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Healthcare Applications of Augmented Reality (AR) and Virtual Reality (VR) Simulation in Clinical Education

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1. Abstract

With the advancement of technology, digital gadgets have progressively become tools for educational pedagogy, enabling the widespread application of Virtual Reality (VR) and Augmented Reality (AR) in healthcare education. Neurological rehabilitation, telemedicine, psychotherapy, medical education, and surgical simulation are among the fields in which VR and AR are used. Studies have shown that VR and AR can reduce medical errors resulting from incompetent medical personnel, lessen the inconvenience of traditional medical care, and save medical education and training costs. The application has improved the quality of diagnosis and treatment, raised the bar for medical education and training, strengthened the bond between clinicians and patients, and increased medical execution efficiency. In an effort to assist clinical professionals in enhancing the standard of care they provide; this study integrates VR and AR technologies into clinical practice and healthcare education.

2. Introduction

A person can interact with a synthetic three-dimensional (3-D) visual or other sensory world through the use of computer modeling and simulation practically offered by virtual reality (VR) for diverse applications [1]. With the use of interactive gadgets that can be worn as goggles, headsets, gloves, body suits, or other wearables, VR applications immerse the user in a computer-generated environment that mimics reality [2]. A person doing a helmet equipped with a stereoscopic screen can see animated visuals of a virtual world in a standard VR format. With VR surgical simulation systems, novice or trainee surgeons can receive surgical training while simulating the realism of the actual operation and decreasing the likelihood of mistakes during the actual procedure in the future. VR and AR are being used in the medical field more and more. VR has been used in healthcare in an increasing amount of ways to improve healthcare education curriculum and offer a system of interactive pedagogy [3]. To help students grasp the relative spatial relationship between items, VR can present three-dimensional stereoscopic visual effects in the teaching of human anatomy. Provides excellent potential applications for medical students or doctors in understanding human anatomy and learning. In simulation education, augmented reality (AR) refers to the real-time, interactive combination of virtual and real-world imagery through display-based systems [4]. With AR technology, students can engage with virtual visuals enhancing real-world settings. Intravenous injection is another topic that may be learned by VR and AR in healthcare education [5], which helps the student advance their clinical skills. Various thickness classes of needles are utilized to create force feedback via hardware devices and simulate the entry of the needle into the patient's arm. The patient experienced pain or discomfort during the actual injection, mostly to prevent inexperienced care for inexperienced injections. Many VR simulation systems exist, including training systems for subcutaneous injection, sigmoidoscopy operations, bronchoscopy surgery, ovulation ligation surgery, EndoVR endoscopy computer simulation, LapVR laparoscopic computer simulation, and CathLabVR computer simulation for catheter interventional treatment [6].

3. Research Background

The current research used a range of methods to show that virtual reality system (VRS) was found to boost skill performance and reinforce knowledge acquisition in most of the experiments [7]. A range of cognitive contexts are assessed in order to investigate knowledge, and VRS enable the acquisition of knowledge through experiential learning a crucial method for nursing students to learn while giving feedback on their work [8]. Moreover, VRS has been demonstrated to enhance information retention through the incorporation of virtual patients into case-based learning approaches and the recreation of real-world locales into realistic scenarios at any time. Conversely, VRS facilitate the transfer of knowledge by utilizing a range of educational programs and are used in game-based virtual reality phone applications [9]. The implementation of VRS in a range of learning methodologies, such as case studies, particular situations in safety education, pediatric courses, disaster training, and psychomotor skills showed improvements in the performance of a number of skills, was evidenced by the study's results. Thus, VRS revealed improved decision-making and the dissemination of safer behaviors that support experience learning.

Within the realm of computer-based environments, virtual reality encompasses a variety of settings that allow users to explore microworlds created by software and hardware technologies that are close to the subject matter [10]. In other hand, VR is a class of computer-controlled multimodal communication technologies that allows for more natural interactions with data and makes innovative, educationally engaging use of the senses [11]. In essence, VR is a way to recreate or simulate an environment and give the user the sense that they are physically there, in control, and actively interacting with it on a personal level [8]. With the use of 3D near-eye displays and location tracking, VR is a simulated technology experience that is utilized in business, education, and entertainment to give viewers an immersive impression of a virtual environment. The experience of being fully immersed in a digital environment that is conveyed to the senses through perceptual and psychological means is evoked by virtual reality [12]. By using a virtual reality system, a user can escape the real world and enter a virtual environment where artificial intelligence is used to produce the sights, sounds, smells, and other senses instead of natural objects. Using VR approaches to create educational applications opens up new ways to teach subjects and makes understanding the technology and processes much more important. VR is categorized into three main forms that facilitate interactive pedagogical learning: (a) Immersive (Fully Immersive) VR systems; (b) Semi-Immersive VR systems; and (c) Non-Immersive VR systems. The least advanced VR technology implementation is found in non-immersive VR systems which entails putting VR software on a desktop Personal Computer [13].

By using a conventional high-resolution monitor and interactive repository of clinical content, users of the desktop system can access the virtual world. Conventional interfaces like a keyboard, mouse and joystick can be used to interact with the virtual world. A relatively high performance graphics processing system that can be connected to a large screen monitor, a large screen projection system, or several television projection systems makes up semi-immersive virtual reality systems. These systems provide an enhanced sense of presence or immersion through a broad field of view, and stereographic imaging can be accomplished with the use of shutter glasses. The most direct way to explore virtual surroundings is via an immersive (fully immersive) VR system [14]. An interface for two-handed haptic interaction was presented by the study's authors. We chose an application scenario where simultaneous hand and needle manipulation is required on a mannequin patient. Utilizing bimanual haptic interaction, the technology combines a physics-based soft tissue simulation visualization for engagement [15]. To the best of our knowledge, modeling deformable objects using haptic rendering in conjunction with finite element methods is not commonly done, especially when working with two haptic devices in a complex scenario. The problems include synchronizing data among system components in the adaptive learning environment and striking a compromise between real-time restrictions and the high computing demands for fidelity in simulation. According to [16] the semi-immersive virtual reality system has been effectively deployed and evaluated on two distinct computer platforms: an adaptable system that leverages an Internet of Things cloud computing infrastructure, and a mobile laptop-based system. These two platforms were selected because of their cost scalability and authenticity. We measured event-based timings and evaluated update loop timings of several software components to estimate latency and compare performance.

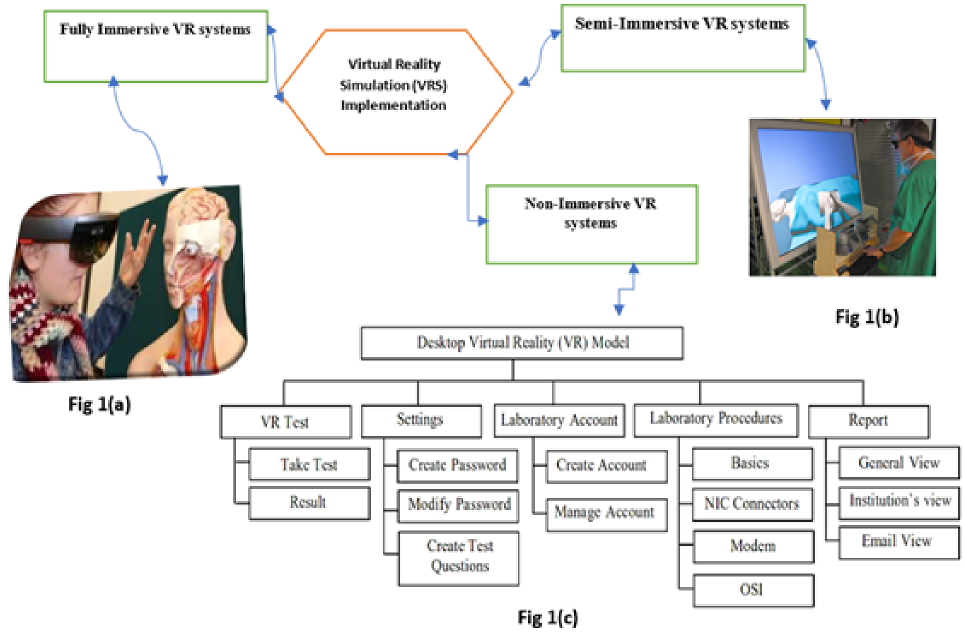

Figure 1: Combined VR Simulation Implementation, Fig1(a) Fully Immersive VR System, Fig1(b) Semi- Immersive VR System[17],Fig1(c) Desktop VR Model[13].

Vendor	Services Provided
3B Scientific Smart Anatomy	This function, which blends analog and digital learning, is included with every 3B Scientific Anatomy model. Together with 3D4Medical, 3B Scientific is able to provide educators and students with accurate digital 3D anatomy content. In order to access interactive anatomy classes, quizzes, and virtual models, 3B Smart Anatomy combines human anatomy models with a computer, tablet, or smartphone app.
OculAR SIM	This app was created especially for the Deakin University Faculty of Optometry on smartphones. With AR, educators and students can investigate the visual system and its elements.
SentiAR:	SentiAR creates holographic simulations of patient anatomy using medical augmented reality. The anatomical picture hovers over the patient while interventional treatments are performed. This piece discusses AR and VR.

AR Simulation Vendor and Product Supplier

4. VR and AR Applications in Clinical and Medical Education

In the medical field, the use of VR and AR is growing. For example, trainee or inexperienced surgeons can receive surgical training by using VR surgical simulation systems, which simulate the realism of the actual operation and lower the risk of errors during the actual procedure in the future.

4.1. Simulated VR Anatomy: An excellent teaching tool for trainees and students in medical institutions or schools is the Anatomage table, a virtual anatomical table that visualizes the intricate structures of every part of the human body, including the head and neck, chest, abdomen, pelvis, joints, and other parts. It is also more convenient for medical professionals, medical students, and clinicians to comprehend and learn. Additionally, it can assist doctors in explaining preoperative information to patients and in some research discussions, allowing patients to have a better understanding of their own surgery circumstances.

4.2. VR Surgery Simulation: Physicians will employ VR technology more frequently for surgical training as it can lower the likelihood of operational errors in the future by allowing for virtual surgery training. A system called Fundamental VR's knee arthroscopy mimics knee cap replacement surgery and enables doctors to practice accurately administering anesthesia throughout the procedure. Numerous businesses have been working on developing VR surgical systems. In order to improve surgical accuracy and comprehension and to enable surgeons to perform the safest and most efficient surgeries possible, Surgical Theater Company developed a VR medical visualization platform that streamlines the surgical planning process.

4.3. AR Anatomy Teaching: Medical personnel can be trained successfully and efficiently with AR-based training, which also provides a safe learning environment, targets certain abilities, and improves learner experiences. AR education is engaging and entertaining, and it's increasingly linked to incredibly satisfying life experiences. Learners express confidence in utilizing AR as a substitute for traditional classroom instruction, possibly due in part to their advanced digital literacy. The option for students to use equipment they already own, without needing to adapt to headgear VR applications, facilitates self-paced learning.

4.4. Knowledge and Understanding: Students studying medicine, nursing, and other health-related fields are exposed to a wealth of information on human anatomy and physiological processes. The ability to immerse students in three-dimensional representations of anatomy, anatomy systems, and the ways in which systems function inside the body is a clear benefit of using AR-based learning applications. Students can focus on intricate anatomical components, recognize and investigate spatial relationships, and alter the digital topic. Students can get an understanding of linked bodily functions and system interactions by manipulating digital anatomical structures through addition and subtraction. Lastly, the variety of diseases that can be included in virtual representation is not limited by the use of anatomical models or human cadavers; rather, it is only as limited as the diseases themselves.

4.5. Practical Skills: The practical and financial challenges that educational institutions must overcome limit the use of expensive simulators and clinical practice, even if they aid students in developing practical skills. But research has demonstrated that using AR-based tools in training improves the caliber and relevance of healthcare education and training, and that AR technology is becoming more widely available. Students using augmented reality (AR) for surgical training, biopsy practice, and practical procedures such as cannulation demonstrate improved learning and reduced procedural mistakes.

5. Challenges of VR and AV in Digital Health Education and Future Considerations

The adoption of AR technologies in medical and healthcare education is beset by challenges such as the high cost of developing interactive platforms, the lack of availability for a growing number of students, and the provision of digital technology in a fair and accessible manner for all students. Despite these challenges, teachers have been successful in providing students with engaging, rewarding, and student-centered experiences in areas where these barriers may be overcome. Along with wearable technology and mobile learning, which are more recent digital learning platforms, digital textbooks—an idea that has been brewing in higher education for almost a decade have a ton of potential. It would be less expensive for students to embrace if augmented reality-based learning was made available on personal devices, such as smartwatches. The University of California, Irvine School of Medicine uses Google Glass in its anatomy classes and hospital rotations as one example. In addition to providing hands-free access to course materials, Google Glass enables voice command communication between users and gadgets.

6. Conclusion

The healthcare industry is paying increasing attention to VR and AR technology. It can enhance the efficacy and efficiency of nursing and medical health care services in addition to lessening the drawbacks of conventional medical practices and education. Nonetheless, a few technical issues still need to be resolved. Examples include the hardware's endurance, the display image's clarity and sharpness, and the integration of the nursing and medical health care information system. Many educational institutions, healthcare facilities, and businesses are currently creating innovative methods to solve connected technical issues. In summary, it is highly anticipated that AR, VR, and MR will become widely used in the nursing and medical fields. The approach shown may be a more cost-effective and practical way to use immersive technologies for improving medical education, especially in cases when it is not feasible for every student to purchase such a device. By offering educational benefits beyond those of conventional simulated learning media, XR technology could assist in preparing graduates who are prepared for the workforce. By enabling students to express their understanding of phenomena, see the dynamic relationships between variables in a system, see abstract concepts in a 3D format, and experience events that might not be possible due to time, money, safety, or availability constraints, the integration of XR technology into nursing education offers a unique and innovative solution.

7. Conflict of Interest

There is no conflict of interest regarding this paper. However, the paper was supported by U&J Digital Consult Limited. An IT and Educational Consulting Firm based in Nigeria.

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