Chapter 46
Application of Virtual Reality Technology in Medical Education

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Abstract Medicine is a special discipline. The bottleneck of its teaching and learning lies in the difficulty of expressing many abstract teaching contents and obtaining many practical teaching contents and emotional experience in the course of teaching. The virtual reality technology is a new type of information technology. The VR technology have exerted increasingly important influence on the medical field due to its unique criticality, interactivity, imagination, and close combination with modern medicine. This article introduced the concept, characteristics, classification and the system of virtual reality (VR) technology, and discussed the application and significance of VR in medical education, as well as the trend and challenges for VR in medical education, to provide theoretical basis for the integration of VR teaching and traditional medical education.

Keywords Virtual reality technology · Medicine · Education · Progress

46.1 Introduction

With the rapid development of scientific technologies, new instructional media have been emerging. A new type of instructional media has become existent in the field of educational technology, namely, virtual reality technology. The virtual reality technology is a new type of information technology that came into existence in the 1990s. Like the birth of other emerging technologies or new media means, the development of virtual reality technologies will inject new vitality into the educational field, thus causing reforms of instructional means and teaching

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methods, which further will bring new opportunities and challenges to modern education.

Medicine is a special discipline. The bottleneck of its teaching and learning lies in the difficulty of expressing many abstract teaching contents and obtaining many practical teaching contents and emotional experience in the course of teaching. In recent ten years, virtual reality technologies have exerted increasingly important influence on the medical field due to its unique criticality, interactivity, imagination, and close combination with modern medicine. Therefore, the research on the application of virtual reality technologies in the medical education is especially important.

46.2 Introduction to VR technologies

46.2.1 Concept of VR Technologies

The VR technology is a computer-generated computer system that can create and experience the virtual world. It acts on the users by vision, hearing, and touching, etc. and brings the users immersive interactive scene simulation. It integrates computer graphics, image processing and pattern recognition, intellectual technology, sensing technology, language processing and audio technology, network technology and human behavioristic and many other disciplines. The VR technology is further development and application of modern simulation technology. Users interact naturally with objects in virtual environments with the help of necessary equipment, which will create immersive feeling and experience and make human–computer interaction more natural and harmonious.

46.2.2 Constitution of VR

General VR systems mainly consist of professional graphic processing computers, application software systems, input devices and demonstration devices, etc. In other words, people can feel the advanced user interfaces of designers' thinking through information channels such as vision, hearing, and touch.

Hardware platform: due to the complexity requirement of the virtual world and the requirement of computational efficiency, calculation needed to create virtual environments is immense, which raises high requirements for the configuration of central computers. Currently, foreign VR systems are generally configured with SGI or SUN workstation and large VR systems adopt computer parallel processing systems. Current research focuses on the desktop virtual reality system, which is cheap, easy to obtain and can meet some characteristic requirements of VR, and thus will be widely used.

Software systems: software systems are crucial to the realization of application of VR technologies. Application of VR technologies abroad is earlier than at home. Currently, typical desktop VR technologies include X3D, VRML, Java 3D, Cult3D Viewpoint, Atmosphere inWeb3D and Superscape VRT, EAI Sense 8 World ToolKit, MPI Vega applied to servers. They all provide tools for the application of VR technologies in virtual medical systems.

46.2.3 Classification of VR

According to the form and degree of immersion of users' involvement in virtual reality, virtual reality technologies can be classified into four classes.

(1) Desktop virtual reality system. The desktop virtual reality system carries out simulations via a personal computer and takes the screen of the computer as the window for users' to watch virtual environments. The participants can interact with the virtual reality world through various external devices and manipulate the objects in it. The biggest drawback of the desktop virtual reality system is lack of real experience, but it is easy to promote due to its simple structure and low price. Currently, the system is mainly used in the preparation of multimedia courseware.
(2) Immersive virtual reality system. It is also called "wearable" virtual reality system. This system provides completely immersive experience. It uses head-mounted displays or other devices to close participants' vision, hearing, and other feelings in order to provide a new and virtual feeling space. It also utilizes position trackers, data gloves, other manually operated input devices, sound, etc. to help participants create an immersive and totally involved feeling. "Sense of immersion" is mainly used in technical training.
(3) Distributed virtual reality system. The distributed virtual reality system makes full use of resources distributed in various areas and co-develops the application of different kinds of virtual reality in the Internet environment. It is generally development of immersive virtual reality systems and connects the immersive virtual reality systems distributed in different areas over the Internet to achieve a certain purpose jointly, taking distance education and remote medical consultation for example.
(4) Enhanced reality system. The enhanced reality system is also called the mixed reality system. It is a system combining real environments and virtual environments which cannot only reduce the expenses used to establish complex real environments (because some real environments are replaced by virtual environments), but also can perform operations on real objects (because some systems are real environments), which realizes a real and imaginary realm and marks the direction of future development.

46.2.4 Basic Characteristics of VR Technologies

As pointed out by Grigore and Philippe Coiffet in the book *Virtual Reality*, virtual reality has three outstanding characteristics, also the well-known three "I" characteristics of VR: interactivity, immersion, and imagination. Interactivity refers to the degree of inspection and operation of simulated environments realized by participants who use special devices and human natural skills. For example, users can directly grab the objects in simulated environments with their hands and they have the feeling about grabbing objects and can feel the weight of objects. The objects grabbed in the field of view should also move immediately as one's hands move. On the other hand, as VR is not simply a medium or a top end user interface, it can be used to solve some engineering, medical, and military problems. These applications are operated by both VR and designers and are designed for giving play to their creativity, which depends largely on human imagination. This is the second characteristic of VR: imagination.

The main technical characteristic of VR is "immersion". The goal of VR is to enable users to lie in a "totally immersive" status in the 3D virtual environments created by computers and have an immersive feeling, namely the so-called "immersion". It is also aimed to make users feel that they are part of the virtual environments rather than onlookers.

The "immersion" characteristic of VR distinguishes itself from general interactive 3D computer graphics greatly. Users can immerse themselves in data spaces and observe outward so that they are able to interact with data in a more natural and direct manner. They can also use immersion feature to isolate themselves from real environments and then immerse themselves in virtual environments, to be able to observe data truly.

46.3 VR Technology and Learning Theory

VR Technology provides a completely new platform for modern learning activities and an ideal stage for implementing various learning theories and ideas, especially for the combination of various kinds of learning theories. VR environment supports the "stimulus–response" and immediate reinforcement of behaviorism. Learning activities under the support of VR Technology can easily satisfy the learners' interior demand and motivations due to the emotional and impact force of its approaching real environment stimulus and feedback.

VR Technology can meet the requirements of the constructivism on scenario design perfectly. Moreover, Constructivism regards the learning as a procedure of learners' construction of their interior mental representations, and regards the interactions between the subjects and the environment as the determine factor of learning. Things created or simulated by VR Technology are produced with the realistic environments, and VR provides diversified natural interactive ways and

conversational modes, allowing learners to move freely and explore the visual world in a controllable environment. Then the learners can acquire various perceptual or conceptual knowledge of objective things. This can motivate the imaginal thinking and research thinking of the learners, thereby deepen the concepts and construct new ideas and creations.

VR can fulfill the educators' idea of humanism. The creation of visual environment provides a new pattern for teaching and communicating. The open environment, abundant resources, realistic environment, engorged emotion, students-oriented environment, and supporting for cooperation of the new pattern enable students to get rid of the coldness of teaching by textbooks and machine screens and take part in active learning and practices. Moreover, all of this reflects the thought of humanism—"people-oriented", "emotional interaction" and "cultivating integrated people".

46.4 VR Technology and Medical Education

46.4.1 The Application of VR Technology in Medical Education

VR technology has changed the passive way of human–computer interaction, and had a profound impact on the traditional teaching mode, teaching methods and teaching approaches. It is developing smoothly as an effective teaching tool in the field of medical education, the main applications of which include theoretical teaching, practical training, virtual experiments, and so on.

46.4.1.1 Theory Teaching

The human body which is built with virtual reality technology is called the virtual human. Virtual human body is by means of computer technology to digitalize the human body structure, convert it into computer language, and reproduce realistic model of the human body. Through regulating, the virtual human can mimic various reactions of realistic human beings; combining with professional medical knowledge and needs, it can generate a variety of medical application models and provide powerful auxiliary tools for medical theoretical teaching.

The first and broadest application of virtual human in the medical theory teaching is its application on the human anatomy virtual three-dimensional expression. At present, the best human anatomy atlas database in the world is the visualization database. Initiated by the U.S. National Library of Medicine and built based on the visual human body plan, it is a digital human image library mouth consisting of three-dimensional human body tomography, nuclear magnetic resonance imaging, and anatomical section. Reconstructed human organs of virtual

human can be rotated, of which the organizational structures such as blood vessels can be displayed individually. Learners can adjust the size, transparency, and direction of various organ models and deep structures to facilitate their comprehensive and intuitive understanding of the anatomical structures and relationships between the various organs. Digital anatomical atlas is with no need to be labeled complicatedly. As long as the computer mouse is moved to on a particular anatomical structure, a detailed description of the structure can be shown through the hyperlinks, making it easy to learn and use.

Dynamic visible human model is a more complex version. It can dynamically display the human physiological events and indicate the state of motion of various organs and systems under normal or disease states and how to respond to a variety of external forces. Such a model has a very broad prospect in medical education. Our research in this area is just entering the first stage, only built human parts data sets on the aspect of virtual visible human in Shanghai, Chongqing, Guangzhou and other provinces, which provides preliminary information for the follow-up study. In addition to the simulation of the completely human body, there also have emerged a large number of local organ VR models in medicine. Satava and others have developed an abdominal virtual reality model which allows the learner to observe the anatomical structure not only from the external of the organs but also from their interior, with the example of roaming in the alimentary canal to observe the gall bladder and pancreas as conducting an endoscopic examination. Lim group have developed a series of consecutive short local tissue anatomical models to demonstrate the local anesthesia related anatomic landmarks and needle control levels. Zito and his partners have generated high-resolution histopathology with VR technology based on a large number of microscopic digital photos of tissues. This sort of virtual slice can have multi-point analysis on key parts, and can be played in a variety of multimedia, which makes the pathological teaching get rid of the shackles of the microscope, and greatly reduces the number and cost of the biopsy.

46.4.1.2 Practice Training

Traditional medical practice training is more performed on the human body model, with part of operations also carried out on a real patient. Such practice-training mode, however, is not only with high cost but also may increase the patient's risk, so it is gradually being limited. The expanding of VR technology applications has promoted the practical training courses onto a higher level. A virtual practice training system usually consists of virtual operating environment, operating related hardware peripherals, back-end database. Utilizing high-resolution, high-contrast advanced image acquisition and other modern technologies, the system maximizes the simulation of real environment, feedbacks the learner's feels on different human organization textures with feel and forces of joystick and other devices, achieving the purpose of training through repeated simulation.

Currently, the most widely used system is the virtual endoscopic operation-training simulator. Collaborated with the School of Computer Science at National University of Defense Technology, the People's Liberation Army General Hospital has developed a virtual endoscopic sinus operation simulation system with a duration of two years. This system introduces feel into the multimedia teaching process and uses the 3D pen power to feedback the device Phantom; it carries out a three-dimensional reconstruction of the human nasal structure with human frozen section data, the result of which is consistent with the nasal structure of the yellow race. With optimized linear elastic model the system has built a virtual nasal tissue organ physiological—physical model; it has conducted research on the real-time elastic deformation algorithm of model; it has fulfilled a realistic demonstration of varying degrees of feedback force of the nasal soft tissues and organs under different pressure and tension of the training equipment; it has also utilized the virtual mechanical sensor and feedback system so that the beginners can experience the whole process of endoscopic operation. Furthermore, the system can provide different perspectives of the endoscope transformation in the entire process. Three degree-free tactile stimulations can even show different feels for minor operating equipment touching the mucosa and bone tissue and penetrating the lateral nasal wall. There are some other invasive operation simulation trainings, such as low colonoscopy training, bronchoscopy training, and venipuncture training under the condition of biological protection. Virtual training system for practical training has showed good results. The features of the virtual system being zero risk and repetitive facilitate the students to practice repeatedly according to the system given feedback until they master the whole skill. In addition, VR training system generally provides a plurality of evaluation parameters, and the database can record the entire operation process, enabling the evaluation function of the practical training. For example, the endoscopic simulation training system, using fuzzy logic methods, can record the time of surgery, vascular cutting length, knotting position and sturdiness procedures, the length of the cut line, the degree of smoothing of the instrument moving and efficiency, and other indicators to determine the operator's operative capacity.

46.4.1.3 Virtual Experiment

Virtual experiment is a visual 3D experimental environment that uses VR technology, computer multimedia technology, database technology, network technology and other virtual technologies and has similar functions with traditional laboratories. In this laboratory, students with full experiment autonomy are able to simulate various practical or even invisible, untouchable, inaccessible and high-risky experiments and imaginative experimental scenes, reducing the dependence of experimental teaching on objective material conditions, with students having chance to do experiments all day. The virtual laboratory makes some boring and difficult to operate experiments and trainings interesting and easy to understand and grasp, which is helpful to stimulate students 'creative thinking, tap their

potentials, and cultivate their interest in learning, practical ability and research ability. For some expensive precision instruments and meters, it is necessary so that students can first use the virtual instrument and then have hands-on real practical operation of the equipment and instruments to rich their perceptual knowledge. Many experiments in medical education and clinical experiments can be conducted in a virtual lab. The hardware of the virtual experiment is only around smothering the input and output of the signal, while the software is the key. The software can easily change, increase or decrease, or improve the function and scale of the system. The software are generally written graphically based on LAB VIEW languages. Coleman experiment at University of California has developed the EXP software, which is a virtual reality-based, multi-function software for neurophysiology virtual experiment.

46.4.2 The Application Value of VR Technology in Medical Education

46.4.2.1 Beneficial Supplement for Theoretical Study

The emergence of VR technology helps to cultivate students' interest in learning, to broaden the students' scope of knowledge and to effectively support the theoretical study. If students can make comparison between a virtual environment and reality in virtual experiments, explored on the basis of cooperation, it can develop the concept in medical field, and help students to develop problem-solving skills, and the ability to migrate from the virtual real-life situation, which will have a great educational value.

46.4.2.2 Avoid the Danger of Real-life Situation

In the past, the teaching of some medical procedures and experiments were generally completed through TV video instead of students' direct involvement in order to obtain the perceptual. However, with VR technology, students can safely do a variety of human trials, such as the virtual heart bypass surgery, to avoid "patient" death medical malpractice injury caused by operational errors.

46.4.2.3 Break the Time and Space Constraints

With VR technology, the space limitations can be completely broken up in medical education. From the body structure to biomedical molecular structure, students can enter the interior of these structures to have observations. VR technology can also break the restrictions of time to present some change processes, which may take

months or even decades to observe, through virtual reality technology in a very short time. Some of the laws of inheritance in biological genetics, for example, may take months to do the experiments with animals, but the virtual technology can achieve the same results within a class.

46.5 Development Trends and Challenges of VR Technology in Medical Education

The adoption of a new education strategy is performed in the diversity of learning styles, structured learning programs, and multidisciplinary teamwork. With the promotion of medical education reform and development of VR technology, how to make full use of the advantages of VR technology and use specific teaching strategies to improve the effectiveness of teaching has become the focus of attention of medical educators. Educators increasingly realize that adult learning programs need to reflect and encourage more active, more independent learning approaches. Therefore, the construction of VR study guide program pay more attention to promote the diversification of learning methods to better integrate theoretical knowledge into the medical skills and practical procedures.

In recent years, the medical profession has made provisions of the medical core curriculum contents and the corresponding communication skills, inspection skills, and practical program are increasingly integrated into the VR training program. In order to fulfill the teaching objectives and tasks better, designers try to design question-based program in VR teaching, and integrate a variety of teaching methods in the horizontal and vertical level in order to ensure that all students master the same content.

The development of the world's health-care system today calls for teamwork that is more multi-disciplinary. Medical VR teaching is paying more and more attention to the cooperative learning between the multidisciplinary. In the early stages of learning, students of various health care majors learn together and late in the learning, some content can be shared.

46.6 Conclusion

With the continuous increase of the hardware cost-effective as well as the continuous development and enhancement of VR technology, virtual technology will surely become more mature, and gradually popularization. In the future of education, virtual teaching and traditional teaching will run neck and neck and become further organic integration, produce new combination of the virtual and real teaching model, and with its powerful level of immersion, interactivity, multi-aware user-friendly features will have a profound impact on the practice-oriented

field of medical education. Therefore, we have reason to believe that the virtual reality technology, which keeps pace with network technology and multimedia technology, will have even broader application and development prospects.

References

1. Andolsek DL (1995) Virtual Reality in Education and Training. Int J media 22(2):145–155
2. Chiou GF (1995) Learning rationales and virtual reality technology in education. J Educ Technol Syst 23(4):327–336
3. Burdea G, Coiffet P (2003) Virtual real technology. Wiley, John & Sons, USA
4. Wang P Becker AA Jones IA (2006) A virtual reality sugery simulation of cutting and retraction in neurosurgery with force feedback. Comput Methods Programs Biomed 84(1):11–18
5. Webster R, Sassani J, Shenk R (2004) A haptic surgical simulator for the continuous eurvilinear capsularhexis procedure during cataract satgery. Stud Health Technol Inform (98):404–406
6. Banks EH, Chudnoff S, Karmin I (2007) Does a surgical simulator improve resident operative performance of laparoseopic tubal ligation. Am J Obstet Gyneeol 197(5):541–545
7. Kockro RA, Stadie A, Schwandt E et al (2007) A collaborative virtual reality envimnment for neurosurgical planing and training. Neurosurgery,61(2 Supp 2):379–391
8. Walsh RM, Tymianski M, Wallace MC et al (2000) The transmastoid partial labyrinthectomy approach to mediaI skull base lesions. Rev Laryngol Orol Rhinol Bord 121:13–20