Virtual Reality in Health Care

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***Abstract*—This paper presents a prime aspect of Augmented and Virtual Reality development in the field of healthcare. We explored several recent works and articles and a comparison between generic application development and immersive technology-based application is included. The paper talks about more practical approaches that can be taken to enhance the effectiveness of the application. The resources (infrastructure) to complete this study are provided by the University of Cincinnatis Center for Simulation and Virtual Environment Research (UCSIM). And several experiments and projects in the field of health care are used as a reference to make conclusions.**

***Index Terms*—Virtual Reality, Augmented Reality, Immersive Technology, Healthcare Applications, Simulation, Immersion Breaking points**

I. Introduction

In every country few sectors like Healthcare, Education, etc. are tangled with numerous challenges. Since the demand for trained experts in these sectors is significantly surpassing the supply this situation is in partial equilibrium. To overcome these challenges many countries are investing in the technologies to find techniques that can help in increasing the number of experts in the field. This paper investigates one such technique and its practical implications. Immersive Technology as per Gartners [1] prediction will be adopted in 20 percent of large-enterprise businesses by 2019 which we are seeing today. After the literature review, this paper presents insights on how immersive technology is developed and used which led to an improvement in Healthcare practices, a short comparison of immersive simulation development and traditional Software Development and, different devices utilized to complete this study. Another important part of this study is immersion breaking points. As of now, very less text is available on this topic which relates to Healthcare application. Paper discusses various immersion breaking points and possible ways to fix them. There are researches in progress to eliminate immersion breaking points using Artificial intelligence (AI) and Deep Learning about which paper discusses briefly. Conclusion over the current adaptation of immersive technology and possible future works are depicted in the last section of the paper. In Augmented and Virtual Reality (AR/VR) based application we try to simulate the real world in a virtual environment, most of the time applications running in a virtual environment are referred to as simulation. So, in the paper to avoid any confusion between similar terms, an application developed for the virtual environment will be referred to as simulation and any other kind of computer program as software. Also, virtual reality nowadays has taken a turn in a new direction and Head Mounted Devices-VR (HMD-VR) are commonly referred to as Virtual reality (VR). So, in this paper, VR is referred to as HMD-VR.

II. Literature Review

Before starting the paper, it is important to understand some important terminology used in this paper. The definitions are obtained from the work done previously in this field.

A. What is Immersion?

Immersion in this paper is used as a measure of a players involvement with the simulation. Jannet Murray [2] defined immersion as, a stimulating rendering that can be experienced as a virtual reality in any medium because of human brains design which tune stories with an intensity that can obliterate the world around us. The experience of being transported to an elaborately simulated place is pleasurable in itself, regardless of the fantasy content. We refer to this experience as immersion. Immersion is a metaphorical term derived from the physical experience of being submerged in water. We seek the same feeling from a psychologically immersive experience that we do from a plunge in the ocean or swimming pool: the sensation of being surrounded by a completely other reality, as different as water is from air, that takes over all of our attention, our whole perceptual apparatus in a participatory medium, immersion implies learning to swim, to do the things that the new environment makes possible the enjoyment of immersion as a participatory activity.

B. What is Virtual Environment?

Virtual Environment also goes with the name Virtual Worlds, immersive virtual environment and meta-verse. The virtual environment enables users to control the environment created in three dimensions as a simulation of the real world. According to Bainbridge [15], they are defined as persistent online computer-generated environments where people can interact in a comparable way to the real world, either for work or for leisure.

According to Fabricio [3], 3D virtual worlds enable the inclusion and practice of activities for experiential learning, simulation, modeling of complex scenarios, among others, with opportunities for collaboration and co-creation that cannot easily be experienced on other platforms.

C. Difference between Augmented and Virtual Reality

The principle difference between augmented and virtual reality is that, in augmented reality the virtual objects and elements are augmented on real-world i.e. User can see the real world along with virtual element while wearing an AR headset whereas in virtual reality the user is totally immersed in a virtual world, and cant see the real world. There are plenty of devices in the market for experiencing both AR and VR. For AR, Microsofts HoloLens, Magic Leap One by Magic Leap, etc. are available in the market. VR headsets are explained in a subsection below Application of Virtual reality in Healthcare. A detailed comparison with example is discussed in [4].

III. Development of Virtual Reality Simulations

The principle that leads to the development of a successful VR-simulation is based on immersivity (The quality of being immersive) of the environment i.e., up to what extent the simulation is capable of captivating the user and make them forget the real world. The methodology followed for the development of immersive technology is not very strict and varies with the field of simulation and with the platforms, it is going to be run. Considering simulation is developed for healthcare and is developed for virtual reality headsets which are discussed in the following section, it is important to understand the purpose of the simulation. As discussed in the literature review, the simulation can be used for training nurses and physician before they start actual practice with real patients or can be used by the patient. These few scenarios add and subtract component in and from the development process.

For the development of any application of type games or simulation, it is required to create three main components, and later these three components can be merged together as an individual package, this series of tasks, to fulfill dependencies can be very complex when working with so many assets. To make this task simpler and make the entire development assets more organized, there are many game engines available in the market. The engines not only help in keeping the files organized but also optimize the entire development process as per the available system resources. An engine is required to merge different components of the simulation in the desired sequence and create events with all three components. The core components of a simulation-development which the user experience while playing it are art, audio, and mechanics.

A. Primary Components of Virtual Reality

Art is described as the environment that player see while wearing the headsets, objects with which the player interact and the animation of the virtual surroundings. Audio can be considered as another dimension which gives a more real feeling to the player during simulation-play. Mechanics is the core programming part that decides the event sequence and gives the player the freedom to interact with the virtual environment.

These three components are developed independently by different experts of their respective fields. There are various tools available in the market to create art, audio, and scripts for mechanics. Most of them are free and open source, but some of them are proprietary and paid. To learn how these tools work one can refer to the documentation provided by the developers of these toolkits. One of the most popular toolkits to develop Virtual Reality application is VRTK [8].

B. Recommended Scenarios

Since this technology involves a lot of both heavy and light gadgets, it is very important for the users to get familiar with the simulation environment and interaction mechanism, just like a manual guide depending upon the audience of the simulation a tutorial is a common part that is developed. The tutorial not only helps the user in getting familiar with controllers but also enhance the users experience with actual simulation. This fact was found while developing a simulation for one of the health care projects at UCSIM, where the real user with minimal familiarity with Virtual reality devices was able to focus on the actual content of the simulation and was comfortable with the virtual environment after playing through the tutorial. This experience of the user is obvious and can be explained with the statement that, the more time you spend with some instrument, the more you get comfortable with it.

Another key part of VR-Simulations is learning outcomes. This scenario becomes more important when the simulation is developed for training purposes. Sometimes when users get very engaged with the virtual environments and its intractable objects, they forget the purpose of the simulation though it is a good indicator of immersivity of the simulation it is important for a player to know that what they can expect or learn after completing the scenarios.

To establish a two-way dialogue exchange between the player & non-player character in the simulation is easy and more script instructions based, to make it feel natural and easy to access is a challenge. The dialogues are recorded clips and every time when they are played, it is an event in terms of development. There are several intelligent agents available with the Game Engines and from other services that you can use to make the entire conversation more natural. The elementary component often used for communication interface is dialog tree, these trees can become very dense depending upon the length of the simulation. To keep them short and confusion-free there are other ways available as well. Dialog boxes are one of them, a dialog box pops up every time when the user has to make a choice. When the user is provided with limitation option to choose, not only it keeps the dialog tree concise but also helps the simulation to trigger the next event depending upon the choice user made.

IV. Comparison of VR simulations with ...

A. Web Application

The main difference between Web applications and VR simulations is the platform on which they are delivered. The development of web application is comparable to simulation development in terms of methodology and data structure concepts. The tech-stack for VR simulation development differs from most of the web application development. Databases

play an important role in web application whereas for VR simulation Database servers are optional. Most of the web applications are more dynamic and are more frequently updated compared to VR simulation which gets updated for only major changes. For more readings about web-based development [10].

B. Game Development

Game development is the closest to VR simulation development. Concepts and algorithms used in game development can easily be implemented for VR simulation development. Sometimes, depending upon the application the hardware for which simulation is developed can differ from the traditional one. Since VR simulations are developed for specific use cases the controllers in the simulation device are designed to look and feel like medical instruments. A description of User Interface (UI) and the gameworld in computer games is discussed by Kristine [11].

V. Application of Virtual Reality

The applications of Virtual Reality in the field of healthcare are growing day by day. Some of them are discussed briefly below.

A. Surgery Training

Practice makes men perfect. It is possible to use VR simulations to get hands-on with surgical practice. Neurosurgery simulators, Laparoscopic simulators, and Endoscopic simulators are some popular simulators in surgical simulation category. In 1995, Whalley [14] stated that complex operative techniques can be taught in a virtual reality machine it is already feasible to use the results of clinical investigations (for example MRI scans) to construct a precise virtual reality model of all or part of a patient. Supercomputers now allow the integration of quite massive databases derived from structural imaging of diseased organs and their simultaneous functional mapping that can be used to give the surgeon the opportunity to rehearse a potentially complex surgical procedure in virtual reality before attempting this with a patient. While using VR simulators, a practitioner is given an explanation of the tasks to be practiced and learning objective assessment of their performance. Beta versions of simulators are developed to provide realistic haptic feedback.

B. Psychological Diseases Therapy

The potential of VR to captivate the user in the virtual world is used for psychological therapies. A detailed discussion on this topic is presented by Claudio [6] in their VR in Medicine. Therapies for Phobias, PTSD, Anxiety Disorders, Rehabilitation, and Pain Management are being performed using VR Simulations.

C. Communication interface

One of the important and rapidly immersing applications of Virtual reality is being a platform to improve communication of the trainee. Not just in healthcare, Virtual reality is helping organizations in different sectors to train their workforce as a good communicator. In reference to Healthcare and Medical Clinics, simulations are developed with a pre-defined script and one or more avatars with whom the player can interact. A detailed discussion on the development of communication interface on VR is included in one of the subsections. The key characteristic of VR, differentiating it from other media or communication systems, is the sense of presence [7].

VI. Virtual Reality Headsets

Most of the headsets available in the market come with a headset and controllers for both hands. Some additional features for navigation inside a virtual environment can be coded in the development phase. Within these headsets, there is variation and can be purchased as per requirement. Tethered Headsets like HTC Vive/SteamVR, Oculus Rift, and Windows Mixed Reality are required to be connected with a device like a laptop or desktop. And are limited to the length of the wire attached to them. On the other hand, mobile headsets like Google Daydream View, Samsung Gear VR need mobile which can fit in them and can be used later. There are very few applications for these devices focused on healthcare. The most recent innovation in the virtual reality headsets is standalone headsets. HTC Vive Focus plus, Oculus Go, etc. are some standalone headsets which give the user more freedom to walk around and interact with the object. Moreover, the dependency in tethered headset on high-end processing machines like laptop and desktop is eliminated in standalone headsets. A comparison between most recent VR headsets available in the market can be seen in a blog post by PCMag.com [9].

It is also possible to replace the regular controllers in virtual reality devices with medical instruments. Tracking and haptics sensors are attached to these instruments that help the simulation in getting input from the user. Such kit makes the simulation more like reality and help practitioners trained better.

VII. Immersion Breaking Points

Immersion breaking points arise as bugs, glitches, and some limitations of the technology. At any instance during the simulation play, if the player gets distracted or comes out of the virtual world due to any technical reason then it is called an immersion breaking point in the simulation. Since VR applications have too many dependencies on hardware, art assets and scripts immersion points are a big challenge to the developers of simulation. Some of the immersion breaking points and possible ways to avoid them are discussed below:

A. Hardware Dependencies

VR applications especially simulations for Medical purpose are equipped with more than usual sensors. And it requires a lot of processing power to collect input from various simulations simultaneously. This dependency on hardware resource can sometimes be the reason that the user loses the immersion. Moreover, the range of sensors that detects headset motion is limited and can lose sync with the headset sometimes and can freeze the simulation for a while. These glitches in VR

technologies are getting improved day by day, and new devices like standalone headsets are developed with more optimized processing.

B. Art Dependencies

One of the important factors that work behind developing a 3D real like environment in virtual space is art. In the past few years, computer graphics has made many advancements in rendering a virtual object as real. Graphics in the virtual world play a significant role in deciding the immersivity of the simulation. A well designed and rendered graphic can easily convince the user to believe that they are in the real world while wearing the headsets.

Nowadays, deep learning algorithms are implemented to adapt the texture from the real-world image and impose it on to graphics. These algorithms use Generative modeling, this is an unsupervised learning technique in machine learning. An Openais blog post on June 16th, 2016, the author shared four projects that have a common theme of enhancing or using generative models to improve the artistic experience in the virtual world. This technology not only helps the graphic designer to develop graphics texture quickly but also create more believable graphics.

C. Audio Dependencies

As humans, we are trained to hear in 3D. Imagine someone calls us from behind, or a plane flies over our head. We are able to determine the direction of the sound source and turn around or look up. This happens because the sound waves when traveling through the air and reach our ears, they reflect and refract off our ear cavity before they reach our eardrum through the ear canal. The way two people hear sound is different because of ear shapes which are different so the reflection and refraction happen differently for two individual. Human ears are also one of the unique biometrics (like fingerprints) that differ from person to person.

Now that was a real life scenario. What about headphones? We don't really get sound localization and externalization on a set of headphones due to the 2 channels. Although, it is possible to get left and right by playing sounds through that particular channel but not 360 audio. To give a user, 360 degrees (or human-like) hearing experience on a set of headphones there is a need to compute ahead-related transfer function (HRTF) for that user. The traditional methods that have been used in the past 10-20 years, they require the user to sit in an anechoic chamber for 6-8 hours without moving their body while they measure the user. Embody, one of the leading company working in this area has data scientists and acoustic engineers, who have developed an AI-driven solution that takes an image of right ear and computes the HRTF for a user on their servers in less than 30 seconds.

Their technology is helping in minimizing the immersion breaking points that usually happen due to audio-video cues not matching. A detailed explanation of the technology behind this is discussed in the paper [12].

Also, some external noise from the background can easily break the immersion and hence it is recommended to use external noise cancellation headphones. Most of the times these headphones/speakers are embedded in the headsets but the older headset does not ensure a noise proof sound quality.

The sound used in the simulation, for example, voice clips of NPC i.e. non-player character needs to be recorded in a soundproof environment. Any compromise with sound quality is another red-flag for the simulations.

D. Mechanism Dependencies

While in a Virtual environment a player may try to sit on a virtual chair object but in reality, there is no chair available in the play space and player may fell down on the floor. Although, most of the physics properties like gravity can be implemented in a virtual environment some kind of collisions are hard to avoid.

Similarly, the height of the player and positional height of the VR camera in the virtual environment may not match and some player can experience the difference. Although this kind of glitch can be fixed by using a script that can take the height of the player and re-adjust the scaling accordingly.

VIII. Conclusion and Future Study

The rapid growth in a number of applications of virtual reality in healthcare is proof that how important it is to know simulation development. The development process of simulations differs just like developing applications for different platform. Core technology and process remain the same. The immersion breaking points and research to mitigate them is continuous and will be very helpful in the near future. Though this study precisely discusses the development of Immersive technology in Health Care, the conclusions from here can be referred to extend it to other sectors than healthcare like education, business, employee training, etc. Future studies can be conducted to determine how long a user takes to forget the real world and get totally immersed in the virtual environment and what are the factors with which this time can be reduced.

References

[1] A. Forni, "https://www.gartner.com," Gartner, 05 May 2017. [Online]. Available: https://www.gartner.com/smarterwithgartner/transform-business-outcomes-with-immersive-technology/. [Accessed 21 04 2019].

[2] J. Murray, "Immersion," in Hamlet on the Holodeck: The Future of Narrative in Cyberspace, Cambridge, MA, The MIT Press, 1997, pp. 98-99.

[3] F. Herpich, G. B. Voss, F. B. Nunes, R. Ribeiro and R. D. Medina, "Immersive Virtual Environment and Artificial Intelligence: A propoal of Context Aware Virtual Environment," in UBICOMM 2014 - 8th International Conference on Mobile Ubiquitous Computing, Systems, Services and Technologies, Rome, Italy, 2014.

[4] M. Sidiq, T. Lanker and K. Makhdoomi, "Augmented Reality vs Virtual Reality," International Journal of Computer Science and Mobile Computing, Vol.6 Issue.6,, pp. 324-327, 2017.

[5] L. Li, F. Yu, D. Shi, J. Shi, Z. Tian, J. Yang, X. Wang and Q. Jiang, "Application of virtual reality technology in clinical medicine," American journal of translational research, pp. 3867-3880, 2017.

[6] C. Pensieri and M. Pennachini, "Virtual Reality in Medicine," Journal of Virtual Worlds Research, 2014.

[7] W. A. Ijsselsteijn, G. Riva and F. Davide, "Being There: The experience of presence in mediated environments," Ios Press, 2003.

[8] ”VRTK,” [Online]. Available: https://vrtoolkit.readme.io/.
[9] W. Greenwald, ”pcmag.com/articles,” 30 April 2019. [Online]. Available: https://www.pcmag.com/article/342537/the-best-virtual-reality-vr-headsets.
[10] A. Abdul-Aziz, A. Koronios, J. Gao and M. S. Suhaizan, ”A Methodology for the Development of Web-based Information Systems: Web Development Team Perspective,” in AMCIS 2012 Proceedings, 2012.
[11] K. Jrgensen, ”Between the Game System and the Fictional World: A Study of Computer Game Interfaces.,” Games and Culture, pp. 142-163, 2012.
[12] F. Shahid, S. Badhwar, N. Javeri and K. Jain, ”AI DevOps for Large-Scale HRTF Predition and Evaluation: An End to End Pipeline,” in Audio Engineering Society Conference: 2018 AES International Conference on Audio for Virtual and Augmented Reality, 2018.
[13] A. Karpathy, P. Abbeel, G. Brockman, P. Chen, V. Cheung, R. Duan, I. Goodfellow, D. Kingma, J. Ho, R. Houthooft, T. Salimans, J. Schulman, I. Sutskever and W. Zaremba, ”OpenAI blog,” 16 June 2016. [Online]. Available: https://openai.com/blog/generative-models/.
[14] L. J. Whalley, ”Ethical issues in the application of virtual reality to medicine,” Computers in Biology and Medicine, pp. 107-114, 1995.
[15] W. S. Bainbridge, ”Introduction,” in Online Worlds: Convergence of the Real and the Virtual, Human-Computer Interaction Series, London, Springer-Verlag London Limited, 2010, p. 1.
[16] P. Cipresso, I. A. C. Giglioli, M. A. Raya and G. Riva, ”The Past, Present, and Future of Virtual and Augmented Reality Research: A Network and Cluster Analysis of the Literature,” Frontiers in psychology, 2018.