ADAPTING CINEMATIC AND THEATRICAL LIGHTING TO VIRTUAL REALITY STORYTELLING

A Thesis

by

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ABSTRACT

When immersed in a 3-dimensional virtual world story, viewers may become distracted because the virtual world affords them freedom to navigate and look around. This also means that the story plot is open to different interpretations. This raises the question of how to best guide viewer experience in virtual world story scenarios. To address this issue, our methodology has been to study the use of lighting in cinema and theater to direct attention and explore how these techniques can be adapted to virtual world scenarios. Some of the techniques studied and analyzed include the use of light contrast, colored lights, moving lights, staged lighting, fading lights, pulsing lights and follow spotlights. Since lighting serves a similar purpose in both theater and cinema, we discuss and propose with examples how these lighting techniques may be used to direct attention in virtual reality storytelling.

The focus in this thesis is on translating principles of cinematic and theatrical lighting into virtual world narratives. From this exploration, we developed applicable approaches and created illustrative examples. A detailed discussion is documented on the process, production and implementation of cinematic and theatrical lighting approaches into VR. From this we gained insights into the effective use of lighting to guide viewer attention. For each lighting technique, the most important function is its ability to selectively direct viewer attention while supporting the narrative. A set of guidelines on how to effectively direct viewer attention using lighting in virtual world scenarios is presented. The purpose of these guidelines is to aid storytellers in creating

lighting to direct viewer attention in virtual world story scenarios. This is achieved by providing information on what to consider when evaluating the story needs, developing the lighting design and its implementation.

DEDICATION

To my family and friends.

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1. INTRODUCTION

1.1 Introduction

Lighting is important to the success of visual storytelling. Illumination and light placement in cinema and theatrical setups are not only for visibility and clarity purposes, but they are structured toward story needs. According to Rangaswamy (2000), the one role of lighting in visual storytelling is to direct the viewer's attention. Ascher & Pincus (2007) explained that "*Lighting directs the viewer's attention, since the eye is naturally drawn to bright areas of the frame*." Lighting also tells viewers the time of day and season in which a scene takes place. Lighting of a scene should influence viewer's emotions to develop and enhance their understanding of the story. (Rangaswamy, 2000)

Successfully immersing a viewer in a story is the goal of storytelling. Virtual reality (VR) is a medium for immersive experiences, an illusion of something real. Blom & Beckhaus (2005), describes VR as having the potential to tell stories that provide new and engaging experiences. VR potentially provides a viewer the sense of presence and full immersion in story scenarios.

In the entertainment industry, VR is experiencing increased interest as a storytelling medium. The immersion of viewers in a virtual reality story enables the viewer freedom to move and look around. This freedom, however, may distract viewer attention from the story. Both cinema and theater provide methods to direct viewer attention in storytelling through the use of lighting. However in cinema experiences, the viewer has little control over where to look. The story is only experienced viewing a

two-dimensional screen. The direction of viewer attention occurs in camera and through the use of lighting. There is not the opportunity for the audience to be distracted by elements or characters that might be present in the scene, but are not visible on the viewing screen.

Theatrical experiences do not constrain a viewer to a viewing screen; they allow the viewer more control over where to look. The viewer can choose to look outside of the acting area, to other elements on stage. Though the viewer is given this freedom to look, the lighting is designed to direct viewer attention from one focus on the stage to another. In VR, the freedom to move and look around, a benefit as it may seem, allows the viewer to be distracted. The viewer can choose to not follow the narrative. There is a need for effective approaches to guiding viewer attention in VR stories.

Lighting for both traditional and computer animated films has often been examined. The function of lighting in computer animation serves the same purpose as in traditional film. Can cinematic lighting be applied to virtual reality storytelling?
Similarly, lighting in theatrical experiences serve the same purposes as in cinema films. The lighting approaches in theater are designed to accommodate viewings from different perspectives. Can theatrical lighting also be applied to VR storytelling?

The intention of this thesis has been to study cinema and theatrical lighting techniques and explore how these basic traditional principles of lighting might be adopted to direct viewer's attention in VR.

We created illustrative examples of the use of these lighting approaches and developed guidelines to consider when using these approaches. The goal of adapting

traditional cinema and theatrical lighting approaches was to explore how lighting might be used to direct viewer's attention in VR story scenarios.

2. BACKGROUND AND LITERATURE REVIEW

2.1 Cinematic Lighting

Lighting in cinema provides effective techniques for directing a viewer's attention. Light color, intensity, and contrast in cinema scenes help direct where the viewer will look.

Certain factors are considered when lighting a cinematic scene, these factors include the kind of shadows the light creates, the direction of the lights, light intensity, lighting contrast, and light color (Ascher & Pincus, 2007).

According to Malkiewicz (2005), the kind of shadow created within a scene is dependent on how hard or soft the light source is. A hard light source is small in size or distant. It casts sharp well defined shadow edges. A soft source of light is one that is larger in size. It creates soft edged shadows. See Figure 2.2 and 2.3 for examples.

Malkiewicz (2005), explains that when a light source is bounced off a diffuse surface or passed through a translucent material, this act scatters the illumination and creates softer shadows.

A second factor is lighting direction. Many light sources are directional. The direction of the light helps suggest the time of day within the scene (Malkiewicz, 2005). The direction of the light can help create a mood and reveal texture and shapes of objects within a scene. Ascher & Pincus (2007), claim the direction from which a light hits objects within a scene is important as it influences how the objects are perceived. Using a single light source, an object can be perceived in multiple ways as the direction of the

light is changed. For example: front, and back lights create different perceptions of a subject. Front light is when the light is coming from the direction of the camera. Back light is when the light is placed behind the subject or object and light direction is towards the camera. Thus creates a halo glow or ring outlining the subject or object's shape.

Light intensity refers to its brightness, how much light it emits into a scene. Light intensity will determine how bright or dark the scene looks and feels.

The mood in a cinematic scene can be influenced by lighting contrast. The difference between the light intensity of lit areas and shadow areas of a scene is referred to as the light contrast. Light contrast is the relationship between the brightest areas and the darkest areas in a scene.

The color of the light source helps establish the time of day. For example, a bright yellow light signifies a day time setting, while a dark blue colored light can suggest a moon lit night time scene. In some cases the color of the light is used as part of the story narrative. Light color can be used as an emotional cue to communicate visual components within scenes to viewers. The light color can be used to represent a certain emotion. It can also be used to call the viewer's attention to certain parts within the scene, see Figure 2.1. An example from the movie *Django Unchained* (Sher et al., 2012).

Figure 2.1: A screenshot from the movie *Django Unchained* (Sher et al., 2012), demonstrates how light color and contrast is used to direct viewer attention. In this image, light from above helps separate the characters from the background while the yellow light from the lantern creates a contrast in color to help direct attention to the main character's face.

According to Lowell (1992), every light source has five main attributes. These include; hardness or softness, intensity (amount of light), direction, color of the light emitted, and the beam pattern.

Hard and soft edge shadows are created differently. Hard edges are caused by a point light and or a distant light. Soft edges are caused by area lights or by reflections from larger surfaces. According to Birn (2006), point light in computer graphics is comparable to light bulbs on a cinema set. It emits light in all directions creating sharp edge shadows. An area light, as a large source creates soft illumination resulting in soft edge shadows.

Larger light source tend to create soft edge shadows consisting of a penumbra and an umbra. According to Shapiro & Badler (1984), these two distinct parts of a shadow are created when soft light source are intercepted by an opaque object.

Umbra is darkest region of shadow which is completely blocked from the light source. The penumbra is the partially shadowed region which receives some light from the source. Penumbra is the region of partial shadow around the umbra. It surrounds the umbra and creates a smooth transition from light to dark.

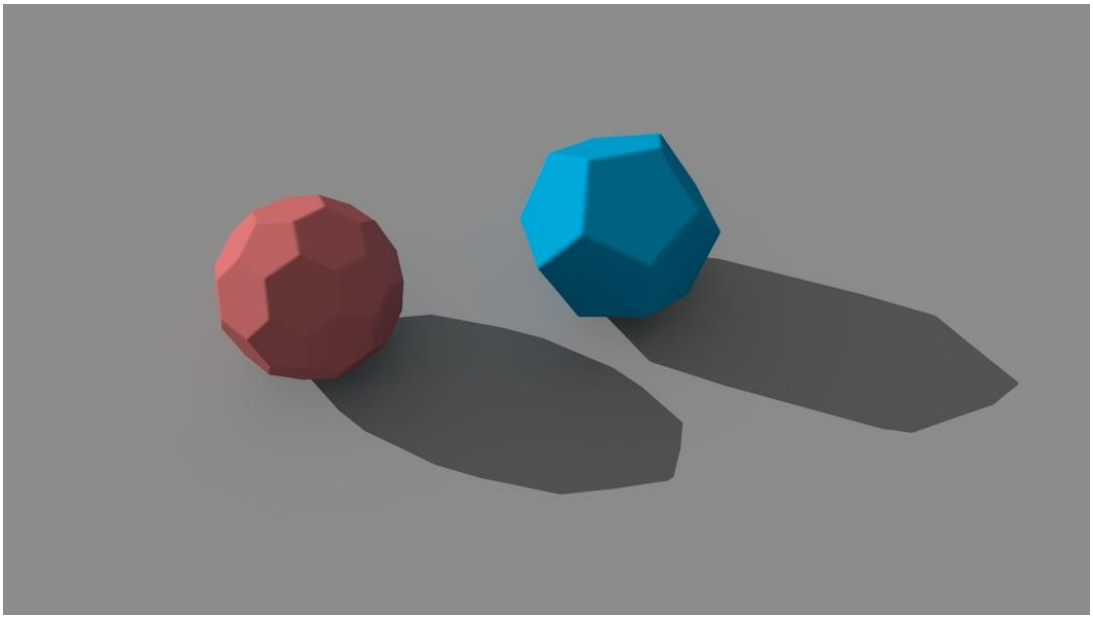

Figure 2.2: A digitally recreated example of a distant light creating hard edge shadows.

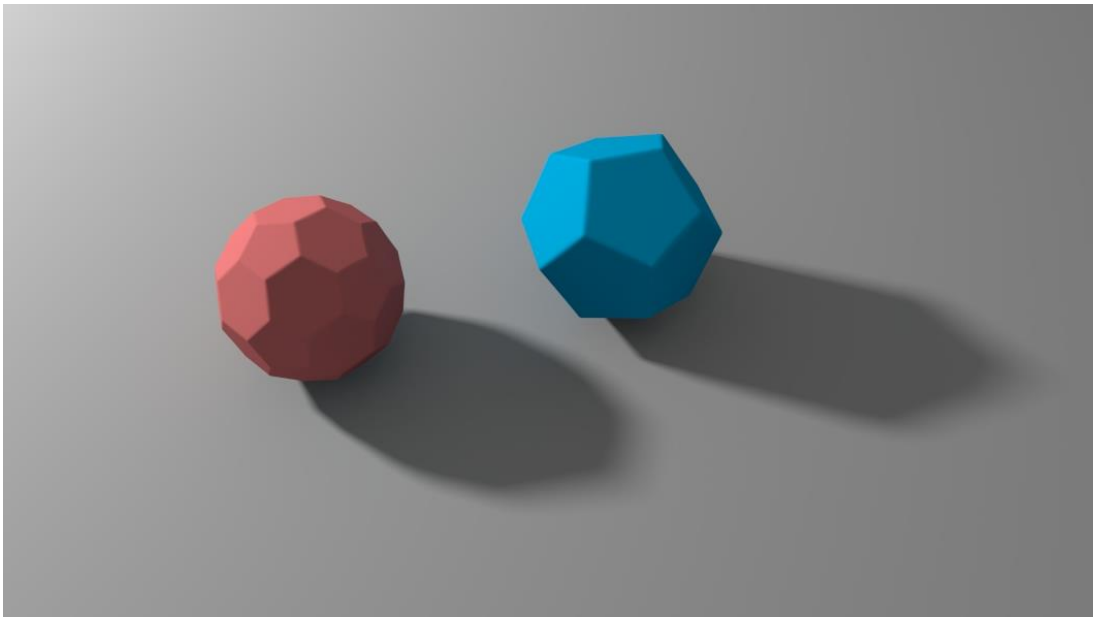

Figure 2.3: A digitally recreated example image shows soft shadows from diffused light source

2.2 Cinematic Lighting Setup

The Cinematographer is the individual on a film production who is responsible for lighting and composition (Lowell, 1992). This individual directs lighting of scenes and the movement and setting of the cameras (Schaefer & Salvato, 1986). The creative decision on light types to use, intensities, positions, directions and color is the task of the Cinematographer, also known as the Director of Photography.

Certain terminology is used to describe light setups in traditional cinema. Malkiewicz (2005), defines the *key light* as the main source of light within a certain area in a scene. Usually this light is placed about 45 degrees above and 45 degrees right or left of the camera. However, based on the desired mood, this light can be placed elsewhere. The *fill light* is used to fill in shadow areas created by the key light.

The *back light* functions as a separator between the elements in the foreground and the background. It is angled from above and placed behind the foreground element (character). It helps give a sense of a depth to the scene. Similar to the back light is the *kicker light*. It is used to add a subtle glow or glare to the side of the character. It is angled towards the camera and slightly left or right of the character. It is also known as an *edg*e or *rim light*.

The combined use of a key, a fill light and back light is referred to as *three-point lighting.* It is a general setup that has been traditionally accepted by cinematographers. It is often the initial lighting setup.

Set lights are used to illuminate specific elements in a scene. Elements within a scene can be fixed or movable, their position and motion affects how set lights are placed.

There are other *effect-based lights* that may be used. These lights are placed based on special needs. For example, *eye lights* are used to create reflections on the eyes (Malkiewicz, 2005). *Cloth lights* are used to lighten dark clothing or emphasize specific details or texture in clothing (Lowell, 1992).

2.3 Cinematic Lighting Styles

According to Malkiewicz (2005), the three most used cinematic lighting styles are *high key*, *low-key*, and *graduated tonality*. High key scenes can be compared to works by Joseph Turner, an eighteenth century English painter known for his use of light and color (National Gallery of Art, 2008).

Malkiewicz (2005) describes high key scenes as scenes that appear generally bright with few dark or underexposed areas. High key scenes use soft lights creating few or diffused shadows. Lowell (1992), describes high key as predominantly containing middle-gray to white tones.

In low key lighting, few lights are used to illuminate the scene, resulting in deep shadows. This effect is achieved by under illuminating the majority of the scene.
The low key style may be compared to works by Dutch painter Rembrandt Harmenszoon van Rijn. He is known for his use of chiaroscuro, meaning the use of light and dark areas in a composition (Lowell, 1992).

Graduated tonality, as in the paintings of Ingres, according to Malkiewicz (2005), is a style of scene lighting that produces a tonal effect of gradated grays. This is achieved by the use of soft lights evenly illuminating a scene. The shadows created are usually weak, and the tonal gradation within the scene is created by artificially painting light colors on darks or shadows onto the sets or the character's costumes.

2.4 Viewer Attention in Cinema

Cornish and Dukette (2009), describes attention span as the amount of time or period a viewer can concentrate on a given task without being distracted. This period in which no lapse of attention occurs is rather short.

According to Van Sijll (2005), an important aspect of storytelling is to direct viewer's attention towards elements important to the story. This can be achieved through the use of lighting, camera placement, composition, editing and motion.

An example from the movie *Citizen Kane* (Welles, 1941), Van Sijll (2005) describes the use of lighting to direct the viewer's attention using contrast between light and dark. In the opening scene, a number of journalists attempt to solve a riddle, while watching a projected film of Kane's life. The screen is kept in light while the journalists are kept in the dark. When the film ends, one might expect a change in light focus from the screen to the journalists. However, this change doesn't occur. The lighting stays the same, cueing the audience that the riddle is important and not the journalist seeking to solve it. The important elements are placed in light and what is unimportant is left in the dark. See Figure 2.4. The lighting in this scene not only creates a dramatic effect, but also serves as a directive to the audience, where its attention should be focused. The use of lighting as applied in this cinema example might also be applied to direct viewer attention in VR.

Figure 2.4: A screenshot image from the movie *Citizen Kane* (Welles, 1941), using light contrast to direct the viewer's attention by keeping the journalist in the dark, and the projector screen in light.

According to Van Sijll (2005), another cinematic tool to direct viewer attention is the use of moving lights. A moving light directs the audience where to look by guiding the audience to follow the light. In the opening scenes of the movie *E.T: The Extra Terrestrial (ET)* (Spielberg, 1982), ET is chased in the dark by humans with flashlights. The humans halt as they spot an alien ship in the distance. They point their flashlights towards the top right side of the screen, indicating the direction of their gaze (See Figure 2.5). This flashlight motion cues the audience to look in that direction, as important aspects of the scene will occur there. In the next shot, the ship becomes visible as it

escapes through the top right corner of the screen. The use of moving lights in this scene not only created tension, and chaos, but also directed audience attention.

Figure 2.5: A screenshot from the movie *E.T: The Extra Terrestrial (ET)* (Spielberg, 1982), showing how moving light sources were used to direct the audience's attention to focus on the right top part of the frame.

2.5 Theatrical Stage Lighting

Lighting for theater is also referred to as stage lighting. Gillette (2008), defines stage lighting as the creative use of illumination to enhance the audience's understanding of the production by visually supporting the concept of the production. Palmer (1985), claims that stage lighting design is the art of arranging light for a theatrical production. Unlike cinema, where the cinematographer is responsible for both camera, and light, the lighting designer in a theater production is only responsible for light and how it relates to

the play. The use of camera is not needed in theater, since the audience experiences the play by looking around as they wish. A lighting designer is responsible for controlling the properties of light to achieve certain functions. In theater productions, the lighting designer is responsible for how the audience perceives and responds to light.

McCandless (1964) explains lighting in theater is designed to convince the audience without drawing attention to itself. According to McCandless (1964), stage lighting *"is the use of light to create a sense of visibility, naturalism, composition and mood"*. Successful stage lighting depends on the understanding the viewer gains through his sense of sight.

According to Palmer (1985), there are certain properties of light which the lighting designer can control, these include; *intensity, color, direction, form, diffusion,* and *motion*. These properties are similar to those of cinematic lighting.

- *Intensity* refers to the amount of light perceived from the stage. The lighting designer controls intensity by controlling the size, type, wattage and number of lights used along with the brightness of each light.
- *Color* is primarily controlled by the use of colored filters. Color refers to the hue, saturation and brightness of the illumination of objects on the stage.
- *Direction* of a light source is determined by the position and orientation of the lighting instrument. Direction refers to the orientation of the light source in relation to the viewer and the on stage objects.
- *Form* is the shape or pattern created by the light. It is controlled by the positioning of shutters and *gobos*. Ascher & Pincus (2007) define gobos as

cardboards, metal cards or stencils that block or allow light through. It produces a design allowing light to pass through and also cuts off unwanted light spills. Light form helps create the visual composition.

- *Diffusion* refers to the scattering of light; it determines the soft or hard quality of light. The size of the light source controls the diffusion.
- *Motion* simply relates to the changes in position or orientation of the light within the space. Motion is controlled by the manipulation of light over time. (Palmer, 1985).
- An additional property controlled by the lighting designer is the area or location of the stage in which gets illuminated. This enables the lighting designer to use the lighting to select components of interest to the narrative.

For stage lighting to enhance the audience's understanding, stage lighting must perform basic functions as described by Gillette (2008). These functions include: *visibility, selective focus, modeling, and mood.*

An important function of stage lighting is *visibility*. The objects, scene and actors should be clearly visible to the audience. It is important for the audience to see exactly what the director and light designer intend them to see. A major challenge of lighting design is to create selective visibility which directs the audience's attention to specific objects, or actors in the scene.

Directing the audience's full attention to an area of the stage is referred to as *selective focus*. The lighting designer usually achieves this by increasing intensity of lights illuminating the area of interest. An example of the use of *selective focus* is when

the lighting designer decides to reduce the intensity of lights in one area of the stage, while increasing the light intensity in another. This change in focus invites the audience to look at the brighter area. Another example is in musicals, where audience attention is directed to the lead singer using *follow spots* that focus on the singer while the rest of the stage is dimly lit. A follow spot is a lighting instrument with high intensity narrow beam of light, mounted so the light beam can follow the actor.

Stage lighting not only illuminates actor, or scenes, it also functions as a sculptural medium to reveal form through the creation of a pattern of shadows and highlights. This function of stage lighting is known as *modeling*. The primary element of lighting used in *modeling* is direction. The direction of the light in relation to the object helps shape how the audience perceives an object as three-dimensional.

The last function of stage lighting is to enhance the *mood* of the play without calling attention to itself. The *mood* of a play is usually controlled by subtly varying intensity levels (Gillette, 2008). In addition, the use of color in stage lighting also influences the mood on stage. For example introducing a yellow light on stage could be interpret a cheerful scene, and red light could signify violence. These meanings may change as they are influenced by varying factors, including how the light is used, or its purpose on stage (Gillette, 2000).

2.6 Virtual Reality

Technological advancements in storytelling have evolved from paintings, to theater plays, opera, books, movies, games and now to virtual reality.

Virtual Environments (VE) are computer-generated simulated three-dimensional spaces with which a viewer interacts (Witmer, Bailey, & Knerr, 1996). According to Belleman (2003), Virtual environments are environments created by VR devices.

According to Kim, Song, Choy & Lim (2005), the sense of immersion in Virtual Reality can be utilized in many fields including; education, military training, medical technologies and entertainment.

Jerald (2015), defined virtual reality as *"a computer-generated digital environment that can be experienced and interacted with as if that environment were real".* VR is usually experienced through both sound and sight.

2.7 Storytelling in Virtual Reality

Storytelling has evolved beyond the flat screen. Storytellers are beginning to utilize virtual reality that immerses viewers in interactive 3D real-time virtual worlds.

However, experiencing a story in a virtual worlds allows the viewer additional freedom. Virtual worlds remove cinematic control of the viewer's orientation and position allowing the viewer to navigate as they wish. There is currently little guidance as to how to direct viewer's attention in virtual world story scenarios.

Galyean (1995), presented a method called "The River Analog" designed to guide the viewer's interactions within a virtual environment. Rather than giving the user control to freely navigate through a virtual space, the River Analogy suggests a river flowing navigation path through a landscape. This river is the representation of how the creator intends for the viewer to experience this journey. The viewer is placed in a virtual boat moving down a river while being pulled and pushed by the current of the

water. The River Analogy ensures the user's movement within the space is restricted to intended paths. The analogy was applied to a VR experience at the Chicago Museum of Science.

The movement of the boat is specified by the creators of the experience. Viewers are allowed to look around as they wish. The longer the viewer gazes in a direction or at an object, the closer the boat is drawn to the object. This allows the viewer some control over their local position. However the boat is still being pulled by pre-defined currents along a path or journey. The River Analogy provides an insight as to how the creator's intentions can guide the interaction of the user within the virtual environment by controlling the path of the journey.

This thesis work focused on developing examples and a guide to directing viewer attention in virtual worlds through control of lighting.

3. METHODOLOGY

3.1 Methodology

The methodology of this research was to study, in some depth, cinematic and theatrical lighting and to explore ways to translate the lessons of these lighting approaches into VR narrative storytelling to direct attention.

First, we studied the basic principles of cinematic and theatrical lighting. This study focused on the process and steps involved in directing audience attention through the use of lighting.

Based on this study, we explored lighting techniques applicable to directing viewer attention in VR. This exploration shed light on some lighting techniques to directing viewer attention in VR. As part of these explorations, we created examples illustrating how lighting techniques might be applicable to direct viewer attention in VR.

We developed guidelines based on what we learned about the use of lighting and in developing illustrative examples. The guidelines provide information on what to consider and be aware of when using lighting to direct viewer attention in VR story scenarios

4. ATTENTION DIRECTING LIGHTING APPROACHES

4.1 Introduction

In this chapter, we discuss lighting approaches to direct viewer attention based on techniques used in traditional cinema and theatrical lighting.

4.2 Cinematic Lighting Approaches

The following are some lighting approaches adopted in cinema to direct viewer attention that may be applicable in VR. They include light contrast, colored lights, moving lights and staged lighting.

4.2.1 Light Contrast

Contrast within a scene may exist in various forms. Contrast may be achieved in color, light or brightness, texture, and size of objects. Contrast in the amount of light or brightness perceived within a scene allows subjects of interest to be separated and stand out. This visual concept is widely used in films to direct attention.

In cinema, scene lighting should draw viewer's focus to areas important to the story. Contrast in lighting is an important element because viewers are attracted to contrast. The technique of silhouettes makes use of contrast in light where the subject of interest is positioned in the dark against a bright background. Cinematographers use this technique to create a strong contrast to separate the focus area from the background.

A scene may have multiple focus points. However, we observed that one focus point is usually more dominant. Focus is usually achieved when an object is different

from other objects within a scene. We studied some film scenarios and observed that areas of interest which are in light draw viewer attention as compared to the others areas in dark or low light.

Figure 4.1: A screen shot from the movie *Manhattan* (Joffe & Allen, 1979), showing the use of light contrast to direct attention. The two characters in the scene are having a dialogue. Their locations within the scene are in light, while the unimportant areas are kept in dark. This directs the viewer to pay attention to the lit areas.

Take for example the screenshot from the movie *Manhattan* (Joffe & Allen, 1979), in Figure 4.1. The lighting designer minimizes areas which might distract the viewer by keeping them in the dark, while emphasizing two lit focus points within the scene. The focus points are two subjects having a dialogue, each one was positioned in light. One subject is seated on the couch and is illuminated with a lamp. Her position is brightest and dominates the scene. The second subject moves from one point to the other while a light gets turned on to track his position. Finally, the second subject makes his

way to the position of the first and both are illuminated by the same light source. This changes the focus in the scene from multiple focus points to a single focus area. In this example, contrast in light was effectively used to direct viewer attention to multiple focus points and areas of interest.

Light may be used to direct viewer attention in VR narratives by creating intensity contrast among objects within the scene. Contrast can be achieved by selectively illuminating areas the storyteller wants the viewer to explore or focus on. Other areas are kept in low light to aid visibility for navigation. The ratio of light intensity of areas of interest to other areas is high to ensure a strong visual contrast. It is expected that viewers in VR would identify contrast and be drawn to areas with brightest intensity. The concept of silhouette is difficult to achieve when adapted in VR story scenarios because the silhouette effect depends on the viewer position which is changeable and isn't controlled by the storyteller.

4.2.2 Colored Lights

In films, viewers are usually drawn to the most saturated colors within a scene. Calahan (1996) explains that perceived color of an object is determined by how it reflects light. Perceived surface color is dependent on the lighting situation. Light can be used to create contrast in color saturation of objects. This contrast allows the most saturated objects to stand out. The more saturated the color of an object, the more attention it gets. Colors can be of strong or weak saturation (Gillette, 2008).

We observed that the use of strong and weak saturated colors in film lends itself to direct viewer's focus. The contrast in hues of colors on objects can also help separate

them from each other. Color contrast can be achieved by illuminating a scene with colored lights that control the hue and saturation on areas of interest relative to other areas.

We studied several scenarios and observed the use of light color to direct attention. For example the screenshot in Figure 4.2 from the movie *The Cook, the Thief, His Wife & Her Lover* (Dauman, et al., 1989). The lighting employs the use of color to direct viewer focus to the subjects of interest. The scene is lit evenly with white lights creating equal saturation across the image. The first subject positioned towards the left of the screen is also illuminated with white lights. A pink light shines through the entrance illuminating the second subject, separating him from the rest of the scene. This pink light creates a contrast in hues. Attention is thus directed towards the second subject. Another pink light illuminates a round table with feminine perfume bottles. It cued the audience to be aware of the location, indicating that this was a ladies bathroom. The pink lit areas contrast in hue with the even white lighting in the scene allowing the subjects positioned in these pink lights to stand out.

Figure 4.2: A screenshot from the movie *The Cook, the Thief, His Wife & Her Lover* (Dauman, et al., 1989), showing the use of colored lights to direct attention.

Figure 4.3: Screenshot from the movie *The Cook, the Thief, His Wife & Her Lover* (Dauman, et al., 1989), showing the use of colored lights.

Another example, in the same movie, employs the use of light color (See Figure 4.3).

The lighting in this scene not only creates an emotional feel, it also directed attention.

The scene lighting setup has green lights cast on the background walls. An orange light

in the center of the frame is focused on the two subjects. The orange lit areas contrast with the overall green lighting in the scene. This color difference created a contrast in hues within the scene. The orange lit areas of the scene invoked a sense of discordance, drawing attention.

Using colored lights is a well-known cinema technique to draw attention. Likewise employing colored lights in a VR scenario may draw a viewer's attention, as colors contrasts demand attention. Since VR scenes are created digitally, the light color can be controlled to achieve visual contrast. Elements of interest can be lit with colored light to stand out from other scene elements.

4.2.3 Moving Lights

In cinema, the use of moving light sources to direct an audience's attention is a common technique. Viewers are drawn to the motion. Moving lights help to cue the audience to the direction or area of the screen where they should focus.

The audience will follow the moving light. For example, a torch light carried by a character in a scene could be used to direct the audience's focus. A specific example of how moving lights were used to direct attention in cinema is described in Section 2.4.

Moving lights can be adapted to direct attention in VR narratives by having a light source follow a character of interest in motion. The light source could also be a physical object that is animated within the scene to guide viewer attention. By design, a moving light could be used to invite the viewer to follow the light source through a suggested story path, while also providing rest points allowing the viewer to explore.

4.2.4 Staged Lighting

Film set productions commonly use staged lighting setups. Staged lighting refers to the strategic positioning of lights to illuminate an area of interest to call attention to particular scene elements.

In cinema, the viewer only sees the action in the scene as seen by the camera. This means the viewers aren't aware of what is outside of the camera frame. This enables lighting to be staged specifically for that scene. Lighting of the environment outside the camera frame isn't generally considered. This environment is usually left in the dark, or illuminated with limited work lights that allow the lighting crew to move around and carry out tasks.

Consider the example of a film set with a character of interest positioned alone in a room. The elements in the room may have little importance to the story, but may add visually. The lighting setup may be staged to draw attention only to the character. The area of the set not visible in camera may have different lighting. It could be completely dark to ensure lights don't spill to areas visible on camera or it may just have work lights.

Likewise, it is expected that in VR scenarios the viewer would naturally be drawn to areas where the lighting is staged to call attention. However, in cinema, staged slighting is dependent on the camera's point of view. Viewers in VR can choose to not focus on the area of interest from the suggested viewing angle. Lighting in VR scenarios needs to be staged to call attention from all viewing angles within the scene.

4.3 Theatrical Lighting Approaches

In this section we discuss lighting approaches adopted in theater that might be applicable in VR to direct viewer attention. They include fading lights, follow spotlights and pulsing lights.

4.3.1 Fading Lights

Theater allows the audience freedom to choose where to look on the stage. Directing the attention of viewers to focus on one area is an important aspect of theater lighting. One way in which this has been achieved is through the technique of selective focus using variation in light intensity.

In theater, the use of fading lights helps establish the visual rhythm of the play. Lights are faded from one area of the stage to the next and within an area to direct the audience where to look. The concept of controlling lights intensities in theater is described as fading in or out, where lights vary in intensity. This creates an opportunity for changes to be made to the set and cues the audience to focus on areas of the stage where light has increased in intensity. It also allows actors the opportunity to enter and exit the stage without drawing attention.

Consider, a stage play where the character is on a journey from one staged environment to another. One way to direct audience attention to areas of interest during changes on stage is through fading lights. The lights on stage in the current area of interest could start to fade out as the character moves to the next area of interest where the lights fade in.

This approach of varying light intensities could be employed in VR. Lights are placed strategically on areas of interest to direct attention from one story beat to the next. By fading lights in a sequence, the storyteller can suggest a sequential path the viewer should follow to experience the story. Fading lights can serve as an integral element that drives the story.

4.3.2 Follow Spotlights

Lighting in theater rarely remain static for the entirety of a scene. Lights change when subjects move from one part of the stage to another. A technique is needed to direct focus to subjects that move. One lighting technique we studied is the follow spotlight.

A follow spot creates a beam of light on the main character or action on the stage. This technique is also suitable for drawing attention to an actor that moves on stage. The follow spotlight is mounted to be able to follow the action of interest. It is commonly used when the stage has a lot of movements and attention is needed on a specific actor.

For example, theater musicals that involves a singing lead actor dancing around a stage filled with backup dancers. The follow spotlight is commonly used in such musicals to focus the audience's attention on the lead singer. It is an effective way to guide audience focus to the singer while other actions or changes might occur within the scene that the viewer is not intended to follow.

In theater, the use of a follow spot serves to selectively direct attention to highlighted areas or actions. Similarly, in a VR story scenario spotlights can be created and controlled to selectively highlight and follow moving objects of interest.

4.3.3 Pulsing Lights

The technique of continuous repetition of a pulsating light tends to draw attention. A pulsing light can be used either in a brute force or subtle manner to direct viewer's focus. The frequency of variation between a quick and slow pulsating light have different attention attracting results. A quickly pulsating light demands attention. It indicates tension or unease. A slow pulsating light could seem inviting, suggesting attention in a subtle manner rather than demanding it.

Pulsating lights could be used to momentarily direct attention to an important action about to happen. For example, consider a scenario where an action is about to happen on one part of the stage that the viewer isn't focused on, however attention is needed on this part for a brief moment. The pulsating of lights in this area could cue the audience to expect an action from that area. Another way pulsing light is used is when there are multiple focus points. Pulsing light could provide a guided path which allows the viewer to discover areas that matter to the narrative in an intended sequence.

The pulsing light works by varying its intensity at some determined frequency. As the viewer reaches the pulsing light, it may become stable. Then another light along the narrative path starts to pulse, suggesting to the viewer to approach it. These lights can be positioned on a suggested narrative path.

5. IMPLEMENTATION

In this chapter, we discuss implementing cinematic and theatrical lighting approaches as discussed in the Chapter 4. Using available graphic and game engine software we created examples to illustrate how cinematic and theatrical lighting techniques could direct viewer attention in VR.

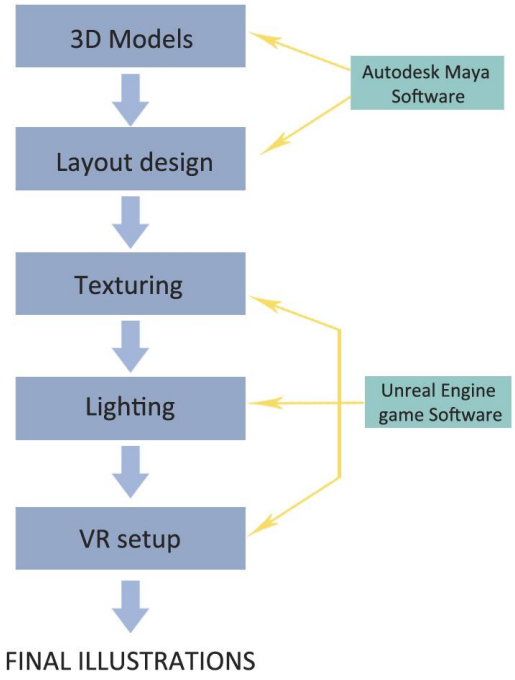

Figure 5.1: Production process stages in creating VR illustrations.

The modeling, texturing, and light setup for each approach are discussed. Figure 5.1 is an illustration of the production process and stages used to complete the VR examples.

A 3D scene of a virtual library consisting of objects/models (chairs, tables, shelfs, book case, floor, ceiling, windows, wall, and books) was first modeled and set dressed using modeling software. The hand painted texture maps required were created in the Adobe Photoshop software and applied in the game engine software. These objects or assets were then exported to game engine software. The game engine uses real-time rendering, allowing the scene to be interactively displayed.

Lights were created using the various lighting approaches to direct viewer's attention within the scene. The same scene was used for each lighting approach explored. The lighting approaches were explored by creating illustrative examples. The scene was interactively explored in real time. Video of these examples was recorded.

In the production of these examples, the following software packages were used. Autodesk Maya was used for 3D modeling and layout design, Adobe Photoshop for hand painted and procedural texturing, Unreal Engine 4 for texturing, lighting, real time rendering and VR animation.

5.1 3D Modeling and Layout Design

The scene was designed as a simplified indoor environment, which allowed the use of multiple lighting approaches. This scene was designed as a small scale library consisting of basics objects that one would expect to find in a library including: windows to create ambient light, books, shelves, an information/receptionist desk, lounge area, cushion seats, chairs and study areas. The layout was designed to allow the viewer to navigate through and explore the scene. Figure 5.2 shows a screen capture of the 3D scene.

Figure 5.2: A screenshot of the 3D scene layout design of the library

The 3D objects in the scene were modeled in Autodesk Maya. The polygon faces of the model geometries were unwrapped to a flat plane in the modeling software. The hand painted textures were created in Adobe Photoshop while procedural texture surfaces were created and applied in the Unreal engine software package (See Figure 5.3).

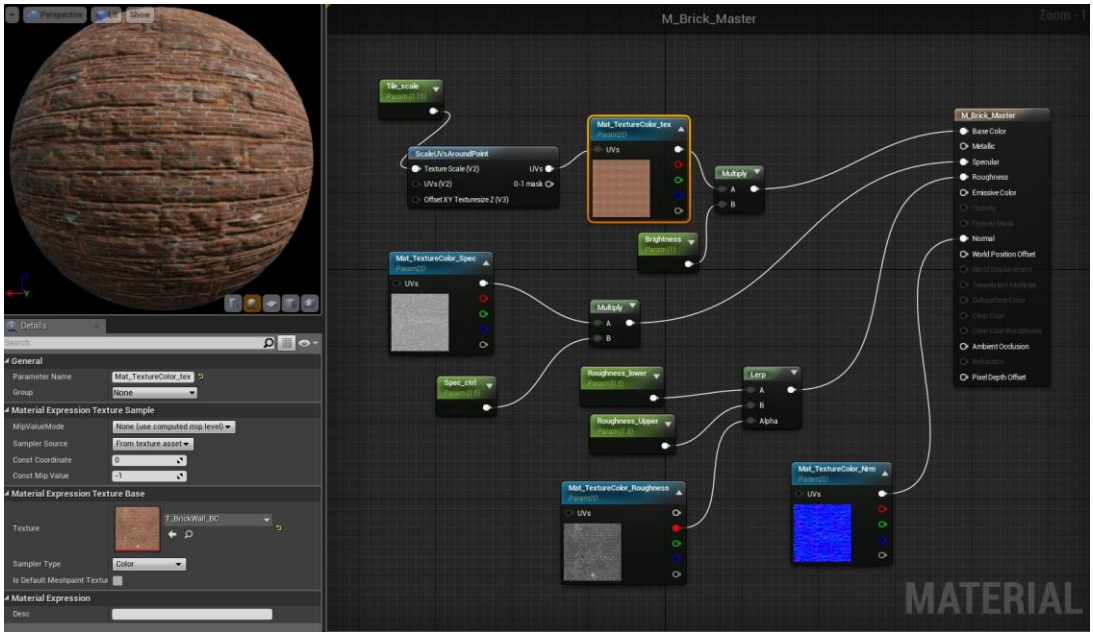

Figure 5.3: Example of a brick material texture node created in Unreal Engine software.

Figure 5.4: A screenshot showing the textured 3D scene of the library.

All texturing for the scene was applied in the Unreal Engine software, Figure 5.4 shows a screenshot of the fully textured scene

5.2 Adapting Lighting Approaches Using the Unreal Engine

Separate lighting setups of the same scene were created to adapt the various lighting approaches including the use of light contrast, colored lights, fading lights, pulsing lights and follow spotlight.

5.3 Adaptation of Cinematic Lighting Approaches

5.3.1 Light Contrast in VR

For the first cinematic lighting approach of *Light contrast,* we created a lighting setup using the opening sequence of the movie *Citizen Kane* (Welles, 1941) as reference (See Figure 5.5). The lighting setup was designed to direct the viewer attention only to elements that mattered to the story using the contrast between the light and dark. Elements important to the story were in rays of light while what was unimportant was left in the dark.

Figure 5.5: Lighting reference from the movie *Citizen Kane* (Welles, 1941), showing light contrast

This cues the audience to look at the elements in the light. We set up spotlights with atmospheric haze pointed in the direction of a book shelf with one particular red book. These main lights illuminated only areas where the viewer is to pay attention. Other areas were left in the dark (See Figure 5.6). Secondary low intensity lights were placed by the windows to simulate ambient light. The secondary lights ensured one could make out shapes of objects in the scene and to also aid the viewer to navigate the scene.

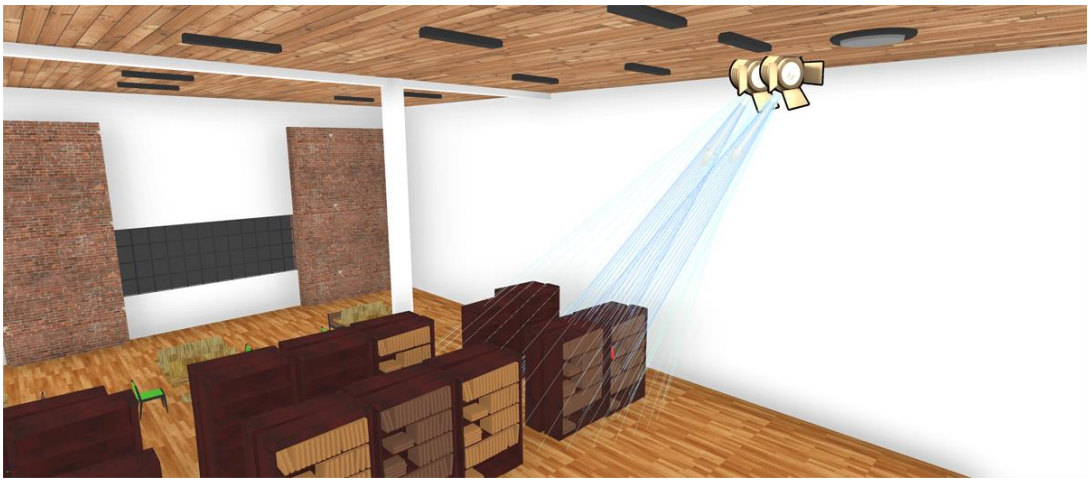

Figure 5.6: A screenshot of the lighting setup, showing the main lights position within the scene.

The main lights were positioned to ensure that light doesn't spill on dark areas that weren't intended for audience attention. The intensity of the light coming from the windows was low so as to not compete for viewer attention. Negative intensity lights were also placed in the corners of the scene to remove light from areas that aren't intended to be illuminated. The result illustration is one similar to the reference (See Figure 5.7 and 5.8).

Figure 5.7: Rendered result of a lit scene using the light contrast setup approach

Figure 5.8: Different perspective of the lit scene using the light contrast setup approach

Contrast was adjusted between the light and dark areas. The dark areas were increased in value to ensure that objects in the scene did not become completely dark. The highlights areas of light are dimmed to ensure overexposure doesn't occur. These corrections were all applied in real time within the Unreal engine software.

5.3.2 Colored Lights in VR

In the *Colored Light* approach, the same library scene was used to create a lighting setup with the use of contrasting color temperatures across the scene. Images from the movie *The Cook, the Thief, His Wife & Her Lover* were used as reference to create illustrative examples (see Figure 4.2). The use of color contrast is an effective way to direct a viewer's focus to certain objects within a scene.

We adapted a light setup using the colors blue and yellow in the library scene. The two colors were selected because they are opposite each other on the color wheel, and have noticeable contrast. The library scene was evenly lit with blue lights. We then added a yellow light aimed at one book shelf with a purple book to create a color contrast (See Figure 5.9). The illumination radius of this yellow light was small. This ensures that the yellow light didn't spill over to the blue lit areas. Similar to the light contrast approach, secondary low intensity lights were placed by the windows to simulate natural ambient light. The blue lights were bright enough to aid navigation.

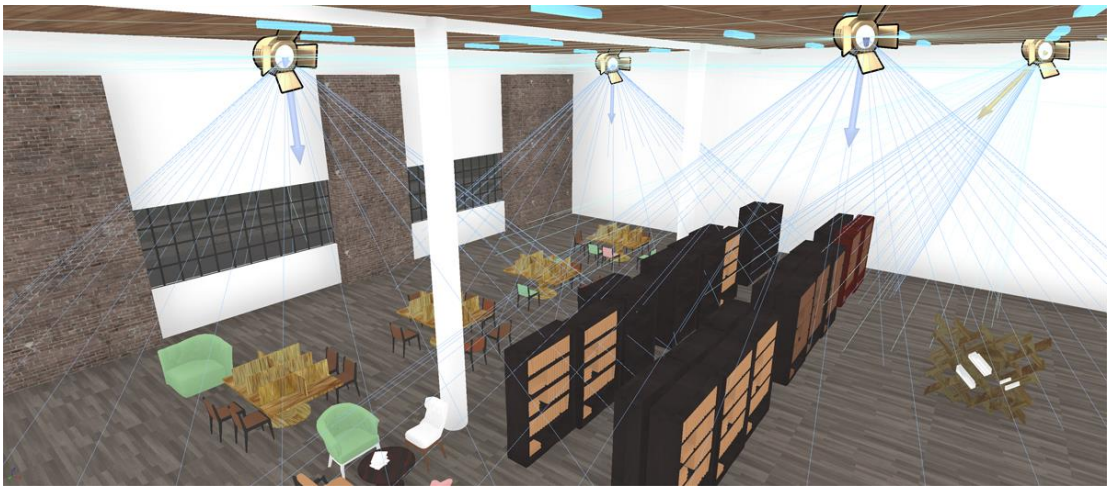

Figure 5.9: A screenshot of lighting setup to adapt colored light approach in VR

By placing the yellow light on one certain object within the scene, we created a sense of discordance in the color scheme. This yellow light doesn't fit in with the evenly blue lit areas of the scene. Its purpose was designed to intentionally draw viewer attention, as viewers tends to spot colors that are out of place. The resulting example is one that adapts the use of colored lights to direct viewers' attention (see Figure 5.10 and 5.11).

Figure 5.10: Rendered result of a lit scene using colored light setup approach

Figure 5.11: Different perspective of rendered result of a lit scene using colored light setup approach

5.4 Adaptation of Theatrical Lighting Techniques

Theatrical lighting approaches include pulsing light, fading light, and follow spotlight approach.

5.4.1 Pulsing Lights in VR

Pulsing lights can induce a sense of panic or fear in the audience. It could signify an emergency. The use of fast paced pulsing lights can be a brute force manner of directing attention. However, when lights pulse at a much slower pace, it can suggest attention with subtlety. We adopted the concept of a slow puling light as an approach to draw viewer's attention to areas of interest. The use of slow paced pulsing lights was incorporated into the library VR scene.

The aim of this lighting approach was to prompt the viewer to move along an intended path within the scene by drawing the viewer's attention to the narrative. The lighting setup was designed such that it called for the viewer's attention from one point to another within the scene. The setup consisted of three pulsing lights, each separately aimed at different objects within the VR scene. The first pulsing light was aimed at the receptionist table. When the viewer approaches this part of the scene, the pulsating light becomes stable; a message is displayed, informing the viewer of what is to be discovered from the exploration. It informs the viewer of a red book located within the scene. Then a second pulsing light is triggered on the cross-shaped book shelf in the center of the hall way. When the viewer approaches this shelf, the light becomes stables and information is communicated to the viewer by text display. This serves as an incentive motivating the viewer to keep exploring the scene. Finally the lights illuminating the book shelf with a red book start to pulse. Once the viewer approaches this book shelf, the light becomes stable as the red book is revealed. (See Figure 5.12, showing the placement of the lights).

To ensure that the viewer doesn't get discouraged in exploring the VR scene by a *negative reward*, the pulsing lights were designed to be stable once the viewer approaches the area. A negative reward is where a viewer approaches a pulsating light and the light get turned off while the viewer was exploring. We resolved this by keeping the light on while the viewer explored that area of the scene.

The successive placement of lights in the scene created an intended path for the viewer to follow to reach the red book. Three low intensity lights were also placed and aimed at the receptionist table and the respective shelves. The purpose of these low intensity lights was to create visibility for ease of navigation.

Figure 5.12: A screenshot of a lighting setup for lighting approach of pulsing lights.

The Pulsing lights were positioned in three locations in the scene with each light triggering in a timed manner, one after the other, to attract the viewer in a sequential

story path. This following screenshots were captured in an example exploration (See Figure 5.13 and 5.14).

Contrast correction was applied to the scene to balance the contrast values between the dark and light areas. These were all corrected in real time within the Unreal engine software.

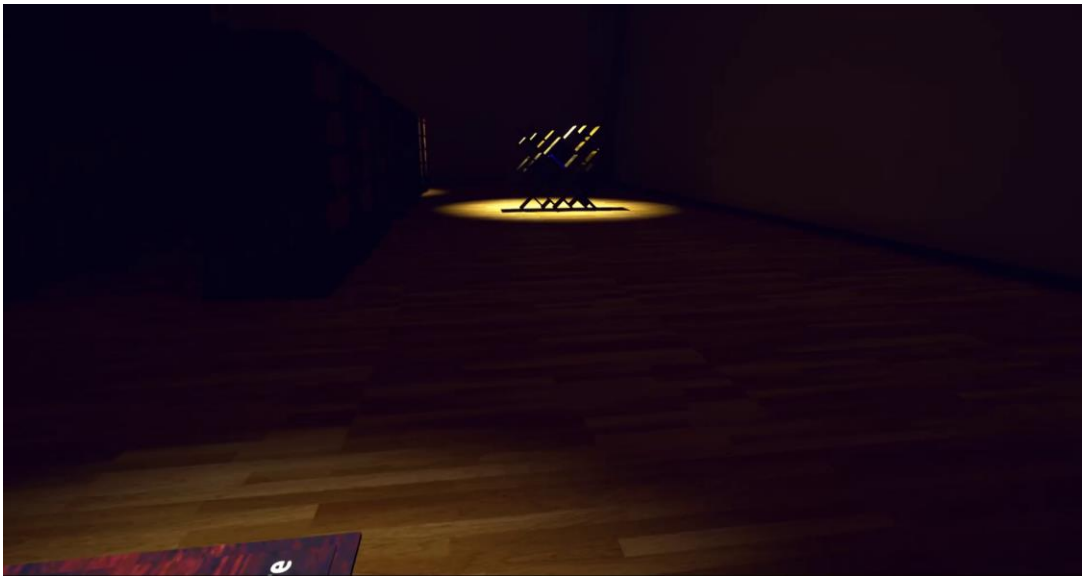

Figure 5.13: A rendered result of a lit scene using the pulsing light approach.

Figure 5.14: Different perspective of rendered result of a lit scene using the pulsing light approach.

5.4.2 Fading Lights in VR

In theater plays, introducing a change in lighting to an established stage, demands a refocus of attention. Fading the lighting from one part of the stage to another is an example. Theater uses such changes to selectively draw the audience's focal point from one area to another on a stage.

In some VR scenarios, story beats can occur in one area of a scene or in multiple areas. One way to direct attention to these areas is the fading of lights. The dimming down of light in one area and fading up in another can provide an opportunity for storytellers to make changes to the scene and direct attention. This concept of fading lights may be used in VR to direct viewer attention and transport viewers from one virtual space to the next. This concept was adapted and incorporated into the library

scene. The aim was to prompt the viewer to explore different areas of the scene in an intended narrative sequence. We created an illustration that demonstrated this.

The setup consisted of two lights, each separately aimed at different story areas within the VR scene. When the viewer is present in the scene, the scene is illuminated with warm blue lights for visibility. After a moment, a warm yellow light illuminates the receptionist table. This change in lighting is intended to prompt the viewer to approach the table. When the viewer approaches this part of the scene, they experience the story beat within that part of the scene. Once the story beat within that part is completed, the light on that area starts to dim down. At the same time, the second light starts to fade up in another part of the scene. Prompting the viewer that another story beat is about to occur in this other part of the scene. When the viewers approach, they discover the final story beat. In this case the red book in the corner shelf is revealed.

The fading lights were position in a manner that suggested to the viewer a path, to follow to discover the story areas. (See Figure 5.15, showing the placement of the lights).

Figure 5.15: A screenshot of lighting placement for fading lighting approach.

The lighting was designed such that each fading light was initiated one after the other by *trigger boxes*. A trigger box is a predefined boundary region of the scene. When the viewer enters this area it triggers an action in the lighting design. Screenshots were captured from this example illustration (See Figure 5.16 and 5.17). A process was also applied to the scene to enhance the color, vibrancy and contrast values in the scene. These were corrected in real time within the unreal engine software.

Figure 5.16: A rendered result of a lit scene using the fading light approach.

Figure 5.17: A rendered result of a lit scene using the fading light approach changing focus from the previous area of the scene to another.

5.4.3 Follow Spotlights in VR

The follow spotlight is a common lighting technique used in theater. It is usually used to light an actor that moves around the stage. It is an effective method for directing viewer attention to the main subject of interest.

This approach is easily adapted in VR. We created an illustration that demonstrates how this approach can be adapted. We created a lighting setup that directs the viewer's attention to a wiggly shaped character as it moves from one area of the scene to the next.

The setup consisted of a yellow light pointed in the direction and at position of the wiggly character. This light was designed to track, follow and illuminate, the subject when at rest and in motion. The scene was illuminated with deep blue lights that created a saturated look. The purpose of these lights was to aid visibility during navigation and minimizes distraction from other objects. Lights also illuminate a book shelf that is also of interest to the scene (See Figure 5.18).

Figure 5.18: A screenshot of the character position and light placements for the follow spot approach.

When the viewer enters, the scene is illuminated with blue light and the character of interest is positioned in the viewer's point of view. The character is illuminated with a yellow follow spotlight. The viewer is given a moment to look around. When the viewer approaches the character, the lighting design is initiated and the first story beat is played. The wiggly character waves at the viewer. It then moves toward the receptionist table. As it moves the follow spotlight tracks it and keeps it illuminated, separating it from the rest of the objects in the scene. This act prompts the viewer to follow the character. When the viewer decides to follow the character to its new position at the receptionist table, the character flags the viewer by pointing towards the next story area. The follow spot continues to follow the character as it hops across the hallway to the corner shelf with a red book. The follow spotlight on the character prompts the viewer to follow. Once the viewer reaches the corner shelf where the character has now come to a stop, the

viewer discovers the red book. The follow spotlight illuminating the character served as a guide that directed viewer's attention to story beats, from one area of the scene to the next in sequence.

The intent was to draw attention to the shelf located at the end of the library. The character was to lead the viewer to this shelf. We employed the follow spotlight to prompt the viewer to follow the character to the book shelf.

The following screenshots were captured from the illustration using the follow spotlight approach created in Unreal Engine (See Figures 5.19 and 5.20).

Figure 5.19: A rendered result of a lit scenario using the follow spotlight.

Figure 5.20: A different perspective of a lit scenario using the follow spotlight shows the character and an area of interest.

6. VR LIGHTING GUIDELINES

6.1 Introduction

Storytelling in VR allows viewers to control their position and orientation in the scene. This gives them the freedom to navigate. This freedom to navigate in a story scenario may lead to distractions from the story plot. Little guidance exists on how to effectively direct viewer attention in a VR story scenario.

Guidelines for lighting to direct viewer attention can aid storytellers in the process of creating VR story narratives. The purpose of the following guidelines is to provide information to aid storytellers in the creation of lighting to direct viewer attention in VR story experiences. These guidelines focus on evaluating the VR story's needs, developing lighting designs and the implementation of the lighting design.

These guidelines are based on our exploration of lighting techniques in cinema and theater used to direct attention and adapting these techniques into VR story scenarios. These techniques are designed to selectively focus attention from one focal point to another or from one virtual space to another in a sequential narrative. The techniques explored include; light contrast, colored lights, pulsing lights, fading lights, follow spotlights and staged lighting.

6.2 Overall Guidelines

Since the viewer has control over navigation, VR storytellers must consider an approach that guides the viewer on a suggested story path. Story progression in VR scenarios can be influenced and guided through the control of lighting. The lighting can

be structured to support story progression and place lighting cues at story areas where attention is needed. These cues involve changes in lighting that communicate to the viewer when and where to look. Lighting can be designed and controlled such that it motivates and prompts the viewer to move from one story beat within the narrative to the next. The decisions of what technique to use will be based on the narrative action or story beats.

. The actions of the viewer within a VR scene will influence how the story is experienced. The lighting needs to be responsive to what the viewer is doing. Its design should accommodate and anticipate when the viewer may be distracted from the narrative and respond to re-direct viewer attention.

Viewers may need a moment to become familiar with the environment, to become fully immersed and comfortable, before the story begins. At the beginning of a narrative, lighting can be staged to draw attention to what the viewer should initially focus on. This should help orient the viewer. The lighting should be staged to initially direct and orient the viewer. How lighting can be used for viewer immersion is discussed in the lighting design section

Once a viewer is immersed in a VR narrative, storytellers must consider timing the progression of the narrative and changes in lighting to respond to the actions of the viewer. Control of narrative progression through lighting depends on monitoring the position and point of view of the viewer. Lighting needs to respond to where the viewer is looking. Lighting changes should be initiated to direct attention as needed.

Caution should be taken when timing lighting changes to avoid creating negative rewards while attempting to attract viewers to narrative focus areas. An example of negative reward is where the viewer is drawn to an area and the lighting changes by turning off the lights while the viewer is still exploring or experiencing the story beat. However, turning off lights while the viewer is exploring could be a benefit, if the purpose is to direct the viewer to the next story beat.

A design or plan is needed of how the lighting may change and where lights are to be positioned and oriented to create the look, mood and focal points in the VR scene as intended by the storyteller. This planning stage helps anticipate viewer actions. Storytellers should consider that viewers can change their position and orientation within the scene. Viewing angles will change depending on viewer actions. Lighting should be by design able to draw attention to areas of interest from all viewing angles. The design should avoid situations where the lighting creates multiple focus areas at the same time.

6.3 Specific Guidelines

The following sections provide guidance on how one would analyze, design and implement a lighting design to direct attention for a specific VR story. These specific sections are; analysis of story needs, lighting design, and implementation issues.

6.3.1 Analysis of the Story Needs

The analysis stage is where the storyteller determines the story beats. These directly relate to how the use of lighting could direct viewer attention. VR stories consist of multiple story beats that should be experienced in a sequential manner. Since the

viewer has the freedom to look around, storytellers need to analyze each story beat and decide where the viewer should be looking during that beat. Once the storyteller has determined the sequence of focus areas, the lighting design can then be developed.

Storytellers should decide how viewers should navigate the story scene. How the viewer moves within the scene should be dependent on the story progression. If the story beats occur in multiple places within the scene, the narrative path should be structured to guide the viewer experience from the start to the middle and final story beats through the control of lighting.

Viewing experience is dependent on whether the viewer is looking where the storyteller intended. For example, if a storyteller wants to tell a story about the journey of a character, the storyteller should decide where the audience should be looking throughout the journey. The storyteller should decide where the audience's focus should be during each story beat, and for how long. How long the viewer focuses on an area of interest should depend on how long the story beat lasts. The storyteller must decide based on the needed characters and areas of interest to determine what lighting will best direct attention and also effectively present the characters and areas of interest.

In a typical story, attention wouldn't stay only within one area of the environment. Areas of interest will change from one story beat to the next. Where the viewer is looking should change based on where attention is needed for the narrative. Viewers need to change their focus when one story beat ends and a next one begins. This change in focus can be achieved through the control of lighting.

6.3.2 Lighting Design

There is a need to create a specific lighting design for each VR story. Each VR story is unique. How the narrative is told, how it is structured and how it should be experienced will require specific lighting approaches to direct attention.

A lighting plan needs to take into consideration the actions of the viewer as well as the narrative story path. The lighting plan should contain a means to track or monitor viewer actions, and to respond with appropriate lighting changes. The lighting design should anticipate what the viewer may do. Each lighting design should be structured to take account of viewer actions during the narrative. These actions will influence when and how the lighting functions.

The actions of the viewer could also initiate specific lighting techniques to direct attention to the story beats. Based on the story beat progression, the lighting design should be capable of directing attention within each story beat and from one story beat to the next. Each lighting technique used should be tailored to support the narrative progression. The plan also needs to specify where light sources are to be placed within the scene, when and how the lighting needs to change and also when the lighting needs to respond to viewer actions. How to achieve this is discussed in the following.

VR narratives will likely use multiple lighting techniques. Storytellers need to decide what lighting technique to use and when. The decisions of what lighting techniques to be used will be influenced by the action within each story beat. For example, consider a scenario that needs viewer attention on a single object in the middle of a clustered environment. We suggest the use of light contrast or light color to separate

the object from the environment and direct attention to it. The structure of the lighting can be accomplished with lights to illuminate the object of interest from possible viewing angles, ensuring that attention is directed to the object even when the viewer's point of view changes.

Another example is where a story beat involves the movement of a character or characters of interest. We suggest a lighting approach flexible enough to illuminate and direct attention to these characters as they move. The follow spotlight technique would be suitable as it is designed to illuminate and follow characters as they move around. The viewer is motivated to follow the light.

In scenarios where story beats occur in multiple areas within an environment, and viewer attention needs to be guided in a sequence from one story beat to the next, we suggest a lighting design that controls the timing and order for illuminating the areas of interest. Pulsing and fading lights are suitable techniques. The structure of both pulsing and fading light are designed to vary light intensities from one story beat to the next. The fading light technique involves fading lights up and down to direct shifts in areas of interest. Pulsing light varies intensity by pulsating on and off on one area to draw attention and then repeats the process on the next story beat area. Both of these techniques can be controlled to illuminate story beat areas in a sequence as intended by the storyteller.

Storytellers should also consider visibility within the scene. The lighting design should provide sufficient ambient light for the viewer to navigate and avoid obstacles.

Each lighting technique discussed requires a different lighting setup. The position and orientation of the light sources in the setup is determined by the storyteller to create the look, the focus area and the mood intended. How these light sources are placed within a scene is also determined by the lighting technique used and what action occurs in the story beat. For example, consider a story beat where attention is to be directed to a character seated in an office that makes use of the pulsing light technique. The lighting setup could consist of ambient lights and the pulsing light. The ambient lights are positioned around the scene to provide a sufficient low intensity light to allow the viewer to navigate to the areas of interest. These lights are usually pointed to the ground. The pulsing lights are positioned based on the location of the areas of interest. In this example, the pulsing light could be placed above the seated character. The light would start to pulse on and off at the position of the character to attract the viewer.

Lighting technique can also be used to transition from one story beat to the next. Controlling these transitions is dependent on viewer actions and the intended narrative sequence. How lighting transitions can be controlled based on the viewer actions and the desired narrative path are discussed in the next section.

The timing of lighting changes within a narrative are important decisions. Poor timing could lead to negative rewards as discussed above. One way to control when lighting changes occur is with the use of lighting timing cues. Lighting timing cues are influenced by when story beats occur within a narrative. These cues are designed to trigger changes in lighting that direct viewer attention. Timing the lighting cues will be dependent on the narrative progression and the duration of each story beat. Lighting on a

current area of interest can remain constant until the story beat has ended. Once the current story beat has completed, a lighting cue could initiate a change in the lighting to direct attention to the next area using a suitable lighting technique. We would suggest the fading or pulsing light technique.

The decisions on lighting cues may also be motivated by the viewer's actions. The position or point of view of the viewer can be monitored to initiate lighting cues that should occur to support the narrative flow. The timing of actions within story beats could also influence how cues control lighting changes to direct viewer focus from one area to the next.

Viewers are free to navigate, because of this freedom, viewers may stray away from the intended narrative path. The lighting should be controlled such that when the viewer strays, he or she is redirected back to the desired narrative path. The lighting should be designed to function in a manner that uses the viewer's position and point of view as lighting cues that initiate appropriate lighting changes. These lighting changes could make use of lighting techniques such as fading or pulsing light.

At the start of a narrative, the viewer needs to be introduced to the story environment. Lighting techniques can be used to achieve this. The light contrast and light color techniques discussed above can be used to attract the viewer to where they should be and look when the narrative begins. These techniques can help viewers identify characters and areas of interests. These areas should stand out by lighting design. A pulsing light on an area of interest at the beginning of a VR narration would be a strong visual cue to help direct viewer attention.

6.3.3 Implementation Issues

The *light contrast* approach is based on light intensity ratios. Areas of interest are lit to stand out from the surroundings. Light contrast is implemented and controlled by directing lights with high intensities on areas of interest while surrounding areas are lit with low intensity lights.

The concept of the follow spotlight involves the use of a light that moves and tracks to follow a character within the scene. The lighting is designed to track the position of characters within each story beat. The lighting technique is implemented by creating a light that is aimed at the character of interest. This light is attached to the character's position so as the character moves the light moves accordingly.

How the position and orientation of the viewer is determined varies with the software used. In the Unreal Engine for example, viewer position and orientation can be sensed using actor tracking nodes. These nodes when initiated can track and monitor the viewer actions throughout the narrative. This information can be used to control the lighting changes to support the narrative. This control needs to be built into the lighting design. For example, one of the features we built was a custom tracking node that accounts for viewer position when approaching a pulsating light. The node was designed to control the pulsating light as needed using the distance of the viewer position from the light to control when the lighting changes.

A VR narrative may have one or more story beats to be experienced. How the narrative is experienced is dependent on viewer actions and this varies among viewers. The uncertain actions of the viewer creates an issue for how lighting transitions are

controlled. Lighting transition control needs to account for the viewer position and orientation. As discussed in the previous paragraph, facilities of the software need to provide a means to track the viewer. In the case of Unreal Engine 4, one way this can be achieved is through actor tracking nodes. These nodes can be used to control when lighting transitions happen. Also, how these lighting transitions occurs should be influenced by story needs and the narrative path as decided by the storyteller.

The choice of supporting software engine is a major implementation issue. One needs to consider what software is available and decide which to use. There are currently two major software engines capable of creating VR narratives. These are Unreal Engine 4 and Unity 3D. Both are available for free download and personal use. The decision of which to use is dependent on the capabilities of the software. Can storytellers achieve what is needed? For our research, we wanted software that wasn't heavily dependent on programming skill. The Unreal Engine provides control with minimal programming. However, the software didn't possess needed features for some of the lighting techniques. This influenced the lighting implementation as the structure and behavior of each technique had to be built.

For our research we built custom event nodes to control how and when each light functioned. This was the case particularly for the pulsing, fading and follow spotlights. Even though Unreal Engine 4 lacked features to directly implement these lighting techniques, we were able to modify and use some of its existing event nodes and functions to our advantage in designing the lighting. For example, for the pulsing lights we were able to use actor tracking nodes to track the viewer and use this information to

control lighting. For the fading lights, the same actor tracking nodes were used along with the timeline nodes to control timing light transitions. In the follow spotlight we made use of the Unreal Engine's socket node to "parent" a spotlight to a moving character. For both light contrast and colored lights we used and modified the software's standard light properties including color value, cone angle and intensity attributes. Additionally, for each technique we modified and used Unreal Engine's post process volume node to control the overall color, and lighting levels.

6.3.4 Early Testing

Storytellers should consider the need to test techniques and lighting control approaches early in the implementation phase. Early testing of these techniques will provide insight on whether the approaches used are suitable and can be controlled as intended. This also ensures that pitfalls or issues that might happen are caught early. For example, from our research, the design of the pulsing light couldn't be controlled to keep its intensity constant when the viewer approached an area of interest. We discovered this during the early testing stages of the implementation. This was resolved by triggering an event node that turns off the pulsating light and turns on a constant light when the viewer approached. We strongly suggest that implementers test lighting approaches early in the implementation phase.

7. SUMMARY AND CONCLUSIONS

7.1 Summary and Conclusions

In this work, we explored the use of lighting to direct viewer attention in virtual world narratives. We studied cinema and theatrical lighting techniques and explored how these basic principles of lighting can be adapted for VR. From the study, we created illustrations of the use of these lighting approaches.

The lighting approaches illustrated in this thesis provided insight into effective ways to direct viewer attention in virtual world scenarios. The examples created from the use of light contrast, light color, fading lights, pulsing light, and follow spotlights indicate that the basic principles of both cinematic and theatrical lighting techniques may be adapted to direct viewer attention in VR scenarios. The most important function of each lighting technique is its ability to selectively direct viewer attention in a manner that supports the narrative.

Finally, we created guidelines to consider when using lighting to direct viewer attention in VR scenarios. These guidelines are intended to aid storytellers by providing basic information on how one could approach lighting design to direct viewer attention.

7.2 Future Work

The created examples are only recorded illustrations of VR lighting scenarios. The effectiveness of the lighting approaches was not tested. User studies with VR narratives should be carried out to test the lighting approaches effectiveness in real VR narratives.

In cinematic and theatrical experiences, sound is also used to direct attention. Surround sound is a common technique used in cinema to immerse the listener. This allows the listener to detect sound, direction and distance. This might be an effective approach to guide viewer attention in a virtual scene. The use of directional sound cues that support attention to the narrative could be employed and studied to direct viewer attention in VR.

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