VR Technology and its Applications, Challenges, and Future Prospects

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Abstract. Virtual Reality (VR) technology is increasingly becoming an important technology. It plays an important role in our daily life. VR technology in general refers to a computer technology that enables the creation and experience of virtual worlds. It has a wide variety use in the fields of education, entertainment, and medication. For example, in education; it can create a more immersive environments for students to learn; in entertainment, there are many VR games for people to have fun; in medication, it can help doctor operate surgeries more smoothly. However, there are some obstacles and challenges currently. VR devices currently can still have delay, which cause dizziness to users. In education, the cost of VR teaching can be too high to afford; in medication, patients personal information can be divulged while transporting. Nevertheless, these problems can be solved. VR devices can collaborate involve and collaborate with other units and devices to reduce dizziness; By mainly adopting traditional teaching methods and supplementing with VR, the cost can be reduced while still allowing students to experience VR teaching; By anonymizing the patient information, personal information can be prevented to spread out. Therefore, although there are challenges in using VR technology, they can be overcome, and we are able to use VR technology to improve our daily life.

Keywords: VR technology, Education, Entertainment, Medication

1 Introduction

With the developments of technology, a new technology was born-- interactive technology. Interactive technology refers to all the ways and methods through which humans interact with machines or system.

Among interactive technology, VR technology is the most significant one. In general VR is a computer technology that enables the creation and experience of virtual worlds. Its core lies in using specific devices to simulate sensory experiences in three-dimensional space (such as vision, hearing, and touch), allowing users to have an immersive feeling as if they were actually present in the virtual environment. It was first proposed by Jaron Lanier, the founder of VPL Research in the United States, in 1989 [1]. VR plays a significant role in our daily life. It improves our lives in many aspects. For example, education, entertainment, and medication.

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This study mainly focusses on the VR technology itself and its influences to the human society. Specifically, it will introduce and reveal the working principle and scenario of VR. Furthermore, it will present and analyze previous researches of VR 's impacts on human society and will propose new ways of how we can apply it in our lives. It will mainly focus on entertainments, educations, and medications. Finally, it will raise overcoming challenges and determining future optimization directions of the application.

This study analyzes the potential uses of VR technology. It focusses on the application of education, entertainment, and medication. It points out current's drawback of VR technology, and proposes some future prospects. It aims to help people make better use of VR technology, which will further improve human lives.

2 Analysis of the basic principles

2.1 Definition

VR is a simulated environment generated by computer technology. It uses devices such as head-mounted displays (HMD) to provide users with an immersive experience, making them feel as if they are in a virtual world [2]. VR contains three core features: immersion, interaction, and imagination. Immersion refers to using multiple sensory stimuli (such as vision, hearing, touch, etc.) to isolate the user from the real world, to enable users to be completely immersed in the virtual environment. Interaction refers to that users can control virtual objects in real time through natural actions (gestures, walking, eye gaze), so the system will respond dynamically to the users' behaviors. Imagination refers to breaking through physical limitations to create scenarios that do not exist in reality or are difficult to experience.

2.2 History

In 1935, American writer Stanley G. Weinbaum described a pair of glasses that could enable the wearer to experience a complete virtual world including taste and smell, which was regarded as an early literary conception of the VR concept. In 1968, the father of computer graphics, Ivan Sutherland, and his student Bob Sproull created the first truly head-mounted display system, which, achieved a real-time interaction between a computer-generated virtual world and the user's head movements for the first time, establishing the basic paradigm of VR technology. During 1980s to 1990s, the concept "VR" was first proposed formally and commercialized. VPL Research became the first company to sell VR commercial products, including Data Gloves and Eye Phone headsets; the Japanese game companies Sega and Nintendo are attempting to introduce VR to the consumer market. In 2000s, VR technology continued to develop and be applied in professional fields such as military, aviation, medicine, and industrial simulation. The processing capabilities of graphics, tracking technologies, and computing power were also quietly improving. Since 2010s, VR industry has been rocketing. In 2012, the Oculus Rift crowdfunding project initiated by Palmer Luckey attracted significant attention due to its excellent design and relatively low

cost. In 2014, Facebook (now Meta) acquired Oculus for $2 billion, which completely ignited the investment of global tech giants in VR. Subsequently, HTC Vive and Sony PlayStation VR were launched, promoting the initial formation of the consumer-level VR ecosystem. In recent years, the focus of technology has shifted to standalone headsets (Standalone HMD) that do not require a connection to a computer, providing a more convenient and free experience. VR has also begun to explore applications in a wider range of scenarios such as social interaction, fitness, and remote collaboration.

2.3 Working Principle

VR system's core hardware components include head-mounted display (HMD), tracker, input equipment, computing element. The function of HMD is to provide binocular stereoscopic vision, presenting 3D images through separate screens/lenses for the left and right eyes. The function of tracker is to capture users' head and limb movements in real-time. The function of input equipment is to map user actions to the virtual world; some examples are handled, data glove, and eye tracker. Calculation unit includes PC, host computer, and system on chip, which are for rendering complex 3D scenes in real-time.

The core technical principles include stereoscopy, motion tracking, real-time rendering, and spatial audio. In stereoscopy, the HMD displays images with parallax for both the left and right eyes, which enables the brain to combines them to create a 3D image with depth perception. The screen refresh rate needs to be higher than 90Hz to avoid sway function, and the field of view (FOV) needs to be higher 100° to enhance immersion experience. In motion tracking, the head position and rotation are tracked through gyroscopes, accelerometers and infrared sensors. In real-time rendering, the graphics engine (such as Unity/Unreal) generates the scene dynamically based on the user's perspective, with the delay being less than 20ms to avoid motion sickness. Spatial audio adjusts the sound direction dynamically based on the head position (such as the Oculus HRTF technology), enhancing the sense of environmental realism.

3 Application

3.1 Applications in Education

VR technology has a wide variety of uses in the field of education. First of all, when it comes to field practice learning, VR technology enables students to interact with surrounded environment in a more immersive way, which will help increase their engagements in class to better understand concepts that are taught in class [3]. Specifically, when teachers are teaching, they may present objects to help students understand the essence. VR technology can scan the object and can provide students with additional information with further explanations; therefore, students can have a deeper understanding. This application can be used in a wider range in the future if the cost decrease.

Secondly, VR technology is a good method to help students observe and decipher objects without being limited physically. VR can create a fully virtual environment which allow students to wonder and explore around without really going to that place [4]. For instance, when learning about the blood system of human body, VR technology can enable student to take a trip through the blood system: Students are able to “miniaturize” themselves virtually to enter blood vessels; therefore, they can take a trip through the blood system by tracking the blood cell’s transportation path, which can help them have a deeper understanding.

Thirdly, VR technology is a good method to enable students to overcome their fears, which will stimulate their courage to explore new knowledge. Specifically, VR technology can stimulate a high-risk situation under a safe environment; therefore, students can take bold attempts without worrying about risks and safety. For example, when students are doing high-voltage electrical experiments, the "blowing up" of the virtual laboratory ensures zero loss, so students can repeatedly adjust the magnetic field parameters without limit on the number of times, and they also do not need to worry about causing severe fire disasters in the real world.

3.2 Application in Entertainment

VR technology has a wide variety of application in the field of entertainment. In the field of tourism, VR technology enables people to travel to a place virtually without really visiting that place in realistic. This can be crucial to students and young workers particularly; as they are scheduled with endless assignments, classes/ meetings, it is hard for them to have time to travel, so this application can be very time-consuming. Meanwhile, VR technology.

VR technology has shaped greatly on the field of games. VR technology can increase the sense of immersive for users. Specifically, VR glasses such as Apple Vision Pro contains Micro- OLED screens and folded optical paths, which can provide users with a high-quality image; additionally, the inertial measurement unit sensors are able to catch up with the user’s head and hand movements, which enables the image to shift in real-time. As a result, this can provide users with an excellent experience while they are playing these immersive 3D games, just as if they were really in the environment. This will increase the immersive sense, letting users to involve a high degree of concentration and a sense of personal control [5].

VR has made significant improvements in the field of sports. First of all, professional athletes can benefit a lot while training. In the field of soccer for example, VR technology is able to map the movements of players to create digital characters. Therefore, athletes can repeatedly observe details such as their running positions and passing angles, and make real-time adjustments to their tactical decisions, which will benefit them in the real game. Additionally, VR technology is able to create a vivid and immersive virtual environment, which enables people to play sports indoors [5]. For example, In Shanghai, the "National Fitness Day" has launched a VR skiing program. Users can control the direction of their virtual skiing through core strength, experiencing the thrill of high-altitude speed descent in a snowless environment [6].

3.3 Application in Medication

VR technology has significantly played a role in health intervention, which greatly help improve people's health and fitness. Weight loss has always been a problem for some young people. In this case, with help of REVERIE system, the AI coach provided empathetic guidance based on deep reinforcement learning. Researchers from The Sixth People's Hospital of Shanghai Jiao Tong University School of Medicine and Shanghai University of Sport found out that after an 8-week intervention, the fat mass of obese adolescents decreased by 4.28 kg, and their liver function and blood lipid levels improved simultaneously [7].

VR technology has helped improve humans' psychological health greatly. It plays an important role in treating people's depression. Researchers from UCLA studied on 80 patients with moderate to severe depression. Researchers randomly assigned them into two groups. One group was the VR Reward Training group (VR-RT), which took place at comfortable and private places. Participants would be immersed into positive scenario and guided positively. The other group was the VR Memory Training group (VR-MT), which provided neutral scene memory training. Patients received either of the interventions for seven weeks. Researchers concluded that the depression symptoms in the VR-RT group decreased by an average of 30%, and the improvement in positive emotions was positively correlated with the recovery of daily functions [8, 9].

VR technology helps doctors and patients a lot in medical workflow. Take Apple Vision Pro as an example, it uniquely combines high-resolution displays, precise eye tracking, and seamless user interfaces, providing significant advantages in clinical environments, particularly in improving patient care, medical training, and immersive visualization experiences [10]. Apple Vision Pro's high-resolution display and mixed-reality functions offer substantial improvements to diagnostic imaging accuracy and surgical planning precision, presenting clinical physicians with comprehensive, interactive 3D visual representations [11]. Additionally, Apple Vision Pro can create immersive and interactive learning environments, which have the potential to revolutionize medical training, as they allow for realistic simulations of complex procedures and emergency situations [12].

4 Challenges And Future Optimization

4.1 Challenges

Although VR technology has helped improved our lives greatly, it still has many challenges. In the hardware of VR devices, users claimed that they have experienced dizziness during the initial stage of use, which is mainly due to a conflict between visual and vestibular senses, such as head movement and a delay of more than 20ms in image update. Meanwhile, the current mainstream VR headsets have achieved a single-eye resolution of 2160×2160, but in complex scenarios, there is still the screen-door effect, and the insufficient GPU computing power leads to fluctuations in the frame rate of dynamic scenes.

In the field of education, the VR teaching experience cannot fully replace the actual hands-on operation. The production of immersive courses requires a professional team, and the cost per class hour can be more than 10 times that of traditional courseware. Meanwhile, VR technology cannot perfectly replicate the actual teaching scenarios. For example, in chemical experiments, VR can only simulate pre-set phenomena. In reality, subtle color changes during solution mixing, the exact properties of precipitates, and the distinctive odors produced are all important experimental phenomena. These multi-sensory, unpredictable details are difficult for VR to fully replicate.

In the field of medication, VR cannot simulate the different toughness and elasticity of real skin, fat and muscle layers. However, in actual operations, surgeons need to rely on their sense of touch to determine whether the needle tip has touched the deep bones or important blood vessels. This "sense of touch" is of vital importance. Additionally, VR medical data involves patient privacy and clinical decisions, and there is a risk of leakage during transmission and storage processes.

4.2 Future Optimization

To solve problems in dizziness, VR devices can integrate eye-tracking with inertial navigation (IMU) to achieve sub-millimeter spatial positioning and reduce interaction latency. VR devices can reduce cross-platform rendering latency to less than 12ms by enabling the collaboration of multi-device through the dynamic rendering technology. This technology can also adjust the dynamic resolution according to the situation. For example, when the GPU computing power is insufficient, it can automatically reduce the resolution. Therefore, dizziness and screen-door effect can be reduced.

Schools and universities can use the cloud rendering technology to reduces the hardware investment of schools, which can make the price of the hardware more affordable, and can thus maintain them in long term. With the help of the AI-driven physics engine, VR devices can create a more realistic scenario, which enhances the interactive realism. VR teaching techniques and methods can be integrated with traditional teaching methods to serve as supplements to develop inquiry-based and collaborative VR learning experiences. This can not only give students chances to experience VR learning, but also help lower the school’s investments.

To solve the problem in medication, developing devices that are lighter, have lower latency, and offer a wider range of force capabilities is crucial. This can not only simulate the "breakthrough sensation" of a needle piercing the skin, but also replicate the tension of the stitches during suturing, the friction during knotting, and the continuous elastic resistance when pulling the tissues. Before transmitting the data, anonymization process of the data can ensure that even if the data is stolen during transmission or storage, the attacker cannot link the data to a specific patient.

5 Conclusion

VR technology has a wide application in real life. In the field of education, it allows students to interact with the environment, help them observe and decipher objects

without being limited physically, and help students overcome their fears. In the field of entertainment, VR technology enables people to travel to a place virtually without really visiting that place in realistic; there are a lot of VR games for people to play; VR technology help people exercise in a fun way and improve athlete's training strategies and environments. In the field of medication, VR technology help improve people's health and fitness, psychological health greatly, and doctors and patients a lot in medical workflow.

However, there are also drawbacks and challenges in VR technology and its application. VR devices can cause dizziness among users. In the field of education, the cost of VR teaching can be too high to afford, and students may be distracted by the novel equipment. In the field of medication, VR technology cannot perfectly simulate an actual operation, and personal information can be divulged.

Nevertheless, there are still optimizations and solutions to the problem. With the help of IMU and collaborations of muti-devices, dizziness could be reduced. By using cloud rendering technology and combining with tradition teaching methods, the costs of VR teaching can be reduced, and students can learn more efficiently. Improving the devices can enable doctor to have a more immersive experience, while anonymization process of the data can ensure data being transported safely.

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