Small Project Proposal Virtual Reality Museum

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1 Introduction

Virtual Reality (VR) is defined by Merriam-Webster [1] as *an artificial world that consists of images and sounds created by a computer and that is affected by the actions of a person who is experiencing it.* The artificial world can either be a representation of the real world, or an imaginary world [2]. VR systems in the past were relatively specialized systems with not many users [2]. In 2012, Oculus created a Kickstarter [3] for the Rift [4], a virtual reality headset. The project was funded and introduced virtual reality to a more general public. As VR became more widely used, larger companies such as Samsung and Google developed their own VR variants [5, 8], enabling the use of VR on mobile devices.

VR can be applied in different domains, including those which do not have a direct association with computer technology. One of such domains is cultural heritage [9], and more specifically, museums. This research will be focused on virtual museums. Work in this domain has focused mainly on realistic recreation of existing museums and collections. However, VR provides many possibilities beyond this purpose. Using VR, scenarios could be created that would be impractical or even impossible to create in the real world. Therefore, this research will look beyond simply replicating museums, and will aim to find new ways of improving the user experience by using illusions in VR to alter the surroundings of a painting in a virtual museum setting.

1.1 Virtual Museums

Many connections have been made between museums and the virtual world. For example, the famous Louvre museum provides virtual tours consisting of 360 degrees pictures through which you can navigate [11]. This gives people a chance to 'visit' the museum without physically being there. Instead of using pictures, Wojciechowski et al. [9] developed the ARCO system that provides museums tools to build and manage their Virtual and Augmented reality exhibitions. Using the ARCO system, whole virtual museums can be built. This enables museums to show pieces for which they do not have the physical space.

The creation of a virtual space can even be taken a step further by creating a whole different virtual scene. The Westfries museum in Hoorn in the Netherlands has created a VR experience [10] as a piece of their exhibition, allowing visitors to relive Hoorn in the Dutch Golden Age. These projects on the domain of VR in cultural heritage focus on imitating the original environment, or on creating a new environment which portrays the environment like it was historically.

1.2 Altering the Environment of Paintings

The traditional setup of a quiet white room is not the only way to display paintings. The Tate Sensorium [6] in Tate Britain added touch, taste, smell and sound in their galleries [7]. The setting of the painting was modified by adding more modalities to change the way viewers perceive it. Using VR, these modalities can also be used, without the need to adapt the physical environment. This project however does not have the goal to imitate the Tate Sensorium in the VR space. Instead, it will make use of a different sense, vision, to enhance the experience of viewing paintings.

The IllumiRoom system [15] enhances the experience of playing a game or watching a movie by projecting additional information around the high resolution display, in the peripheral view of the user. Various illusions are discussed in the paper, all of which add extra context based on events occurring on the display. The IllumiRoom system augments the physical surroundings of the player to create a better gaming experience. In the IllumiRoom system, this augmenting feature is used with games to create a better gaming experience. However, changing the surrounding can also be done for other objects of interest. In our case, the environment of paintings will be changed in order to create a different experience while viewing them.

A museum usually provides different types of exhibitions pieces. This project will focus on paintings as exhibition pieces, and like the Tate Sensorium [7], changing the perception of the paintings. It will lend the idea of the IllumiRoom system [15] by changing the visual surroundings of a painting to enhance the user experience when watching a painting.

The environment of the paintings is changed by adding illusions. They can for example consist of creating new objects or showing animations. These illusions are not simple to realize in physical museums. Especially animated illusions are difficult to create in galleries without the necessary equipment. Projectors can be used to project animations on the walls, but this would result in shadows when people are walking by. The room would also have to be dark in order to make the projection properly visible. Large displays can be used to avoid these issues. However, these screens require a considerable amount of money.

Finally, using VR allows us to create a unique experience for each user, as opposed to having them all see the exact same thing. For these reasons, VR museums are a more suitable medium for the realization of these illusions. Additionally, the benefits and novelty of VR could create a stimulating effect for people who otherwise would not visit museums, which could eventually generate interest in museums in general.

2 Research Goal

The goal of this research is to find ways of improving the user experience in a virtual museum setting. While there are various types of museums, we focus on exhibitions of paintings in particular. Since paintings can be displayed as 2D images, various image processing techniques can be applied to them, which are useful for some of our methods. Visible alterations are used to change the environment of the paintings. We call these changes illusions. We aim to

find interesting illusions that could be applied in various applications related to virtual museums. The user experience can be measured by different factors, but for this research, we will focus on the enjoyment and interest of the users when they are looking at the paintings. This might open up new possibilities and ideas for creating new virtual museums and possibly spark interest in those who are normally not interested in visiting museums.

2.1 Research Questions

As indicated by our research goal, we want to make viewing paintings more enjoyable for people who would normally not enjoy viewing paintings very much by visually altering the environment of the painting. We call these alterations 'illusions'. We aim to answer the following question:

- *How do illusions affect the enjoyment of viewing a painting in a VR museum setting?*

The illusions will be defined and explained in section 3.

In this research, the enjoyment of the user is seen as a big part of the user experience. As the virtual museum is a VR experience, the user's sense of presence, the feeling of being in the virtual world, might influence the level of enjoyment. These two metrics have been shown to be connected in related applications [17]. This is a strong indication that enjoyment is influenced by presence in the context of virtual museums, and thus in the context of our research. Therefore, measuring the presence is essential, as it influences enjoyment in our setting. Enjoyment is measured to get an indication of positive user experience. This results in the subquestion:

- *How do the illusions influence the sense of presence in the world of the virtual museum?*

Besides the sense of presence and enjoyment the user experiences in the virtual world, it is also important to look at the user's connection to the painting specifically. With the illusions, we aim to create a stronger connection between the user and the painting by extending characteristics of the painting beyond its frame. We aim to make the user feel more like he is part of the world of the painting, than of the world of the museum. This type of connection can be seen as another layer of presence in a virtual world; the presence in the world of the painting. We will refer to this type of presence as connectedness, and ask the following subquestion:

- *How do the illusions influence the sense of connectedness to the painting?*

Furthermore, we are interested in whether or not the illusions can generate more interest in art for people who are generally not interested in visiting museums. For this we want to know if the illusions create more interest to users compared to the VR museum settings without illusions. One indication for interest would be the duration people look at the painting directly, versus how much time they spent looking at the illusion. Additionally, users can be asked about their willingness to visit an art museum before and after using our VR application. This gives raise to the following subquestions:

- *How do the illusions influence the interest in the painting?*
- *How do the illusions influence the willingness to physically visit art museums?*

3 Design Space

There are lots of ways to alter the surroundings of the painting that could potentially enhance the experience of looking at a painting, and make it more interesting. For example, the color of the walls can be changed depending on the painting, or an image can be used to decorate the walls, instead of having a regular wall that is painted in one color. A few more examples of these illusions with their details will be given in sections 3.2.1 and 3.2.2. There are also many possiblitities for the space of the room where the illusion is displayed. Those are described in section 3.1.

3.1 Space in the room

Like in [15], there are many possible locations to project the illusions in this application. The design space can be exhaustively categorized based on the space used in the following way:

1. Affecting the walls
   (a) Directly around the painting
   (b) The entire wall behind the painting
   (c) Multiple walls or parts of walls
2. Affecting objects in the room
   (a) Affecting the painting itself
   (b) Affecting other objects in the room
3. Affecting the 3D space of the room
   (a) A specific area
   (b) The entire 3D space

For this research, only illusions affecting the entire 3D space (3b) or the entire wall (1b) behind the painting will be considered. Since there are infinitely many ways of designing and partitioning a room, this decision is necessary to reduce the design space to a feasible number of possibilities.

3.2 Types of illusions

Besides the shape and location of the illusions, we can also distinguish between static and animated illusions. We will describe these categories of illusions in sections 3.2.1 and 3.2.2 respectively.

3.2.1 Static Illusions

In this subsection we will discuss the part of the design space consisting of static illusions. These illusions will alter the surroundings of the painting without the use of animations. This will serve as an introduction to the animated illusions, which will be discussed in section 3.2.2.

- **Static color on the wall**
  One of the most basic things to do to change the direct environment of a painting is to simply paint the wall in a color that makes the painting stand out better. The best color is a color that the user does not notice and where he only remembers the colors of the painting [19]. These colors could also affect the ambiance of the room and the mood of the person[18] viewing the painting. This illusion could affect only the whole wall the painting is hanging from, or the entire room.

- **Picture of a subject related to the painting**
  Another change would be to decorate the wall with a picture. Sometimes, when displaying a collection of pictures or drawings, a museum shows one of the images on the back wall behind the frames (fig 3.2.1).

Figure 1: An exhibition piece used as wall image at the Studio Ghibli Layout Designs exhibition in the Hong Kong Heritage Museum [20]

- **Picture in style of the painting**
  In [12], a picture is altered to be stylized in the same way as a painting is. An image is produced that still shows the content of the picture, but it appears to be painted in the same style as the painting. Instead of using a regular picture as in the example above, the picture could be processed to get the same style as the painting. That picture can then be displayed on the wall behind the painting. This could make for a better backdrop to the painting than a regular picture would, as it better resembles the painting. Since the algorithm can be applied to any type of image, three different ways of applying it in our museum setting come to mind.

Firstly, the style of the painting could simply be applied to a single object in the environment, such as a picture projected on a wall. This could easily be done using preprocessing.

Secondly, the style could be applied as a post-processing effect to the user's field of view. Each frame the user sees through the VR device will be processed to have the same style as the painting. However, some issues can be foreseen with this type of application, as processing might take too long to maintain a decent framerate. Additionally, a very subtle change in head orientation could cause a very large change in the rendered view, as the entire frame would have to go through the process again.

Finally, we can apply the style of the painting to the textures of all objects in the room. This way we can take advantage of preprocessing and therefore avoid the drawbacks of the previous method. A possible downside however, is that the illusion would only be applied to textures and therefore would not affect 3D shapes and shadows.

- **Extending the painting**
  If a painting is a window into the world of the painter, then what is behind that museum wall? With a method called inpainting [16], it is possible to extrapolate information from the painting and apply it to the empty wall surrounding it. In this way, the wall can be made to look like an extension of the painting - like the wall and the painting are actually one big painting.

3.2.2 Animated Illusions

Some illusions mentioned in the previous section can also have an animated variant and some illusions can only be achieved when animated.

- **Changing colors on the wall**
  In the virtual space, the wall would not need to be one color, but could change color over time to create different moods.

- **Video related to the painting**
  A video would be the more dynamic version of the still picture. For example, behind old news pictures, a news video covering the same event could be shown. The emphasis would still be on the pictures, and the video could intensify the experience by making the surroundings supplement the displayed art.

- **IllumiRoom 'weather illusions'**
  The idea of using related objects can be extended to 3D. The room or the walls can be filled with particles that relate in some way to the painting, like snowflakes for a snowy painting or leaves for a painting of a forest in fall. Instead of basing these illusions solely on weather, they can be generalized to various particle effects based on the setting of the painting. These illusions are based on the IllumiRoom *Snow* illusion [15] and are discussed in more detail in section 4.

- **Picture in style of the painting**
  Another animated illusion uses a picture shown on the back wall, while

	Space		Animation	
	Wall space	**3D space**	**Static**	**Animated**
Stylized	√		√	√
Extended	√		√	√
Weather	√	√		√

Table 1: The illusions used in this research and their tested spaces in the room

the picture slowly morphs into the same style as the painting. In [12], the grade of stylization can be controlled. In this way, multiple images can be produced that are in style somewhere in between the unaltered picture and the style of the painting. With those, an animation can be made of the picture slowly changing to match the style of the painting.

- **Extending Painting**
  For this animated illusion, the painting expands over the back wall while the user is watching it. This can be done by using painting expansion software [16]. The wall around the painting is filled with textures extrapolated from the painting.

3.3 Utilized design space

For this research, the animated illusions of the stylized picture, extension of the painting and the IllumiRoom weather illusion appear to be the most promising to see as a visual effect. These illusions can be applied to almost any kind of painting and use modifications based directly on the painting. They can be customized extensively to fit the need of the user or curator, but also leave open the option of automatization. These illusions are very hard or even impossible to create in real museums. However, by utilizing the aspects of virtual reality, these illusions can be created in a virtual museum.

Not every type of illusion is suitable to be applied on both the wall around the painting as well as in the 3D space. The same can be said about whether these illusions only have an animated version, or a static version as well. In table 1, the suitable combinations that are going to be tested can be found.

4 Methods

The application will be implemented using Google Cardboard. Google Cardboard is a VR device that uses a smartphone as a display. This device has the benefit of being cheap, portable and easy to use, making it easily accessible to museums or individuals.

To answer our research questions, we will implement various illusions for different paintings and use them to conduct a user study. Paintings with three different types of content, painted in two different artistic styles will be used. For each combination, two different paintings will be selected as a representation. This means that we will use a total of twelve different paintings. In order to achieve reliable results, the paintings used will be carefully selected, so that they provide a good representation of a large collection of paintings. The selected paintings can be found in appendix A. Even though this will likely not be

sufficient to represent all paintings, with this selection, we aim to provide a fair sample of a vast group of paintings they belong to.

For the content we will use the following categories:

- **Forests.** Paintings of forests, depicting trees and other foliage.
- **Seascapes.** Paintings of open sea or seashores containing both sea and land.
- **Snowy environments.** Paintings of landscapes covered in snow, paintings where snow is falling.

We have chosen these categories because they are general enough to represent a large subgroup of all paintings, yet they are easy to distinguish between because of their well-defined characteristics.

We will use the following artistic styles:

- **Photorealistic paintings.** Paintings depicting the content in an accurate and realistic way.
- **Stylized paintings.** Paintings depicting the content with a distinctive style, like coarse brush strokes.

We have chosen these two different styles to be able to investigate the effects of the illusions for different types of paintings. If an illusion works well for a photorealistic painting, this doesn't imply it also works well for a stylized painting.

As discussed in section 3.2.2, we will apply the following three animated illusions for each painting:

- **Stylized picture.** For this illusion we will overlay a picture on the wall behind the painting. The style of the painting will be applied to the picture using methods described in [12]. Pictures will be different for each painting and will be selected to have content similar to the painting. This illusion will be used as animation as well as static.
- **Extending the painting.** For this illusion we will display content based on the painting on the wall behind it [16]. This illusion will be used as animation as well as static.
- **Weather-like effects.** For this illusion we will create 3D particles or objects based on the weather conditions and content of the painting. These particles will include snow, rain or falling leaves. This illusion will be tested both when displayed on the wall behind the painting, as in the 3D space of the room.

4.1 Experiment Setup

The animated illusions can be implemented in various ways, including different values for parameters such as speed or behaviors of animation. To get a set value for these settings, a pre-experiment will be done to find the most promising settings in terms of enjoyment and presence. This can first be done internally and then tested on three to five people, giving their opinion about the different

settings of the illusions. These participants are not allowed to join the main experiment anymore as they have seen the illusions before. This can influence their final judgment.

For the main experiment, combinations of paintings and illusions will be subdivided into four groups. This is done to create four different combinations, where every painting-illusion combination can be rated by a user who has not seen that painting in our museum setting before. This means that each group will consist of twelve paintings. This means there are three paintings of each illusion, and three paintings without an illusion per group. For each participant, the environment for the twelve settings will be similar. Every time they will be placed in a room based on a part of a museum. The room will contain one painting and will have some additional objects such as chairs or plants. Apart from this, the room will be fairly plain in order to avoid distraction.

Before and after a participant has finished the tests, he will fill out a questionnaire. The before-questionnaire will be shorter.

4.1.1 Measurements

The user will first be interviewed about their interest in art and willingness to visit art museums by means of a questionnaire. This questionnaire will then be repeated after the experiment so see whether their opinion has changed.

Using a questionnaire, we capture the user's sense of presence in the virtual museum, connectedness (presence in the world of the painting) and enjoyment. This survey will be an adapted and combined version of the presence questionnaire by Witmer & Singer [13] and The Groningen Enjoyment Questionnaire [14]. We will have to come up with additional questions for the very specific subject of connectedness.

To measure the participants' interest in the painting and the illusion, the direction in which they are looking will be tracked during the experiment. The amount of time the participants are looking directly at the painting or at the illusion will be measured in order to determine whether or not the environment draws away the user's attention from the painting.

The measured variables will be statistically analyzed. We will compare the results of all groups to determine the difference between each illusion and the default case. Our results will show the differences in terms of interest, presence and enjoyment for each combination of groups. These results will grant insight into the impact of the different illusions.

4.2 Analysis

We will analyze the results of the presence, connectedness and enjoyment questionnaires with one-way repeated measures ANOVA. The final scores of the questionnaire will give a number that represents the enjoyment the user experienced. This is the continuous dependent variable that is needed. However, for ANOVA this has to be a variable with normal distribution. If this is not the case with the score, the Friedman analysis of variance by ranks can be used. The results of the ANOVA test will indicate whether the mean score of the control setting (no illusion) differs significantly from the mean across the three illusions. If this is the case, additional pair-wise testing will have to be done to decide whether this is true for all of the illusions, and to rank the illusions in

order of desirability. Tukey's HSD is an example of a test that can be used to do this. It is better to not use a t-test here, as a t-test would be less robust.

4.2.1 Answering the Research Questions

How do illusions affect the enjoyment of viewing a painting in a VR museum setting?

This will be tested with one-way repeated measures ANOVA on the final score resulting from the questions in the questionnaire about presence, connectedness and enjoyment. If the score does not have a normal distribution, the Friedman analysis of variance by ranks will be used instead. The results will indicate whether the score of the control illusion differs significantly from the score for the three illusions. If this is the case, additional pair-wise testing will be done to find out whether this is the case for all illusions, and to establish a ranking of the illusions.

How do the illusions influence the sense of presence in the world of the virtual museum? How do the illusions influence the sense of connectedness to the painting?

These will be tested with one-way repeated measures ANOVA on the scores resulting from the presence- and connectedness-specific questions in the questionnaire. If either score does not have a normal distribution, the Friedman analysis of variance by ranks will be used instead. The results will indicate whether the score for presence or connectedness of the control illusion differs significantly from the score for the three illusions.

How do the illusions influence the interest in the painting?

-Open, will probably be tested by asking details about the paintings-

How do the illusions influence the willingness to physically visit art museums?

This question will be answered by reading and assessing the answers of the participants to the open question asked before and after the virtual museum experience.

4.2.2 Feasibility

The three illusions and the control without illusion serve as a 4-level categorical independent variable. With forty participants, this means that each illusion has been seen and rated 120 times, three times by each participant. Every unique painting-illusion combination will be seen and rated ten times. The central limit theorem can be used to prove a normal distribution in sample size of thirty or more. Forty participants seems more than sufficient. However, in ANOVA, the score has to have a normal distribution. Whether this is the case will have to be tested when the results are in. If a normal distribution cannot be proven, the Friedman analysis of variance by rank will have to be used.

Another issue is whether showing every painting-illusion combination ten times is enough. Since this research is about applying illusions to any painting, this is not an issue: each illusion is shown 120 times, to forty different participants.

5 Hypothesis & Conclusion

We expect that every illusion will captivate users more than a regular painting in a white room would, causing them to use the application for a longer period of time. Adding these illusions will create a new virtual museum experience, that might pique the curiosity of those who are normally not interested in museums. They might take the virtual museum tour for the illusions, and will then be exposed to the paintings nevertheless, providing a chance to raise their interest in art.

This research will help expand the world of digital museums. In virtual reality, not everything has to behave like it would in the real world. This research explores and tries to expand the borders of virtual museums by adding illusions that would be impractical without the use of VR. This specific area is largely unexplored. Research in this area could open up a lot of possibilities.

Real life museums could make their exhibits more interesting to people who would normally not visit them. This research could tell them what kind of illusion would be interesting to those people. These people could then look at the paintings through an Augmented Reality headset, or through the camera of their smartphone, while the regular visitors can still enjoy the painting on the background of a bland wall. Alternatively, they could visit parts of the museum in VR, and visit the real museum afterwards.

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A Paintings

A.1 Forest

A.1.1 Realistic forest paintings

Figure 2: *Autumn Oaks* - George Inness

Figure 3: *Birch Grove* - Isaac Levitan

A.1.2 Stylized forest paintings

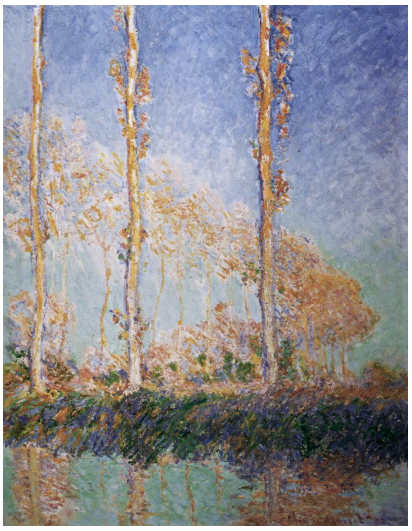

Figure 4: *Poplars* - Claude Monet

Figure 5: *Autumn Color* - Marsden Hartley

A.2 Sea

A.2.1 Realistic seascape paintings

Figure 6: *Ships Running Aground in a Storm* - Ludolf Backhuysen

Figure 7: *Storm on the Sea* - Bonaventura Peeters

A.2.2 Stylized seascape paintings

Figure 8: *Stormy Sea* - Claude Monet

Figure 9: *Beach at Scheveningen in Stormy Weather* - Vincent van Gogh

A.3 Snow

A.3.1 Realistic snow paintings

Figure 10: *Fir Trees in the Snow* - Caspar David Friedrich

Figure 11: *Dolmen in the Snow* - Caspar David Friedrich

A.3.2 Stylized snow paintings

Figure 12: *The Magpie* - Claude Monet

Figure 13: *The Yellow Log* - Edvard Munch