Chapter 8
Prototyping VR Training Tools for Healthcare With Off-the-Shelf CGI:
A Case Study

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EXECUTIVE SUMMARY

Cloud computing, big data, wearables, the internet of things, artificial intelligence, robotics, and virtual reality (VR), when seamlessly combined, will create the healthcare of the future. In the presented study, the authors aim to provide tools and methodologies to efficiently create 3D virtual learning environments (VLEs) to immerse participants in 360^0, six degrees of freedom (6DoF) patient examination simulations. Furthermore, the authors will discuss specific methods and features to improve visual realism in VR, such as post-processing effects (ambient occlusion, bloom, depth of field, anti-aliasing), texturing (normal maps, transparent, and reflective materials), and realistic lighting (spotlights and custom lights). The presented VLE creation techniques will be used as a testbed for medical simulation, created using the Unity game engine.

DOI: 10.4018/978-1-7998-8790-4.ch008

INTRODUCTION

Over the last decade, constantly decreasing computer hardware and software costs and increasing processor speeds have made computer simulations more popular in the classroom. Furthermore, Virtual Reality (VR) and Augmented Reality (AR) platforms are rapidly maturing. As technological capabilities have grown, the applied uses of such technologies for education and training have also become more accessible. In particular, VR enables the user to submerge themselves into a virtual environment fully. As a result, VR can be used in training situations that would be too dangerous to have users participate in the physical world (Stansfield et al., 2005). VR training dramatically reduces risks and improves logistics by (re-)creating virtual environments where staff and operators can practice realistic simulated critical situations or scenarios. XR (Extended Reality) combines real and virtual environments where the interaction between humans and machines is generated by wearables or computer technology. In other words, XR is an umbrella term that captures all augmented, virtual, and mixed reality together (Mann et al., 2018). In this paper, we will focus on VR as a subset of XR technology in healthcare only.

Moreover, Sulbaran and Baker (2000) have shown that learners enjoy VR training more than other traditional training methods and can retain the knowledge gained longer than acquired using different ways. Recent studies by Baukal and Ausburn (2013) show that the retention rates for VR learning reach over 75% compared to only 10% for reading and less than 50% for lecture-style education. In VR, trainees typically wear head-mounted displays (HMDs) with six degrees of freedom (6DoF) and wireless controllers for navigation and interaction, with more recent developments facilitating full hand tracking. Instructors can initiate immersive scenarios depicting any of a series of emergencies. Trainees can be graded, and they lose points whenever they create incorrect actions or make unjustified decisions that would lead to injuries in the real world. Therefore, VR can effectively build knowledge and understanding in the classroom (Young et al., 2020).

Researchers have proposed a virtual system to help prepare miners for dangerous situations that could not be addressed through traditional training methods (Kizil & Joy, 2001; James et al., 2013). VR has been used to train emergency first responders and their commanders (Li et al., 2005). VR has also been used in fire-hazard training systems (Smith & Ericson, 2009). Researchers have created various virtual fires where school children were asked to respond to the situations. However, using purely synthetic VR, trainees performed virtual, rather than actual, fire hazards. This researcher's approach has found that virtual learning environments (VLEs) offer significantly less risk to trainees (Tate et al., 1997). Further studies have shown that VR systems can effectively isolate trainees from dangerous threats during highly critical skills training. Thus, VR gained-skills training has the great potential to reduce risk, increase acceptance, and improve effectiveness over classic training methods alone (Fan et al., 2011).

The perceived reality of the experienced virtual scene is crucial to immerse the user in the content. Currently, readily available modeling technologies, like CGI tools, create new standards and demands. Computer games are filled with virtual humans that are visually pleasing but highly unrealistic. Evaluation of perceived information is more often based on emotional than rational aspects; if the authors create a simulation that looks more like a game, then there is a risk that the user won't take it seriously. Prior studies have focused on communicating key learning concepts, while others focused on creating general "sandboxes" that freely allowed trainees to explore pre-defined VLEs. Recent research has also focused on developing more realistic lifelike scenes and humans in VLEs (see digital humans) ("Digital humans," n.d.).

The main goal of visualization is to bring an understanding of data. The task is to present highly complex information most comprehensively and legibly. When considering 3D, the visualization process mainly focuses on understanding spatial relations and recognizing a particular physical object or phenomenon. The most natural way to convey this information is to build a three-dimensional model or evoke the sense of presence in a specific place with 360-degree panoramic images. Virtual visualization might be the next stage in developing visualization systems, and 3-dimensional computer graphics is currently the market standard even on mobile devices. The adequate definition says virtual reality is applying information technology to create an interactive 3-dimensional world effect, in which every object has presence property. It is possible to create single objects, digital humans-avatars, virtual buildings, or even whole virtual cities. Unfortunately, most visualizations depict static models with none or only simplified atmospheric/light/material effects (weather, light, skin textures) and often with limited or no environmental context (pedestrians-humanoids and foliage). Animation and narratives help to bring some life to VR. Digital narratives techniques have been successfully adapted to history, architecture, and journalism. This approach, along with virtual humans, can form a breakthrough solution. We must remember that avatars are processed in the brain like real people, and players can recognize varying levels of familiarity in avatar faces. Hence, social norms such as interpersonal distance are maintained when interacting with avatars.

The current research proposes to combine findings from several research areas and, based upon these findings, design a VR medical-examination training system for teaching MD students and support personnel in hospital environments. The current project is meant to serve as a testbed for a larger, more comprehensive long-term research project aiming to use interactive VR to provide practical high-risk-critical training for medical staff. The analysis of computer games (Mütterlein et al., 2018) shows that the interaction with humanoids (and other users) can significantly affect the user's psyche through the emotional charge.

Virtual reality has become increasingly used for medical-therapeutic purposes. The therapeutic potential of VR technology has already been experimentally tested, ranging from physical rehabilitation (Levin et al., 2015) through rehabilitation of violent offenders (Seinfeld et al., 2018) to the treatment of people experiencing or at risk of psychosis (Rus-Calafell et al., 2018). VR applications also include pain management (Matamala-Gomez et al., 2019), anxiety disorders, and phobias (Freeman et al., 2017). The potential of VR for training purposes in several areas, including medicine, surgery, and disaster response, is also gaining popularity (Spiegel, 2018; Vehtari et al., 2019). It is reasonable then to suppose that more realism in VR training scenarios will increase their effectiveness.

Alongside the prevalence of high-speed data processing computers, it has become easier to construct immersive 3D scene interactivity (from elements of VR game engines). Integration of virtual information within photorealistic or cinematic quality scenes will recreate critical situations with lifelike fidelity. It creates a possibility of displaying additional information about an examined patient and guarantees much more realistic experiences than pictures, films, or 3D images displayed on a screen.

One of the crucial features of our approach to VR is immersion, which enhances users' situated experience. The sensation of being there no longer necessitates a physical presence (Flower, 2018). In healthcare, it is vital to get VR to the level as realistic and detailed as possible, especially when there are plans to perform very complicated operations in a virtual environment. It has been found that presence and interactivity contribute to immersion by using a flow-based conceptualization of immersion. Likewise, interactivity contributes to "presence," and "immersion" influences satisfaction with a VR experience, indicating that a flow-based conceptualization of immersion is a suitable predictor in VR contexts (Mütterlein, 2018). In our case, the authors will focus on developing various graphical enhancements, such as post-processing, texturing, and lighting. Techniques such as ambient occlusion lighting, where enclosing spaces receive less ambient light, virtual endoscopy is an excellent example of ambient occlusion. It provides a more realistic representation of the 3D geometry than standard Phong lighting. Depth of field and bloom effects can be utilized in healthcare to produce virtual cinematic experiences, while anti-aliasing improves the overall quality and presence within VR. Texturing techniques (especially using normal maps) and reflective materials can create photorealistic scenes and medical training simulations. Real-time lighting is also essential for fully immersed VR experiences.

The presented research is organized as follows. First, the background of VR and immersive environments are discussed. Then, the design of an interactive VR training system and visual scene enhancing is described. A discussion of the issues encountered during the creation of the system is then given. Finally, concluding remarks are presented.

AN APPLICATION - VR MEDICAL-EXAMINATION TRAINING SYSTEM (VR METS)

Unity Game Engine

The VR Medical-Examination Training System (VR METS) was created in the Unity game engine. Unity software can run on multiple platforms Windows, Linux, Mac, with online and offline modes (Che Mat et al., 2014). In our case, we focused on the Windows platform only. Unity supports multiple XR application development, and in our case, VR METS focused on VR only. In the future, our project can be expanded to AR or MR.

The outlined process was started by importing the Vive Input Utility (VIU) plugin to the engine. The VIVE Input Utility is a toolkit for developing VR experiences in Unity, especially for the VIVE/VIVE Pro, and targeting many platforms from a joint code base, including Oculus Rift, Rift S Go, Quest, and Google Daydream.

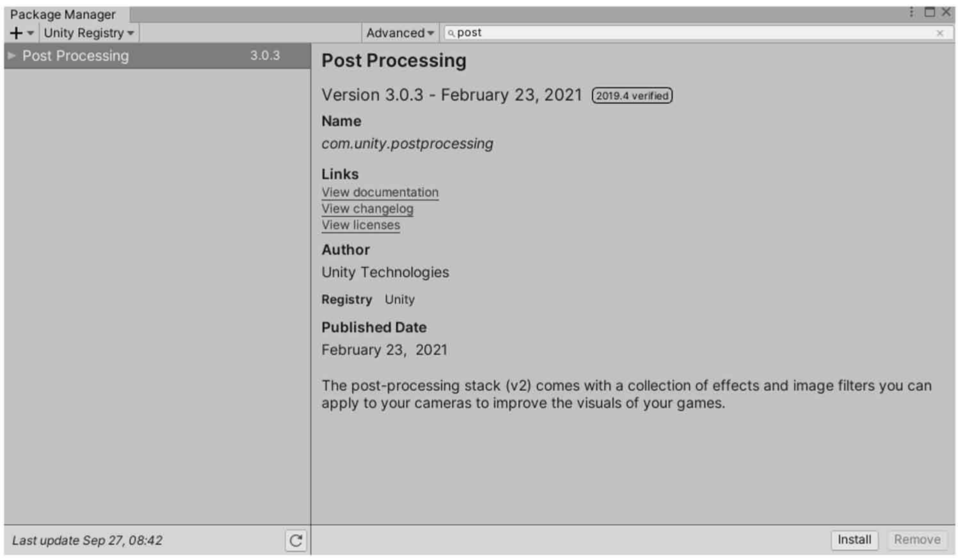
Our solution was based on a single camera as implemented in ViveCameraRig (Figure 1.). Using two cameras: one for the left eye and the second for the right eye as available in other VR packages (SteamVR). Sometimes other Unity post-processing effects packages and VR packages may cause conflict problems.

Figure 1. Vive input utility - ViveCameraRig

In this chapter, we have focused on six special effects, four of them were created using a post-processing package: ambient occlusion (AO), depth of field (DoF), bloom (BL), and anti-aliasing (AA) to smooth the corners and improve visual quality; the rest are related to other effects, such as reflection probe (RP) to enhance reflections and improve texture, and normal map (NM).

The next step was to import the post-processing package from Package Manager in Unity (Figure 2.).

Figure 2. Package manager – post-processing effects



The imported post-processing package included additional features: post-processing Profile, post-process Layer, and post-process Volume. First, we had to create the post-processing Profile for each effect: ambient occlusion, depth of field, and bloom, in an area called – Project (where the project hierarchy and project files we located) (Figure 3.).

The next step was to create Layers for each special effect in the VR camera, add a post-processing Layer, and select all results to be displayed (Figure 4.). The rendering path was set to Deferred.

Anti-aliasing was embedded in the post-processing Layer and could be controlled independently (Figure 5.) There was no need to create an additional post-processing Profile for it as it was already embedded.

Figure 3. Creating post-processing profiles – steps

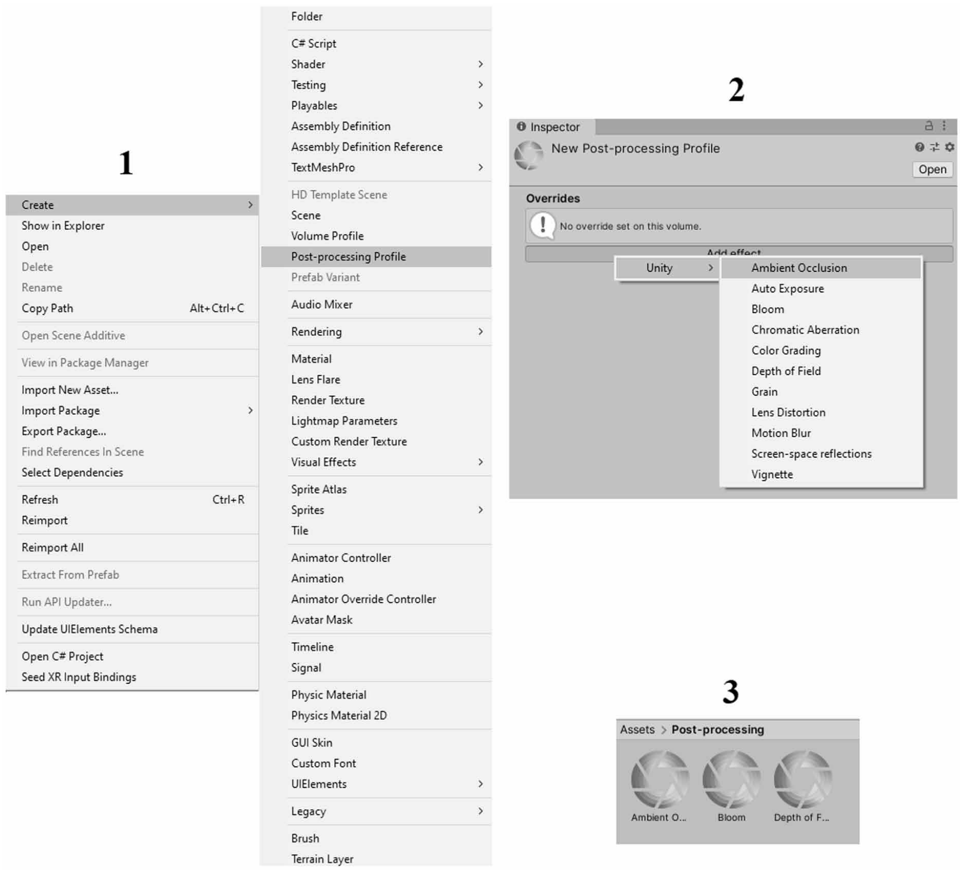
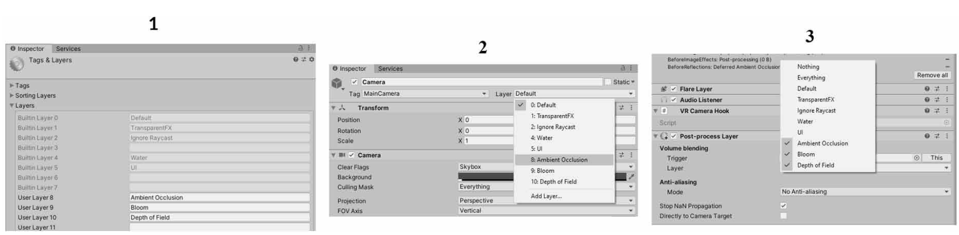


Figure 4. VR camera - creating post-processing layers



The last step was to create an empty game object and add Volume to it to control each special effect separately (Figure 6.).

Figure 5. Anti-aliasing

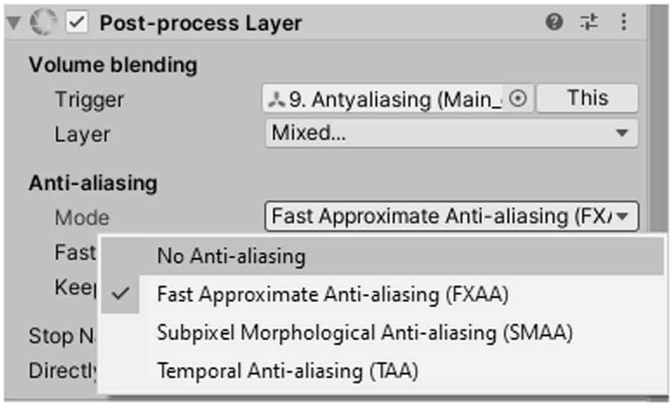
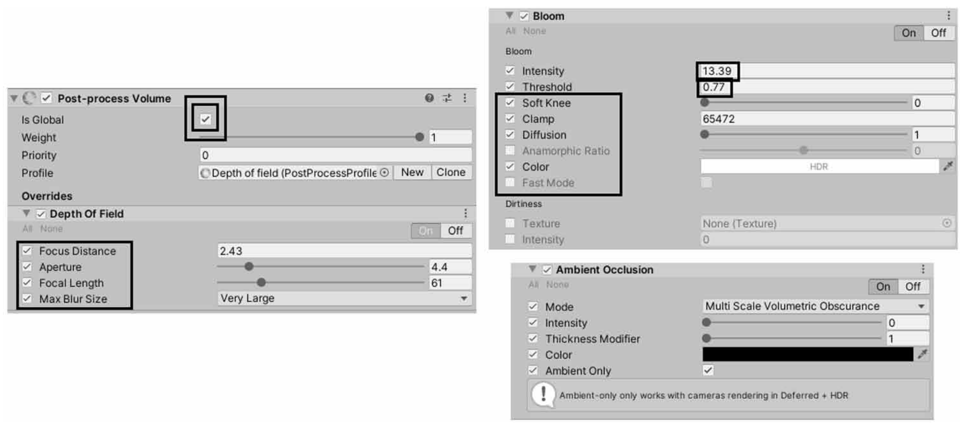


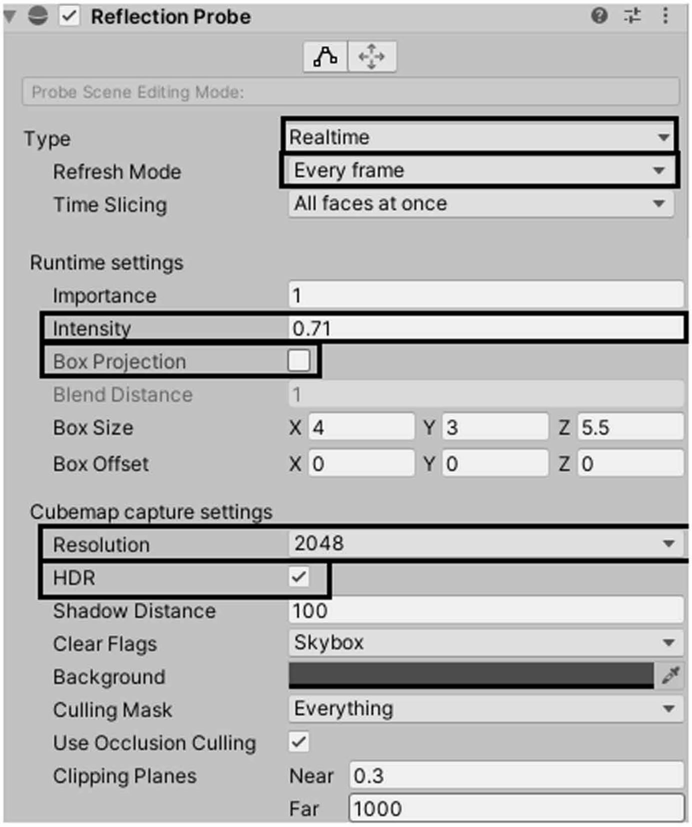
Figure 6. Post-processing volumes and parameters for DoF, AO, BL effects



Other effects in the scene were created using standard Unity components. Set up started from Type - Real-time and Every frame refresh mode. A reflection probe was created using the reflection probe component from the "Lights" setting to improve reflections in the background. This effect was controlled by intensity, box projection, resolution, and HDR parameters (Figure 7.).

The texture's visual quality was enhanced using the Normal Map technique, which imitated a flat texture bump map effect (Figure 8.).

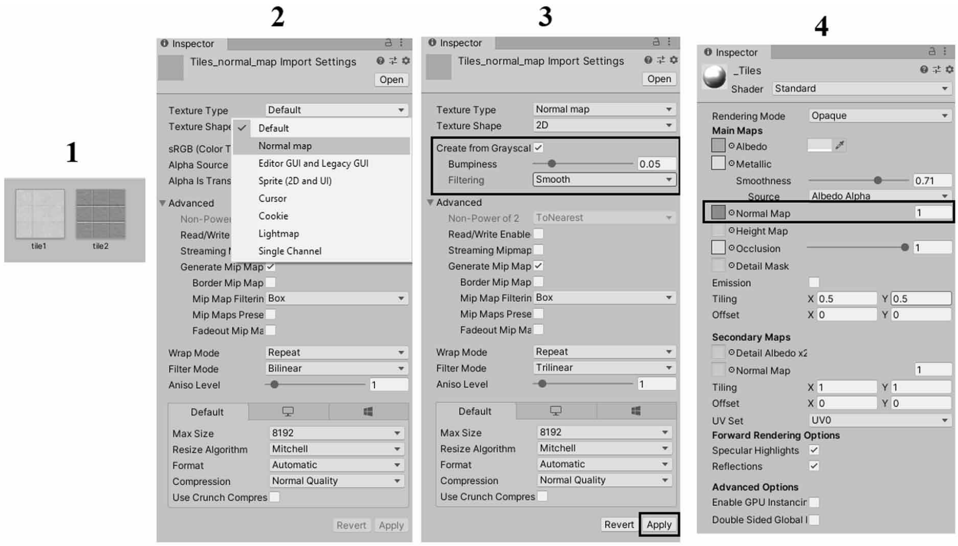
Figure 7. Reflection probe



RESULTS – ENHANCING VISUAL QUALITY IN VR METS

Scene realism is an essential aspect of creating VR training systems that might be used for healthcare. Among various approaches, manipulating visual effects to achieve a higher level of visual realism was widely adopted. For instance, additional details of the textures were added to control visual realism (Davis et al., 2015; Jaeger and Mourant, 2001) or allowing users to watch scenes with different altitudes (Kingdon et al., 2001; Watanabe et al., 2008). Besides influencing the visual aspect of virtual environments, there are other important factors. One of them is manipulating visual realism by cognition. Golding et al., 2012 created two VR scenes with different levels of visual realism triggered by the change of the camera (up-right or inverted). While the up-right scene was assigned to a higher realism state, the inverted stage was set to a lower level of graphical realism, and the inverted world was unknown to most users.

Figure 8. Normal map texture creation – stages



Unfortunately, higher visual fidelity in VR did not correlate with a better user experience and can generate a more motion sickness effect. Finding a golden mean between visual realism and user experience is still a difficult task in VR. Users who experienced better immersion and higher graphic realism showed a higher-level discomfort. This unexpected result may come from a sensory mismatch between visual and vestibular information. In the study, most participants could passively navigate in a virtual scene and received some limited vestibular details while sitting in their seats (Davis et al., 2015; Jaeger et al., 2001; Kingdon et al., 2001). This asymmetric interaction can exacerbate the conflict between sensory information. In other words, as the stimulus gets closer to reality, the user is more immersed in VR and expects atrial input signals corresponding to visual stimulation. However, users cannot obtain such vestibular information, so the conflict and VR disease also worsen.

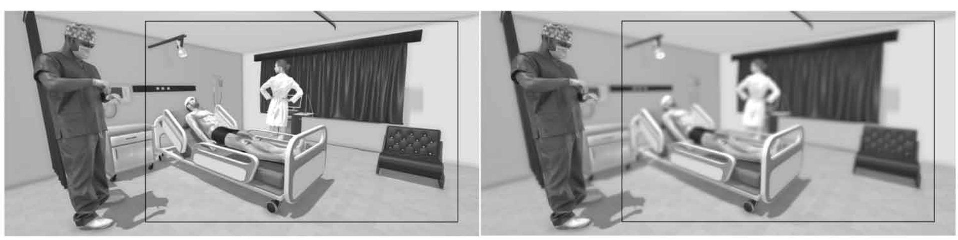
Alongside the prevalence of high-speed data processing computers, it has become easier to construct immersive 3D scenes using interactivity (virtual reality elements). Combining virtual information with the photorealistic (or cinematic) quality will re-create critical situations with lifelike fidelity. It creates a possibility of displaying additional information about an examined patient and guarantees much more realistic experiences than pictures, films, or 3D images displayed on a screen.

Ambient Occlusion is a post-processing effect that approximates crevice shadows, simulating what happens in natural environments by darkening creases, holes, intersections, and surfaces close to each other. This approach gives a more realistic appearance to objects where ambient light is blocked out or occluded. The quality of computer rendering and perception realism largely depends on the shading method used to implement the interaction of light with the surfaces of objects in a stage. Ambient Occlusion (AO) enhances the realistic impression rendered objects and scenes. Properties that make up the screen Real-time ambient occlusion in space (SSAO) of interest the graphics are independent of the scene's complexity and fully operational dynamic settings (Figure 9.).

Figure 9. Ambient occlusion: left – off, right - on

Depth of field (DOF) is the distance between the nearest and the farthest objects that are in acceptably sharp focus in an image. The depth of field can be calculated based on focal length, distance to subject, the acceptable circle of confusion size, and aperture (Figure 10.).

Figure 10. Depth of field: left – off, right - on



Bloom is an effect used to recreate the imaging artifact of actual cameras. The result creates streaks of light that extend from the border of bright areas of the image, creating the illusion of very bright light overwhelming the camera or the eye registering the scene (Figure 11.).

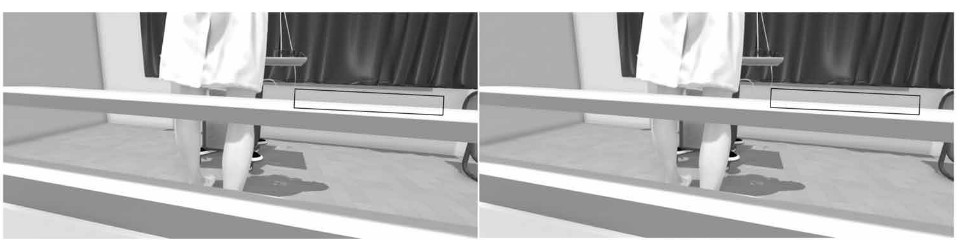
Figure 11. Bloom: left – off, right - on

Normal mapping is a texture mapping technique used for faking the lighting of bumps and dents – an implementation of bump mapping. It is used to add details without using more polygons (Figure 12.).

Figure 12. Normal map: left – off, right - on

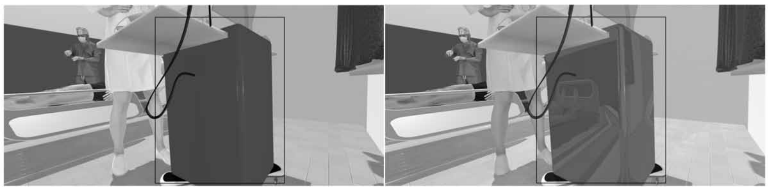
Post-processing anti-aliasing, each pixel is slightly blurry after rendering. The GPU determines where the edge of the polygon is by comparing the color contrast between each of the two pixels - two similar pixels indicate that they are part of the same polygon. Pixels are blurred in proportion to their difference (Figure 13.).

Figure 13. Anti-aliasing: left – off, right - on



A reflection probe is like a camera that captures a spherical view of its surroundings in all directions. The captured image is then stored as a cube map that objects with reflective materials can use. Several reflection probes can be used in a given scene, and things can be set to use the cube map produced by the nearest reflection probe. The result is that the reflections on the object can change convincingly according to its environment (Figure 14.).

Figure 14. Reflection probe: left – off, right – on



DISCUSSION – VR METS OTHER KEY ASPECTS

Creating a virtual reality simulation that faithfully reflects natural phenomena is not an easy task. The virtual set should convey the desired event and conform to the designer's vision and expectations as visual stimuli. Moreover, the film and game industries offer new user engaging experiences with even better photorealistic three-dimensional (3D) graphics, surrounding sound, and complex interaction. This method induces increasing demand for better non-entertaining visualizations for a more expansive (VR-game-educated) audience. Different approaches were considered, exploiting a range of technological solutions that challenged the production of the real-plus-virtual performance. The main goal was to provide the best technical and narrative quality possible with available means. The technologies used in the projects included stereoscopic 360 environments depicting hospital examination scenes and HMDs untracked and with user tracking. We should consider/solve the following issues from the authors' experience and available scientific resources confirming observations, and we should consider/solve the following problems when preparing virtual simulations.

Uncanny Valley

Generally speaking, the "uncanny valley" is a hypothesized relationship between the degree of an object's resemblance to reality (in a particular case – to the human being) and the observer's emotional response to such an object. In the field of aesthetics, the uncanny valley is defined to be "a term used in the scientific hypothesis, according to which a robot, drawing or computer animation that looks or functions similar (but not identical) to a human, causes unpleasant feelings or even disgust in observers" (MacDorman, 2006). The uncanny valley concept was defined early in the 70s of the 20th century when the first humanoid robots were constructed. The more the constructed humanoids resembled humans, the more they were accepted by human users, but it worked only up to a point where robots with an external appearance very close to human beings turned out to be very discomforting or even scary because of the small, elusive details disclosing their artificiality. That moment was called the uncanny valley. The uncanny valley denotes an observable dip in the human affinity for the replica, a relation that otherwise increases with the replica's visual and behavioral reality.

Nowadays, examples of the uncanny valley hypothesis can be found mainly in robotics, computer graphics/virtual reality, and lifelike dolls. With the proliferation of virtual reality and highly realistic cinematic/photorealistic computer animation, the uncanny valley has been referred more and more to reaction to the authenticity of artificial stimuli as it approaches indistinguishability from reality. The uncanny valley hypothesis predicts that virtual objects appearing almost real will risk eliciting eerie feelings in the viewers. What happens next after crossing the uncanny valley? According to some researchers, we go straight to the perfect simulation indistinguishable from reality, but another opinion assumes other scenarios. A very high acceptance of an almost ideal medium is followed by a drastic decline to the second valley of singularities (Mitchell, 2019). Such a situation usually occurs in some horror-themed VR environments, e.g., when we encounter a "virtual" precipice. The VR user is fully aware that they experience computer simulation, but the body/subconsciousness reacts with an atavistic fear of taking a step into the "chasm." Also, radical alterations of avatar behavior and actions cause uncanny valley and are rejected by testers (Padrao et al., 2016).

The recent development of improved hand tracking also introduced specific uncanny situations related to virtual hands and direct manipulation: jitter defined as misalignment between the virtual hands and user's actual hands, so-called "drift" is the feeling that the user is moving in the virtual world, even while they standstill. Virtual objects appear to move around for no reason because of a constant offset of where the VR headset/computer thinks the user's hand is compared to its actual location. This incongruence is usually caused by insufficient lighting or too much light coming into the headset. Grotesque Teleports are situations when a part of the virtual hands or whole virtual hands appear completely disjointed somewhere else in the virtual environment, thus breaking the immersion. In virtual reality, one does not watch someone else having an experience (as in the movies). The VR user is not in control of the character (as in computer games). In virtual reality, the VR user is part of the medium, which personally experiences all sensory experiences.

The so-called "second uncanny valley" exists in the transitional period between the suspension of unbelief and the inability to suspend faith in the incident, which is not taken seriously as the surrounding "real-life" reality. Moving on further, one can reach a perfect simulation utterly indistinguishable from real life.

An example of this may be seen in human faces generated by the GANN artificial intelligence; they are neither beautiful nor ugly, they are ordinary, and although there are no such people physically, we are entirely unable to distinguish them from photos of real people (Karras, 2018). To avoid the uncanny valley side effect, we can stick to the artificial-looking scene (particularly the humanoids), preserving visual clues to perceive three-dimensional environments fully. As far as hand tracking and direct manipulation are considered, to avoid jitter, virtual hands are represented in abstract ways, like with shapes, clouds, or sparkles in some applications. This design is made to hide the jitter effect, so users don't pick up on any obvious jittering.

Scale/ Homuncular Flexibility

VR users can accept substantial structural transformations to their virtual bodies, temporarily altering self-body perception (Normand et al., 2011, Yee et al., 2009; Slater et al., 2010). This effect was first observed in the early 1980s and was dubbed Homuncular Flexibility (Lanier, 2006). Some formal studies of Homuncular Flexibility have confirmed the earlier, informal observations (Won et al., 2015a). One example of this effect is that participants embodied in differently shaped avatars can overestimate their body size (Piryankova et al., 2014). It can be felt to be changed after using VR in the first weeks. People previously thought to be larger seemed smaller, and the VR user's size seemed larger. Other studied examples are that adults can have the illusion of having a child body (Banakou et al., 2013) or a black body (Peck et al., 2013; Banakou et al., 2016). Such experiences change the attitude of participants; for example, parents may change their behavior toward their children (Hamilton-Giachritsis et al., 2018), white people may become less biased against black (Maister et al., 2015), or domestic violence offenders may improve upon their recognition of fear in women after being virtually embodied as a woman subject to abuse by a virtual man (Seinfeld et al., 2018). Most of the currently available scientific research has explored positive benefits, but there is a risk of homonuclear feasibility or more dangerous body dystrophia where a virtual body/avatar may seem to be much more attractive than a physical body.

Reality Dissociation

In VR optics, despite the perception of depth, the user's eyes focus on the approximately two-meter artificial focal plane created by the lenses (for Oculus VR headsets).

This optical effect causes a temporary disassociation, which develops the eyes' difficulty focusing correctly in real life and will generally disappear after a few days. Adjusting time will vary for different users, but it may cause a disconnect in viewing the world after experiencing VR (general feeling of lightheadedness) vs. how one usually does. We can think of it akin to how looking at a static image for a reasonably long period will cause an afterimage effect thanks to the nerves involved becoming overexerted (same for other sensory nerves and muscles). That effect can be limited by careful use of focus. We can either build a virtual environment with the essential information placed in the focal plane or slightly blur objects of secondary value (props, background), forcing viewer eyes to concentrate on the focal plane. More prolonged exposure to VR HMD may infer behavior in real life. VR users who move through the virtual environment with the joystick/controller sometimes have to make the conscious effort/thought to move around in real life. VR experiences with limited user movement or sitting down (or standing still in one place) usually have less of the reality dissociation side effect.

Cybersickness

VIMS (Visually Induced Motion Sickness) is the broad term the encompasses simulation sickness, or cybersickness is an effect of a mismatch among visual, vestibular, and proprioceptive senses that occurs with changes in the motion of the user. Slowing down or stopping, turning while moving or stepping are all forms of movements that may induce VIMS. The VR rendering engine uses some software tricks (e.g., predictive tracking, TimeWarp) to shield the user from the effects of latency, but it is not always practical. To minimize the VIMS VR simulation, viewing the environment from a stationary position should be avoided. This perspective is the most comfortable in virtual reality, then. When moving through the environment is required, users are most comfortable moving through virtual environments interactively, with 6DoF, and at a constant velocity (humans walk at an average rate of 1.5 m/s). If one moves in virtual reality, they need to pick up the pace of stomping so that the brain starts making mistakes, and then nausea will be dramatically reduced. VR researchers should, therefore, make use of careful design considerations when creating character locomotion (Lewis-Evans, 2018).

Perception of Time

Virtual reality is a highly immersive experience that engages users in various ways. Some researchers have found that virtual reality interaction creates an effect called "time compression," where the time goes by faster than in real life (Mullen, 2021). Prior studies of time perception in virtual reality have often used surveys asking participants about their experiences after the fact. The current research team wanted to integrate a time-keeping task into the virtual reality experience to capture what was happening at the moment. The actual amount of time that had passed when each participant stopped the incident was recorded, and this revealed a gap between VR participants' perception of time and the actual time. The time gap was approximately 30 percent longer than in the classical desktop version of the simulation. That time compression effect was observed among test participants who played the game in virtual reality first. The paper concluded this was because participants judged time in the second round on whatever initial time estimates they made during the first round, regardless of format (Mullen, 2021). Some researchers struggle to discover why virtual reality seems to contribute to time compression. According to Mullen, one possible explanation is that a VR user has less body awareness. Future experiments to test this theory could bring new insights to help designers maximize benefits and minimize side effects from time compression. The result of time compression could be beneficial in some situations, for instance, enduring an unpleasant medical treatment or long and repetitive training, but in other circumstances, it could also have harmful consequences.

Stereopsis

The nature of human vision is highly complex, and understanding the very heart of seeing things involves research both in physiology and psychology of perception (Gombrich 1999, Gombrich 2001). Humans are accustomed to viewing the world through two eyes. Two-eyed vision provides extra cues to estimate image depth. Stereopsis or binocular vision enables humans to measure distance with eye convergence and stereoscopic vision. Eye convergence is a measure of the eyes' optical axes when fixating on some point in the space. In reality, the convergence angle for distant views is near zero, and for closer objects, optical axes converge to keep the center of visual interest positioned over the two sensitive foveae (Walius, 1962). The range of the convergence angle depends upon the physiological abilities of the observer. Within the high-acuity foveal region, depth perception is fading at 100-150 m. At that distance, motion parallax and perspective become much more helpful to estimate distance. Perception of distant and closer objects depends on accommodation as well. The mechanism of accommodation provides clear vision by tensioning or relaxing the ciliary muscle attached to the periphery of crystalline lenses. With age, the lenses become less flexible and result in a person focusing at a constant distance.

Bela Julesz proved that stereo perception was independent of object recognition (Walius, 1962). When two identical patterns of random dots are viewed through a stereoscope, they are perceived without the sensation of depth. However, it was shown that if a portion of one pattern was displaced horizontally, the stereogram tricked the brain into believing that a 3D structure was observed. The brain uses that displacement or disparity between the two stereoscopic images called parallax (see below) to measure depth. The first attempts to create stereoscopic images were described in 1832 by Charles Wheatstone, who invented the stereoscope. The idea was perfected by Sir David Brewster (Vince, 1995). The Brewster's stereoscope consists of two pictures and a couple of mirrors redirecting and separating views for the left and right eye of the observer.

Currently, VR Head Mounted Displays work in precisely the same way. The parallax controls the depth of view, the difference between the left and the right eye determining the distance we perceive. Generally, it is possible to obtain greater variability in image depth with the more significant Field of View. When the parallax is equal to zero, we see objects "on the screen," so the distance between the virtual and real image is the same. In the case of HMDs, the perceived screen distance is determined by so-called focal distance or infinity optics (dependent on the set of lenses), and it ranges from 2 meters (Oculus Rift/Quest) to 7 meters (military-grade HMDs). Negative parallax makes the objects "pop up" from the screen/focal distance and the effect that can give eye strain when observed for a longer time. Positive parallax puts things farther behind the screen and seems to be more comfortable for the viewer. Depth perception from stereopsis is susceptible up close but quickly diminishes along with distance. Mountains that are miles apart in the space will provide almost the same sense of depth as two objects' inches apart on the desk distanced one meter from the observer.

Increasing the distance between the virtual cameras can enhance the understanding of depth from stereopsis but may result in unintended side effects. It may force users to converge their eyes more than usual, which could lead to eye strain. Moreover, it can give rise to perceptual anomalies and discomfort if one fails to scale head motion equally with eye separation. The optics of the Oculus HMD make it most comfortable to view objects that fall within a range of 0.75 to 3.5 meters from the VR user's eyes. The virtual things users will look at for extended periods (such as menus and avatars) should fall in that range. One must remember that perception of the stereoscopic space is relative, and the sharpest image is guaranteed only with the zero parallaxes (focal distance of the HMD). Moreover, to obtain immersion, one does not have to rely entirely on the stereoscopic 3D effect to provide depth to virtual content; proper lighting, delicate texture, motion parallax (the way objects appear to move concerning each other when the user moves), and other visual features are equally (if not more) important to conveying depth and space to the user.

Stereo Blindness

To obtain stereoscopic sensation, the human observer needs to adjust their vision. For some people, this is sometimes hard or even impossible and approx. 10% of the human population cannot obtain stereoscopic 3D sensation. The so-called stereo-blinded people perceive two overlapping images. Even for the average observer, when viewing stereoscopic images, they may induce eye strain and other neuro-psychological side effects after some time. The reason is that the observer must force the eyes to stare in parallel (as for distant views) while focusing on relatively close print, thus fighting the stimuli to converge eyes on objects recognized as close ones. However, there are some (yet not clinically tested) opinions that people who have been stereo-blind their entire lives and using VR regularly can cure it (also outside of VR). There is probably some retraining of the brain, but the science behind it is not well understood.

Depth of Field

Each three-dimensional scene created in visual reality has a maximum usable depth to develop effective and "user-friendly" 3D stereography. If the virtual production is to have captions, this should be taken into account when working out the total depth budget. This depth budget may be calculated as a percentage between the left and right eyes separation concerning screen width. We need to remember that the sharpest image is guaranteed only with zero parallaxes (placed in the focal distance of the HMD). When visual objects are placed too far in front of the focal length of HMD and too far behind the focal distance of HMD at the same time (too much depth), the viewer will not be able to 'fuse' the stereo 3D image.

Ghosting

If we provide two versions of the same virtual scene, however, one set is slightly different from the other it is called ghosting. The rendering of these scenes into the left/right eyes takes two different environments and pretends they're one. For example, in one eye, a room looks new and full of life, wherein the other is old, and the furniture looks slightly deteriorated. Everything is kept precisely in the same position and shape, so the viewer's eyes would still get a perception of 3D and will process the scene, but perhaps having these two slight changes of images. These issues could be an effect of a glitch in visual stimulation (e.g., wrongly constructed reflection probe) or turn to be a perfect tool for representing a whole new VFX possible only in fully immersive virtual reality. These could be ghosts, madness, drugs, deja vu, alternate realities representing things that the character can see but other people in the game or simulation. Several VFX can be used to model the simulation scene to avoid ghosting, including the ambient occlusion, bloom, and normal mapping. Generally, the images presented to each eye should differ only in terms of viewpoint; post-processing effects (e.g., light distortion, bloom) must be applied to both eyes consistently and correctly rendered in z-depth to create an adequately fused image.

Retinal Rivalry

This side effect is very similar to the ghosting mentioned above, considering specific /pixel size visual disparities. When something appears only in one eye, the viewer very often cannot reconcile the images. This effect can occur in reflections, aliasing, glints, lens flares & motion artifacts. One needs to close one eye, then the other, to see the differences between the eyes. Bright, thin objects/images, particularly in the periphery, can create noticeable display flicker and retinal rivalry for sensitive users. To avoid retinal rivalry, darker colors, normal mapping, anti-aliasing, and carefully adjusted reflection probe techniques can be used.

Screen Door Effect

Visible pixelation (often referred to as the "Screen Door Effect" or SDE) of the perceived image in HMD results from low quality of hardware display. The pixel density of the display matrix is a dominant factor in SDE. However, the pixel configuration also matters, as does the type of used lenses either. Looking at what is displayed on the VR head-mounted display screen, one will notice that the frame's shape is distorted and somewhat rounded rather than square. This alteration is because the lenses then distort that to the viewer's eyes, giving the appearance of a regular image. What is seen through the center of the lenses will be a reasonably decent resolution, but what is seen as the gaze is moved away from the center is that things become a little less crisp. The image contents at the peripheral view are displayed with a lower pixel density. One can consider supersampling or anti-aliasing to remedy low apparent resolution. Another solution is to use high-end HMDs like Varjo or Pixmax to provide display resolutions that eliminate the screen door effect.

CONCLUSION AND FUTURE WORK

At the forefront of emergent technologies that can reshape the world of healthcare are VR and AR. Putting doctors and patients into a VLE enables education and healthcare to improve its current performance and become even more efficient. VR has many benefits in terms of security and training. It is particularly possible to simulate critical or highly uncomfortable situations for doctors/nurses and supporting personnel, helping them know how to react in real-world cases. Before being used in examination and intervention applications, MD students can be virtually immersed in their future work environment and be trained in various instances. And since new technologies like the Oculus Rift and the HTC Vive keep track of things like how your head moves in space, it is possible to use that data to give trainers insight into what trainees are paying attention to in VR. Immersive technology is changing the way organizations train their people. The virtual training of medical staff facilitates a set of acceptable solutions characterized by different configurations of real-life scenarios that guarantee timely completion of interventions with a minimum total cost of the training process. This approach makes it possible to benefit in the service of the efficiency of the healthcare.

Immersive learning and training platforms more commonly apply multimodal design elements, such as avatars and anthropomorphic virtual agents, impacting students' motivational outcomes and delivering novel forms of visually enriched embodied communication (Rasimah et al., 2011). Previous research has highlighted tendencies, such as gender-specific preferences for exergames and the familiarity effect when engaging with XR technology (Buchem et al., 2021). Furthermore, simulation training in VR is advantageous for medical professionals (Tsai et al., 2021; Shah et al., 2021). However, due to the small number of case studies and lack of comprehensive comparisons between VR and conventional medical interventions, contemporary studies lack a solid foundation for comparing the physical world with the digital (Safikhani et al., 2021). Therefore, additional student-user-focused studies are needed to evaluate the impact of the VR environments' technological and design aspects, as introduced in this chapter.

The VR experiences described in this chapter are based upon the simulation of a domain-specific environment, the virtual operating theatre, a doctor's office, etc., with visual enhancements made via the introduction of various graphical effects. In general, XR simulations (and VR as a subset) are becoming more widely adopted in medical education as they offer low-risk exposure for students to clinical environments and situate the requisite knowledge and skills for clinical teaching. Although the authoring of VR/XR medical education spaces, from a user-experience perspective, rests upon other modalities, such as 6DoF movement, 3D assets, interaction, and the modalities of the platform (Antoniou et al., 2021), the visual components of the reconstruction remain fundamental. Therefore, by incorporating realistic VR/XR simulations and training into student programs, the platform offers novel opportunities for educators to provide personalized domain-specific instruction to prepare students for the many complexities of patient care, treatment, and well-being.

The global COVID-19 pandemic has introduced new social distancing measures and lockdown protocols that have had an immense impact on medical students' lives, affecting their instruction in many ways. Research has shown that the pandemic has chiefly affected the younger populations (ages 18-25), who have developed symptoms of post-traumatic stress disorder (PTSD), anxiety, depression, and other signs of emotional distress (Office of National Statistics UK, 2021). In addition, remote learning has been introduced to protect students and staff, creating an additional barrier for students who require further support. The introduction of realistic VR environments and social VR can perhaps alleviate these negative impacts in future remote learning and social distancing educational contexts.

ACKNOWLEDGMENT

This publication has partially emanated from research conducted with the financial support of Science Foundation Ireland (SFI) under Grant Number 15/RP/2776.

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