inter- acting with. Mainly they would be interacting with the input json file. Therefore, the structure of the input json file was kept very simple and the object names were as legible as possible.

Figure 12: The picture object within the input json.

Figure 13: A true false question object within the input json.

6 Results and evaluation

At the time of writing, no formal experiments have been performed yet. Several informal tests have been performed though and I will explore them in this section. These tests have been largely performed by student volunteers and most of them were given zero information about the mechanics of the application prior to the start of the experiment.

6.1 Players vs Controls

As the target audience for this application is people who don't have much experience with virtual reality and technology, it was crucial to test the control scheme to see through our own developer bias. Throughout development we performed many informal usability tests with students of all backgrounds. In these tests we found that the amount of buttons and being in a virtual environment was overstimulating for most people upon entering the application. However, most, if not all of the subjects were able to gain a base level of competency in navigating the application.

The best feature for helping subjects gain competency of the mechanics was the curved pointer for the teleport. Prior to the curved pointer, subjects were consistently getting stuck, not understanding, or worse being afraid to use the teleport feature.

The feature that gave subjects the most trouble was the quiz answers. Most subjects have some level of difficulty in submitting their answers for the quiz questions. A graphi- cal redesign of the quiz GUI could help.

6.2 Comments

Some of the most common comments on the application are if there is a zoom feature and if it is ok to move. The first was a cool idea for a mechanic, however due to time con- straints it was not able to be implemented. The second comment, about moving, is a more difficult challenge. Throughout testing we've come to find that there are many styles of player. The two most common are also unfortunately the most extreme cases, the player how stands completely still and the player who will not stop moving.

The player who stands still is a common archetype of player that is either uncomfort- able with technology or hyper confident in technology. The uncomfortable player will stand straight up with their hands and arms locked in one ”safe” position. They do not try any new features unless prompted and a slower to gain competency as a result. On the other hand, the player who is over confident with technology usually stands in one spot in a slouched, relaxed posture. In our limited experience, this player type tends to look at the controls initially, decide what controls are necessary to play and not explore further after that. An introductory scene utilizing the controls in a safe interactive manner could help both of these players become more engaged.

The second architype is the player that will not stop moving. They are highly eager to explore the possibilities of virtual space and therefore can be easily distracted. They also run into things in the real world a lot. Adding an in game representation of the real playspace helped curb the more destructive parts of their behaviour. Adding more notifi- cations for the start and ending of the various phases of play could help keep these types of players focused on the experiment.

7 Discussion

7.1 Future developments

For the future of this project, there are several major areas of development. The first is developing a dynamic point/bounding box system that will allow for exam creators to add questions in which the student has to identify objects on the painting. Other developments include an in-engine run editor. This would allow for exam creators edit the exams without having programming experience. Other improvements could be to the quiz system. More metrics could be recorded during the quiz phases that could potentially yield more useful data.

7.2 Personal reflection

This project was a massive learning experience and highly enjoyable. I was able to de- liver on most, if not all, of the tasks assigned to me. I’ve learned a lot working on this project about VR, Unity, programming, design, working in a multi disciplined team and software production. I feel privileged to have gotten to work with new technologies and I am grateful to have gotten to work on this project.

8 Conclusion

Virtual reality is a rapidly evolving new technology. New applications of VR are being discovered on a daily basis. This project seeks to explore one fasit of an academic applica- tion utilizing VR. The VR Museum examined the effects of virtual reality on art students learning new paintings.

During production, it was found that subjects often need to be prompted to explore the virtual space. However after they felt comfortable with the controls they moved fairly freely. It was also found that the relation between the painting being displayed and the room that was displaying it is important. Many subjects had an enhanced experience with the larger paintings in VR due to the scale of the room. Another take away was that the Vive headsets have a limited resolution, therefore readjusting the resolution of the paint- ings relative to the subjects distance was necessary to maintain immersion. Finally, we found that subjects maintained immersion more consistently when there was background music playing.

While the experiments have not been officially conducted yet, I believe that there will be a high correlation between subjects immersion and their retention of the information presented to them. This immersion will be highest in the virtual reality environment. I believe that many more advancements can be made to improve this immersive quality of virtual reality, however its current capabilities make it the best option for learning.

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