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C E R T I F I C A T E

This is to certify that the Seminar work entitled
AR AND VR APPLICATIONS IN HEALTHCARE

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is a bonafide work carried out under the supervision of Dr. Shweta C. Dharmadhikari and it is submitted towards the partial fulfillment of the requirements of Savitribai Phule Pune University, Pune for the award of the degree of Bachelor of Engineering (Information Technology).

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Abstract

Virtual Reality (VR), Augmented Reality (AR) and Head Mounted Displays (HMDs) are revolutionizing the way we view and interact with the world, affecting nearly every industry. These technologies are allowing 3D immersive display and understanding of anatomy never before possible. Augmented and virtual reality are transforming the practice of healthcare by providing powerful and intuitive methods of exploring and interacting with digital medical data, as well as integrating data into the physical world to create natural and interactive virtual experiences. These immersive technologies use lightweight stereoscopic head-mounted displays to place users into simulated and realistic three-dimensional digital environments, unlocking significant benefits from the seamless integration of digital information with the healthcare practitioner and patient's experience. This seminar explores some of the current and emerging technologies and applications in surgery, therapeutic approaches in rehabilitation, pain management, and psychology, their benefits and challenges around immersion, spatial awareness and cognition, and their reported and projected use in learning environments, procedure planning and perioperative contexts.

Keywords: Augmented Reality, Virtual Reality, Healthcare, 3-D environments, HeadMounted Displays, Anatomy, Rehabilitation, Psychology.

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Abbreviations

AR	:	Augmented Reality
VR	:	Virtual Reality
HMD	:	Head Mounted Display
2D	:	2-dimensional
3D	:	3-dimensional
4D	:	4-dimensional
PTSD	:	Post-Traumatic Stress Disorder
ADHD	:	Attention-deficit/hyperactivity disorder
CPR	:	Cardiopulmonary Resuscitation
MRI	:	Magnetic Resonance Imaging
CT	:	Computed Tomography
PET	:	Positron Emission Tomography
CT	:	Computed Tomography
MIT	:	Massachusetts Institute of Technology
USD	:	United States Dollar
MIT	:	Massachusetts Institute of Technology
FDA	:	Food and Drug Administration
SDK	:	Software Development Kit
GPS	:	Global Positioning System

1. Introduction

Here I'll be discussing about the basics of AR and VR, the motivation behind this seminar, what objectives I aim to cover and the seminar's scope.

1.1 Introduction to AR and VR

VR is a technology that immerses the user in a synthetic 3-dimensional (3D) environment via wearable screens in the form of VR headsets, while closely related augmented reality (AR) uses elements of VR and superimposes them on to the real-world environment in the form of a live video displayed on the screen of an electronic device. AR and VR both are aimed at providing and experience for the users that engages their visual and auditory senses by creating an illusion of the surroundings[2].
VR and AR are two contemporary simulation models that are currently upgrading medical education. VR provides a 3D and dynamic view of structures and the ability of the user to interact with them. The recent technological advances in haptics, display systems, and motion detection allow the user to have a realistic and interactive experience, enabling VR to be ideal for training in hands-on procedures. Consequently, surgical and other interventional procedures are the main fields of application of VR. AR provides the ability of projecting virtual information and structures over physical objects, thus enhancing or altering the real environment. The integration of AR applications in the understanding of anatomical structures and physiological mechanisms seems to be beneficial. Studies have tried to demonstrate the validity and educational effect of many VR and AR applications, in many different areas, employed via various hardware platforms. Some of them even propose a curriculum that integrates these methods[2].

1.2 Motivation

The motivation for this seminar is the fact that how AR and VR try to provide solutions for complex real world problems in the field of healthcare and how their applications are abundant if we work towards them in the right manner.

1.3 Objectives

- To give a clear understanding of Augmented and Virtual Reality and their applications in healthcare.
- To understand how AR and VR technology is used and implemented.

1.4 Scope

Improving healthcare facilities around us by using Augmented and Virtual Reality applications and devices.

2. Literature Survey

Here I'll be discussing about the various existing applications and devices of AR and VR that are in use already or have been used in the past.

For at least 20 years, VR simulations have been used to treat patients with conditions such as post-traumatic stress disorder (PTSD), severe pain in burn victims and phobias or fears. VR has been used since at least 1997 to treat soldiers with PTSD. Bravemind is a virtual reality exposure therapy program offered by Virtually Better that helps clinicians expose their patients gradually to stimuli that trigger their traumatic stress responses, allowing them to help the patients recover[4].

The University of Southern California Institute for Creative Technologies is developing prototypes and conducting research in many areas of medical virtual reality. SnowWorld, developed around 15 years ago by Hunter Hoffman at HITLab and Firsthand Technology, was an early VR environment to help distract burn patients from the pain associated with their treatments. It is effective, but there is certainly more to be done in the field of pain management beyond chucking virtual snowballs at polygonal penguins. The founders of Firsthand have recently launched a new venture, DeepStream VR, to continue developing healthcare VR apps[4].

Some other areas of research and development in virtual reality for clinical healthcare include managing phantom limb pain, brain damage assessment and rehabilitation, social cognition training for young adults with autism, meditation for treatment of anxiety and depression, stroke rehabilitation, Alzheimer's, management of ADHD in children, diagnostics and imaging visualizations[4].

In addition to their clinical training modules, Next Galaxy will be releasing CPR and Heimlich maneuver software to public app stores for anyone to learn these life-saving techniques. Vivid Vision is a new company attempting to treat vision disorders such as amblyopia (lazy eye) and strabismus (crossed eyes) using VR headsets. The founder thought of the idea while attempting to treat his own vision disorder. For overall wellness, relaxation, meditation and stress relief there are already many applications available and in development[4].

Personal fitness and exercise is a very large market segment ready to be disrupted by virtual reality. Fitness apps such as Runtastic help you perform a workout, while virtual cycling and bicycle hardware companies like Widerun, Activetainment and VirZoom allow you to enjoy the "outdoors" in any weather condition. Icaros is a particularly fun-looking fitness gaming device that can simulate flying while you work on your six-pack[4].

In 2006, Luminetx introduced a device called VeinViewer and Accuvein introduced a prod-

uct called Accuvein in 2008. They use near-infrared light reflection to create a map of the veins. The received imagery is then either displayed on a screen or projected back onto the patient's skin. Near-infrared vein finder are devices used to try to increase the ability of health-care providers to see veins. Nurses and other health care practitioner can easily pass IV cannula and other parenteral dosage with the help of a vein finder[4].

In 2017, EchoPixel gained 510(k) FDA clearance for the True3D Viewer, the first platform to convert anatomical data from patients into fully interactive, 3-D VR images, allowing one to interact with patient-specific anatomy, from prior MRI or CT scans, in an open 3D space emanating from a desktop display. The system has been used by interventional Radiologist pre-procedural planning of Trans-Hepatic Portal Systemic Shunt placement for portal hypertension-related variceal bleeding/ascites. Radiologists have applied it to CT Colonography to better understand colon lumen morphology and increase polyp detection sensitivity, speed, and accuracy. It was shown that Cardiologists could more accurately and quickly diagnose complex congenital cardiac pathology using EchoPixel. The "body VR" is also one of the first medical commercially available VR visualization tools enabling an immersive holographic view of previously obtained MRI, CT, or PET images. The VR display of patient-specific anatomy can be used for preprocedural planning to affect how procedures are performed[8].

In September 2018 Leica Microsystems received FDA 510(k) gave clearance to market its AR based "GLOW800 surgical fluorescence for vascular neurosurgery". In combination with ICG (Indocyanine Green) and GLOW800, surgeons can view cerebral anatomy in natural color, augmented with superimposed coregistered real-time vascular flow allowing full depth perception. This AR application provides the surgeon with a never before possible immersive view of anatomy and physiology aiding in additional understanding during vascular neurosurgery[8].

In October 2018, The FDA granted 510(k) approval to the OpenSight AR System. This represents the first FDA approved AR medical application for Microsoft HoloLens, now cleared for use in pre-operative surgical planning. This system interactively overlays 2D, 3D and 4D images of patient's relevant anatomy, obtained from pre-operative MRI, CT or PET imaging onto the patient's body. "Persistent Registration™ technology" continuously aligns images with the actual patient. It is suggested that medical surgical procedures could be performed with decreased operative times, with improved precision, and safety. A multi-user experience is possible if multiple operators wear the HMDs. The system also allows AR-based intra-procedural guidance, which has been shown when applies to percutaneous biopsies using 3D freehand biopsy guidance utilizing needle sensors combined with scan-head localization sensors[8].

Recently MedTech Boston listed the top 7 VR digital health companies, which included the following companies. Osso VR which uses VR and HMD to track movements in a sim-

ulator environment to train orthopedic surgeons. SentiAR has developed an AR system for the visualization during interventional procedures. An interactive 3D hologram of the patient's anatomy and catheter location is displayed. "Through the Microsoft HoloLens, physicians have full control of their view using real-time navigation data, rather than MRI/CT, for procedures like catheter-based electrophysiological ablations for the treatment of arrhythmias." The AR platform enables real-time mapping/catheter location outputs into a real-time hologram in the clinical field of view in an immersive patient-specific cardiac model resulting in significantly faster and more accurate procedures. FDA approval is currently pending. MedTech Boston stated that ImmersiveTouch has been a premier provider of Medical VR and AR products for over 13 years. Their proprietary haptic technology, incorporating tactile feedback into VR based simulation is FDA approved for pre-procedural planning[8].

3. Methodologies

3.1 Framework/Basic Architecture

Studied about the various frameworks and tools used in the development of AR and VR applications. Few of the various software frameworks used in the development of AR and VR devices and their applications are listed below :

- Vuforia
- ARcore
- Wikitude
- Unity AR
- Amazon Sumerian
- Blender 3D Computer Graphics Software Toolset
- OpenVR SDK
- Unity Virtual Reality Engine
- Autodesk 3ds Max® Modeling and Rendering Software
- Eyeware Beam Head and Eye Tracking Software Development Kit
- Google Cardboard – Cardboard VR Developer Tool

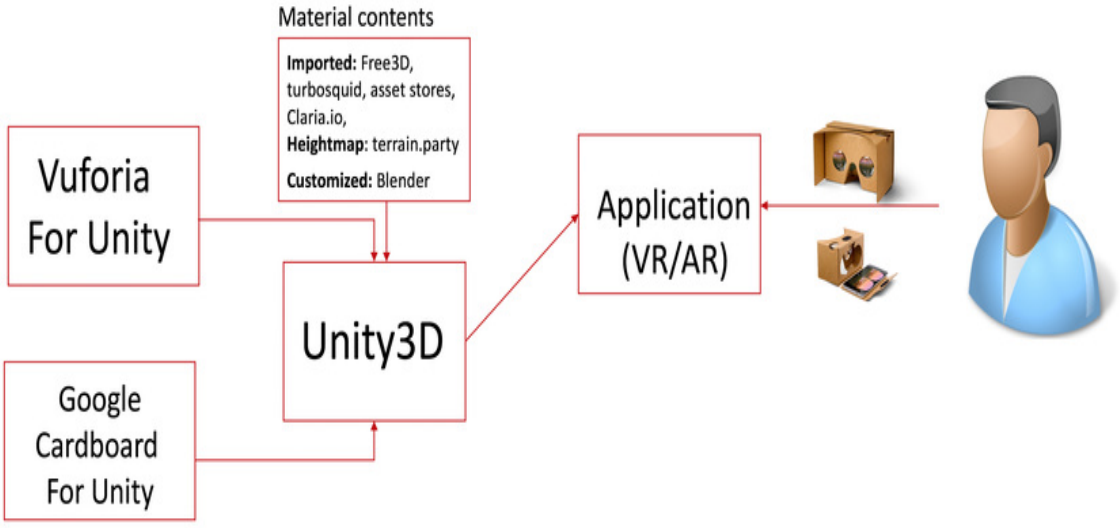

Fig. 1 : AR/VR application frameworks[10]

3.2 Applications of AR and VR in Healthcare

The various applications of Augmented and Virtual Reality in Healthcare industry are :

1. **Advanced Diagnostics / Risk Assessment :**

   Diagnostics is one of the critical areas of healthcare that often relies on precise results and a close assessment of various symptoms. It is a dubious and often tedious task where every detail matters and can potentially break the diagnosis in a different direction (for an illustration, watch a random episode of House M.D.).

   What Augmented reality can add to the table? Lots of stuff. AR can play a significant role in more efficient detecting, preventing, and treating many diseases. Starting from visualizing information coming from sensors into one cohesive interface to showing potential causes of a patient's state via analysis.

   With AR - a doctor can look through the layers of the patient - check veins, organs, lesions, and other things without actually penetrating. All this can increase the precision of diagnosis. And that is always a good thing.

   Microsoft's HoloLens is one of the premier examples of this. With its help, doctors can do all sorts of checks and simulations with live stats and extract more valuable data for further research[5].

2. **Improved Patient Experience :**

   Patient experience is one of those elusive things that barely gets mentioned when it comes to talking about how VR AR can make the Healthcare system better. However, in reality, patient experience is the one field that gets the most out of the implementation of VR AR to the operation.

   Immersion and engagement matter a lot for successful treatment, and it is often the one thing that gets limited attention due to its relatively inconsequential influence in the grand scheme of things. I mean - when it comes to matters of life and death, customer experience is not the thing that comes to mind first.

   Augmented Reality solutions can significantly improve the overall patient experience and make it less problematic by adding pop-up information and navigating features among other things.

   The other way, AR VR healthcare applications can improve Patient Experience is via an extension. As you know, chronic patients often experience the discomfort of being partially left to their own devices in-between the procedures. VR AR can make their

experience a little bit less uncomfortable and probably more exciting.

For example, AR VR can be used to maintain better communication with their relatives. Also, Virtual reality physical therapy can be used to spend time in places outside the hospital in an elaborate variation of the "try before you buy" scenario (you can read more about this in our article about VR AR tourism). On the other hand, AR can help the patient to keep track of their vital stats and stay tuned with their therapy progress in a more engaging manner[5].

3. **Psychological Relief and Treatment :**

   The immersion factor also opens up a gateway toward new ways of therapy. For example, an elaborate virtual reality environment can be used for pain reduction and improvement of sleep habits. Also, VR can be used to help amputees to get accustomed to their state and experience once again their missing limbs.

   On the other hand, specific environments can be used to treat mental conditions, such as anxiety, various kinds of phobias, and addictions. VR Healthcare Simulation of events can help better understand the patterns of disorders and develop more effective treatment strategies.

   VR has proved to be extremely useful in treating Post-Traumatic Stress Disorders of a different kind. VR PTSD treatments have two modes:

   * aimed at relaxation and stabilization of the patient.

   * aimed at teaching the patient to overcome the PTSD bouts.

   However, in this case, it is too early to claim that this approach is useful in the long run[5].

4. **Body Mapping :**

   When it comes to visualizing patient data, Augmented Reality plays a major role there. AR has so far been successful in calculating the possibility of live stats on the basis of collected patient data. To be more clear, AR eliminates the need for multiple machines required for accessing patient data and directly points out the problematic areas further saving both time and money.

   Body mapping is one such great use case of Augmented Reality and Virtual Reality, as the combination helps doctors in recreating patient's body which was previously a prolonged and complicated task. The body areas that were previously inaccessible even after a physical examination, AR and VR recreates the patient's body map efficiently and

in far lesser time as compared to the traditional body mapping methods[5].

5. **Surgery Run-Throughs :**

   Surgeries require intricacy and attention to detail to be effective. Surgery done right is something like a military operation. It goes in bouts of intense planning and consideration of various options results in a systematic realization of the plan step by step over short periods. Seems like a perfect place for Virtual Augmented reality solutions.

   AR VR Surgery can provide models for planning an operation and playing out various scenarios to optimize the sequence and prepare a course of action for any circumstances. While there are doubts that the VR environment will be able to play out every detail of the proposed scenario any time soon, the prospect of the technology improving the process of preparation is exciting[5].

6. **Surgery Assistance :**

   Surgery is one of the most exciting areas where Augmented reality can be implemented. There can be several ways it can be done.

   Let's count them down :

   * As a visual shorthand for operating procedures required in different scenarios (for example, with the assistance of Hologram monitors);

   * As a reference board with various information emerging at request - such as patient care, patient's vital stats, critical information on a disease and its treatment.

   * As remote assistance in complicated cases that require increased caution over possible consequences;

   With the help of VR, surgeons can work out the surgery beforehand and experience possible outcomes without actually having to deal with them in reality. Such "rehearsals" can help to make the whole operation more precise and controlled.

   Virtual Reality can also solve the issue of availability in extreme scenarios. VR environment can be wired to the remote-controlled robot which will handle actual operation while the surgeon performed the routine elsewhere. While this approach is unlikely to replace surgeons completely, it can come in handy in some situations[5].

7. **Medical Education/Training Simulation :**

   One of the biggest global challenges of the health care system is an infinite lack of trained professionals. However, the implementation of VR AR solutions can seriously simplify the whole process of medical education and subsequent training. For starters, VR Health-

care Training is a good way of studying human anatomy layer by layer and the mechanics of the human body. On the other hand, AR VR provide interactivity which provides much more profound insight into nuances of the body functions.

Cutting edge technology is especially critical when it comes to the training stage as it is near-impossible to imitate near-real life conditions to prepare professionals, which is less of an issue with the implementation of VR.

With a little help of a headset and a wide array of various sensors - it is possible to recreate a scenario that will put to the test trainee's skills in a much more engaging manner. A possibility to experience a surgery not as a passive spectator but in a simulated scenario is a valuable test of ability[5].

8. **Doctor Consultation :** Doctor consultation is one of the integral elements of the healthcare system. It is what makes it the backbone and serves as early warning protection from potential threats.

   However, doctor consultations are not always available in specific remote locations. Implementation of VR services for that is a logical solution to this problem. With its help, doctors will be able to provide consistent eye-to-eye contact and also deliver essential services like pulse examination and emotion reading (vital for psychological therapy consultations). and For example, such a thing is practiced on American Antarctic Research Stations. On the other hand, such practice is tried out in India[5].

9. **Emergency Navigation :** Healthcare apps can also benefit from navigation and geolocation features as well. First and foremost, routing can be used in finding the closest hospital and guiding to it. While its practicality is still limited, it is an option that can potentially save someone's life, and that is always important.

   On the other hand, routing can be used by patients to navigate in large hospital structures to find where their doctors are situated or how to get to a place where their procedure will take place. It might seem unnecessary when you're healthy, but when you're sick and need the path of least resistance, an app like this might be a lifesaver (especially when you're at a large hospital.[5])

10. **Cognitive Recovery and rehabilitation with VR :**

    Virtual reality aids in speeding up the recovery and cognitive rehabilitation for patients. Patients with cognitive or similar disabilities caused by brain injury are often faced with the lack of abilities and motivation to participate in the rehabilitation can have effective

treatment through VR tools. Patients can interact in the virtual environment and practice some tasks that are hard to do for them in reality. There is already a developed virtual reality-based neurorehabilitation gaming system that helps patients a lot in their motor and cognitive recovery.

While VR devices can record and track all activities and personalized the virtual experience for each user's needs. As a result, it helps speed up patients' recovery process, and they get better and heal VR helps to regain muscle control[5].

Company	Application	Function	Type	Headset
Medical Education & Image Guided Treatment				
ANIMA RES	Insight Heart	Provides medical education on the heart	MR	HoloLens
Case Western Reserve University	HoloAnatomy	Allows users to study human anatomy	MR	HoloLens
FundamentalVR	Fundamental Surgery	Surgical simulation	VR	HTC Vive, Oculus Rift
ImmersiveTouch	ImmersiveView VR	Surgical planning; **FDA 510(k) Class II; Europe CE Class IIa**	VR	HTC Vive, Oculus
Medivis	AnatomyX; SurgicalAR	Anatomy education platform; surgical imaging solution	MR	HoloLens; Magic Leap
Novarad	OpenSight® Augmented Reality System	Surgical planning; **FDA 510(k) Class II; Europe CE Class IIb**	MR	HoloLens
Mental Health, Pain & Wellbeing				
Karuna Labs	Virtual Embodiment Training	Chronic pain management	VR	Oculus Quest
OnComfort	Aqua; Amo; Kimo; Spacio; Stella	Stress, anxiety & pain during medical procedures and chemotherapy	VR	Gear VR
Virtually Better	Phobias, Addictions & PTSD Suites	Phobias, Addictions & PTSD	VR	HTC Vive
XRHealth	Relax8	Pain management	VR	Oculus Go and Quest
Behavioral Health				
Cognoa	Superpower Glass	Improve social skills in autistic children	AR	Google Glass
Brain Power	Empowered Brain	Improve social-emotional skills in autistic children	AR	Google Glass
Rehabilitation				
Immersive Rehab	VR Neuro-Rehab	Improve the effectiveness of physical & neuro-rehabilitation	VR	HTC Vive, Oculus Rift
Rewellio	Rewellio app	Stroke rehabilitation	VR	Oculus Quest

Table 1 : Healthcare applications for AR/VR

3.3 Discussion

This analysis of various publications on VR and AR applications in medicine revealed that the field began to develop in the 1990s, grew in the 2000s, and has been thriving in the 2010s in terms of both publications and citation counts.

The use of VR simulators helped in diagnostic and surgical procedures, such as improving novice hospital residents' laparoscopic skills in terms of error and procedure time reduction. It was also used to assess the suturing skills of different groups of operators. In surgery, it was suggested that VR and simulation could be of value for 4 aspects, namely training and education, surgical planning, image guidance, and telesurgery.

The use of VR might also help rehabilitation clinicians conduct tele-rehabilitation on a remote basis so that the patient (eg, after stroke) carries out exercises at home in a virtual environment and data are then transmitted to the clinician. Moreover, VR could incorporate gamified elements so that the process could be more rewarding (eg, for encouraging patients with PD to do more remotely supervised aerobic exercise). Non-immersive VR has also been used to add cognitive challenges and virtual obstacles to treadmill training for older adults, targeting attention, perception, and dual tasking during walking with the aim to reduce fall risk. Since the existing studies were quite diverse, more studies should be conducted to optimize the implementation and evaluate the beneficiary effects in different population groups, so that a recommendation can be made for how to use VR in cognitive rehabilitation.

This seminar focused on the various applications of Augmented and Virtual Reality in the Healthcare Industry. Based on the applications of AR and VR in Healthcare industry as discussed above, it will be safe to say that AR and VR will improve the Healthcare industry only towards a positive path. The applications of these two technologies are still abundant and once we are able to harness their power much more efficiently, the human race will start progressing at a much greater rate.

In order to switch completely towards AR and VR solutions, more research and development is needed to be done on them. Students should be taught about these emerging technologies in school itself which will act as a base for them and help them to develop an interest into these fields which will in turn harness the effectiveness of these technologies.

The direction in which the world is moving towards right now, it will be fair enough to say that AR and VR will be playing a huge role in almost all aspects and industries. The future can be seen as where there are much better healthcare facilities all around the world thanks to the advancement in AR and VR. Better healthcare facilities include highly skilled medical practitioners, fast medicinal facilities, better and efficient solutions to complex medical problems, low-cost, more no. of hospitals and an increased life expectancy rate.

4. Implementation

4.1 Algorithm/Methodologies

1. **Vuforia :**

   Vuforia is an augmented reality software development kit (SDK) for mobile devices that enables the creation of augmented reality applications.[1] It uses computer vision technology to recognize and track planar images and 3D objects in real time. This image registration capability enables developers to position and orient virtual objects, such as 3D models and other media, in relation to real world objects when they are viewed through the camera of a mobile device. The virtual object then tracks the position and orientation of the image in real-time so that the viewer's perspective on the object corresponds with the perspective on the target. It thus appears that the virtual object is a part of the real-world scene.

   The Vuforia SDK supports a variety of 2D and 3D target types including 'markerless' Image Targets, 3D Model Target, and a form of addressable Fiducial Marker, known as a VuMark. Additional features of the SDK include 6 degrees of freedom device localization in space, localized Occlusion Detection using 'Virtual Buttons', runtime image target selection, and the ability to create and reconfigure target sets programmatically at runtime.

   Vuforia provides Application Programming Interfaces (API) in C++, Java, Objective C++, and the .NET languages through an extension to the Unity game engine. In this way, the SDK supports both native development for iOS, Android, and UWP while it also enables the development of AR applications in Unity that are easily portable to both platforms.

2. **Blender 3D Computer Graphics Software Toolset :**

   Blender has been a titan in the 3D model and animation industry since 1994. It's free and open-source software built to design 3D printed models, animate 3D models, and use those assets in 3D applications like animated films and VR games.

One of the best features for virtual reality developers will be the built-in rendering tool. Blender has an unbiased path-tracer engine that offers stunning ultra-realistic rendering. This powerful rendering developer tool has a real-time preview, CPU GPU rendering, PBR shaders, HDR lighting support, and of course, supports VR rendering, modeling, rendering, animation, rigging, sculpting, and simulation processes are compatible on many systems, including Linux, macOS, Windows, Android, FreeBSD, OpenBSD, NetBSD, DragonFly BSD, and Haiku.

3. **OpenVR SDK :**

   OpenVR SDK is an open VR software development kit (SDK) and API that supports HTC Vive and other VR headset related devices. SteamVR SDK and VRTK (Virtual Reality Tool Kit) are also used for HTC Vive. These offer additional benefits like access to controllers, chaperoning, models, and preview in Unity playmode.

4.1.1 Limitations and Constraints

Potential limitations to the use of AR and VR in healthcare need to be considered. For example, the amount of information a surgeon has presented to them through AR during a surgery is increasing and may become distracting or imprecise due to latency issues or misalignment of imaging data or annotations. Therefore, it is necessary to display only important data or provide a method to switch between different sets of information on demand. Hansen et al. proposed a method for the reduction of cognitive demands, where they developed a series of algorithms for silhouettes and texture gradients beneficial for distance assessment in liver surgery, with the goal to increase acceptance of AR in the operating room. However, participants in the study reported that too much information was presented to them, and the authors highlight that the usability of the visual cues correlates with the user's familiarity with the illustrative techniques, proposing their integration in surgical training. 4 Another key factor is assuring clinical staff with regard the anatomic fidelity of any images, particularly when there may be remote interventional guidance in an AR environment.

Clinicians would want to know discriminatory resolution between vital structures and have confidence they would not miss any injury or other pathology. Main challenges remaining for future research include improving the experience in immersive VR/AR simulators of organ movement and deformation, human factor issues, and the undertaking of large clinical studies. Basic human perception and interaction factors need to be further developed to improve the experience. Rendering of content is commonly required to be commensurate with photo realism, particularly in training environments. Another unresolved issue is the influence of audio–visual quality in aiding human cognition, and defining clearly this quality concept in this surgical context—for example, a vascular surgeon in an operating theatre and a paramedic on a car accident site might require different levels of visual detail and audio quality.

5. Applications

5.1 Applications of AR and VR in other Industries

1. **Hospitality :**

   There are various ways in which the hospitality and tourism industry can benefit from implementing virtual reality training. Still, the most significant benefit is soft skills training since soft skills are essential for this industry. A great example of companies using virtual reality training in the hospitality industry is Honeygrow, a fast-casual restaurant chain. VR provided trainees with a tour of a Honeygrow location with a 360-degree view while employees listened to the company's values from the Founder and CEO of the company[9].

2. **Tourism :**

   There's nothing like a global pandemic and lockdowns to make you miss the freedom to travel to different countries, visit world-famous landmarks, and experience a glimpse into another culture. Imagine being able to experience a guided tour of Barcelona or Budapest from your home in California or Singapore. With VR, you can do just that. You can even take a Harry Potter tour of Edinburgh from anywhere in the world!

   In the post-Covid era, the developments in VR for tourism enable you to try a holiday before you buy it. Thomas Cook launched their 'Try Before You Fly' VR experience back in 2015, where potential holidaymakers could visit stores in various countries to experience the holiday in VR before booking it. As a result, there was a 190 percent uplift in New York excursions bookings after people tried the 5-minute version of the holiday in VR[9].

3. **Retail :**

   The way we shop online is set to drastically change with 'the metaverse'. With VR retail experiences and body-scanning technology, we will be able to try on clothes in the virtual world to see what they'd look like in person. Not only is this a time-effective experience for shoppers, but it's also more sustainable because customers will know be-

fore they order whether the item fits their shape and size, reducing the environmental cost of production and shipping fast fashion. Various companies are attempting to bring us the VR shopping experience, including the European retailer ASOS, who invested in software development company Trillenium. Fashion houses like Hugo Boss will be amongst the first taking part in the first Metaverse Fashion Week in March 2022, where there will be virtual catwalks, stores, and fitting rooms. And it's not just fashion getting a makeover. Back in 2015, eBay launched 'the world's first virtual reality department store' in partnership with Australian retailer Myer. Is this the future of shopping?[9].

4. **Manufacturing :**

   In manufacturing, various aspects of training can be improved with virtual training technology. With manufacturing, one wrong move can have harmful consequences. Employees who are unfamiliar with machine controls are prone to injure themselves as well as their co-workers. A great example is the company Airbus where the implementation of VR training enabled them to reduce the duration of maintenance processes by 25 percent. Virtual Reality training allows manufacturing workers to grasp the system and develop an efficient routine for operating the equipment. It's also an excellent tool for instructors to monitor their performance[9].

5. **Education :**

   The impact of e-learning apps amid coronavirus where the educators have begun to use of AR and VR in education with this technology in their teaching practices as the technology advances. Teachers employ augmented reality applications in the classroom to animate scientific texts and study flashcards, making the learning process more engaging for students. Some teachers utilize AR to supplement their students' assignments by integrating interactive puzzles and quizzes.

   How AR can help in education with virtual reality classrooms has also begun to include social events and training programs. They provide a platform for individuals to connect and work in virtual settings, intending to improve the learning process once more. Learners can accomplish 'impossible' tasks like visiting inside a brain cell or going back in time.

The usage of interactive 3D models in VR/AR in education helps students become more engaged in learning about a topic. Virtual reality education software may gamify technology to enhance the learning experience rather than just presenting facts. It can help the student understand the information by visualizing it; it can also provide challenges to encourage them to engage with the topic[9].

6. **Military :**

   Military technologists are of the opinion that the technologies like VR have the potential to redefine the modern day warfare and there is a need to research more on such technologies beyond the fighter pilot heads-up-display and medical applications. Currently, the work is under progress to develop the soldier helmets which could communicate with a main server that collects and delivers 3-dimensional information onto the wearer's goggles in real time. With the help of a color code, the soldiers would be warned of the things such as friendly forces, potential danger spots, impending air-raid locations, rendezvous points and many other important aspects[9].

7. **Entertainment :**

   AR and VR in entertainment and media were worth 5.12 billion USD by 2019 and are projected to reach a CAGR of 31.8 percent by 2027 to 45.20 billion USD. The entertainment industry consists of various subsets such as the film industry, the live events industry, sports, gaming, theme parks/ amusement parks. Each of these subsets could find different ways to integrate augmented and virtual reality. For example, in the live events industry, people in Delhi could view a concert taking place in Hyderabad. Perhaps, they could download a replay and view it at their own time. It doesn't have to be a concert, it could be a play, an opera or even a comedy show. The technology is currently being applied to allow users to immerse themselves in various games and sporting events. It has also been a staple in the news, especially the weather where graphics are displayed on television to indicate the climate. VR forms a predominant part of the media entertainment industry that is focused on enhancing and producing video-based immersive media like movies, TV shows, and other forms of video content. Beyond this, VR is also being implemented in museums and art galleries to make the tour interactive with a contextual

background and to provide a rich user experience. On the same lines, virtual rides are being developed for theme parks which are usually difficult to simulate in reality. Virtual reality in entertainment is undergoing rapid changes, especially with the launch of 5G on the horizon. With VR technology creating more immersive experiences wherein the viewer will be able to watch the sports from any angle they wish to, and even be part of the action on-field while being able to retrieve player information at will, VR technology is touching science fiction[9].

5.2 Challenges

1. **Monetary/Funding Issues :**

   Many of the respondents are startups developing AR/VR content, eyewear, or end-to-end solutions. So it's not surprising that money and funding for product development, research and other marketing costs are at the top of the list. VR/AR for healthcare is still in its infancy, in search of technology innovators and visionaries willing to demo, refine and evangelize widely marketable applications. Given the obvious benefits of various emerging VR/AR technologies including pain diminution, surgical planning and practice, 3D radiological imaging and medical education, we're confident that it won't be long before customers and investors start to invest in best-in-class solutions.

   Committee members have noticed that hospitals are increasing budgets for clinical simulation centers to allow them to purchase VR/AR equipment. Third party companies that work with medical organizations are starting to budget for VR/AR solutions as well[6].

2. **Technical limitations :**

   This is a broad category and responses reflect a multitude of use cases. For some, the size of VR systems limits their use in certain clinical settings. For others, mobile VR platforms can only provide so much immersion with a pocket size computer. Computer specifications and resolution of available devices can also be limiting factors for some medical centers. VRARA Digital Health committee members are working on near-term solutions to these challenges. This is another area that we feel confident will improve over time as Moore's law and market competition lead to improvements in both size and

power[3].

3. **Clinical organizational issues :**

   You've probably heard that healthcare is a hard industry to change, and not lacking in bureaucracy. Electronic medical records, for example, have been in use at major hospitals for almost two decades, yet there are many places that still use paper charts.

   Committee members and respondents identified several aspects of modern clinical organizations that can impede adoption of VR/AR technologies in healthcare, such as: availability of and access to infrastructure (i.e. bluetooth connectivity); platform friction (compatibility of VR/AR software with other healthcare software, EMR issues, and privacy issues); and procurement procedures (vendor relations, lengthy and complex public tender processes, and arduous hospital board decision making processes.)

   AR solutions are likely to be adopted more quickly due to decreased platform friction of widely-adopted smartphone technologies. But it's our guess that clinical organizational issues are likely to be some of the hardest (and slowest) issues to resolve[6].

4. **Lack of enough research studies around VR/AR in healthcare :**

   A quick search of research studies shows over 3536 publications with "virtual reality" or "augmented reality" or "mixed reality" in the title since 1991. However, depending on the clinical use case there may only be a handful of useful studies. AR/MR tech is so new that only a small fraction of published research (574) examines its use in healthcare. Several areas still need randomized control trials to show evidence for mainstream adoption of AR/VR/MR by healthcare providers[6].

5. **Side effects of virtual reality :**

   Common side effects Cybersickness and perceptuomotor after-effects have been reported as the potential side effects of VR. In fact,the main concern for VR users is simulation sickness, or cybersickness.Also, headaches and eye strain are seen in prolonged exposure with VR systems.

   Similar to motion sickness, cybersickness (for example, nausea, vomiting, eye fatigue, dizziness, ataxia, dizziness, etc.) is related to the conflict between different body sensory systems,32 which is due to an inconsistency between the sensory inputs. Some cybersick-

ness cases persist such as when the real gravity is in contrast with the seen environment, for example, when the user is flying in an airplane in VR[7].

6. **Safety considerations :**

   VR treatment based on the expert opinion Like any other type of treatment, VR should only be used when it is prescribed by the appropriate clinical expert. Using services such as VR rehabilitation or any type of emerging technology such as telepsychology and online therapy, according to the patients' opinion (self-diagnosis, self-help, and self-treatment) can place patients at potential risks.

   Creating safety parameters VR can cause problems in the cognitive organizations, human experiences, memories, judgments, beliefs, and distinguishing between themselves and the environment. Having multiple virtual experiences over the years can make real judgment and self-identity difficult. Therefore, managing the health and safety implications of VR are important things to be considered. Regarding telerehabilitation, home-based VR therapy without the direct supervision of the therapist may pose certain risks[7].

6. Conclusion

Advances in VR and AR are undoubtedly transforming healthcare processes, enabled by collaboration between clinicians, scientists, patients, software companies, and hardware manufacturers. Technical, cognitive, scalability, and adoption challenges are driving further innovation toward industry-specific solutions for more proactive and personalized health services. AR and VR bring new data integration capabilities that are supporting efforts worldwide toward the digitalization of hospitals, delivering unique benefits including enhanced medical training, remodeled patient experience, distribution of centralized expertise, and streamlined medical procedures.

The effects of AR and VR on the Healthcare industry have proved to be much and much better as compared to the methods used in the past due to which patients also have a sense of relief amongst them while going under and medical operation. The AR and VR in healthcare industry will continue to rise high in the future because of it's vast applications and better results over time which will be a good thing for the entire human race.

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