Pathology & Oncology Research (2020) 26:765–769
https://doi.org/10.1007/s12253-019-00590-8

ORIGINAL ARTICLE

The Development and Application of Virtual Reality Animation Simulation Technology: Take Gastroscopy Simulation System as an Example

Qianru Wang[1] · Chunjiao Li[1] · Zhongli Xie[1] · Zhiguo Bu[1] · Liwei Shi[2] · Chuan Wang[2] · Feng Jiang[2]

Received: 28 January 2018 / Accepted: 15 January 2019 / Published online: 26 February 2019

Abstract

Virtual reality (VR) technology has a great potential in the field of medical simulation due to its immersion, interactivity and autonomy. It provides a new direction for integration and application in various disciplines. Combination of VR technology and clinical practice brings great convenience for medical education and experiments. Modern VR simulators can create realistic environments that capture minute anatomical details with high accuracy and solves the problem of difficulty in mass productions with traditional devices. Taking gastroscopy simulation system as an example, this paper discusses the development and application of VR animation technology, together with its excellent performance and current research status in surgery, scientific research, training and education.

Keywords VR animation · Medical simulation · Gastroscopy simulation · Operating system · Cross-border fusion

Introduction: VR Animation Simulation Technology in Medical Applications

Virtual reality (VR) technology originated in the United States in the 1960s. It has been for now for more than 50 years. In the twenty-first century, with the development of computer and other high and new technology, VR technology has made a major breakthrough [1]. Due to its advantage of immersion, interactivity and autonomy, VR provides a new direction for integration and application in various disciplines [2].

Integration of VR simulation in the training curriculum was shown to be effective in improving trainees' skills [3]· In the field of medicine, the application of high simulation devices as a supplement to the traditional medical training mode has long been in the vision of medical educators. In fact, the traditional high simulation devices is very expensive and unable to be used widely in medical schools [4], It can only be used as a supplement to clinical practice teaching and the results are unsatisfactory.

Simulation aim to imitate real patients, the anatomic regions, clinical tasks, and/or mirror the real-life circumstances in which the medical services are rendered [5]. Simulation was particularly useful in better understanding of the complicated spatial relations of the anatomical landmarks and in examining surgical approaches [6]. By using VR technology medical simulation operating system, the shape and movement pattern of the human organs, and its pathological manifestation can be restored via computer technology. In terms of equipment, it only needs to purchase the VR device to run the simulated program, thus saving a large amount of material and labor costs, shortening the training period and lowering the training cost. Therefore, combination of virtual reality technology and medicine will be the new direction in medical teaching and training in the future [7].

This type of medical simulation operating system combines the main application of surgery and scientific research, teaching and training, with treatment. Among the item in the treatment combined group includes optimization of surgical procedures, psychotherapy, rehabilitation training, doctor-patient communication and large data image combination to achieve precise and accurate medical treatment. Simulators may be used in surgical training and evaluation of surgical capability [8]. Studies showed that patients who exposed to preoperative VR had increased satisfaction during surgical encounter [9]. There is substantial evidence supporting the use of VR simulators in surgical training [10, 11]. VR simulation reduced

✉ Feng Jiang
FengJiang17@126.com

1 Sichuan Fine Arts Institute Film –Video-Animation School, Chongqing 401331, China

2 Digestive Department of Chongqing General Hospital, No. 104, Pipashan Main Street, Yuzhong District, Chongqing 400014, China

operative time and improved the performance of surgical trainees [11]. Performance metrics produced by the VR simulators have been shown to be strongly correlated with the operating room performance [12, 13]. In this paper we discuss by taking VR gastroscopy simulation operation system as an example.

The Idea of Creating Gastrocopy Simulation Operation System Based on VR Animation Simulation Technology

Based on VR animation simulation technology, with gastroscopy simulation operating system as the breakthrough point, the application of VR technology in the field of digestive endoscopic treatment is gradually extended.

By applying the hospitals, colleges and universities as the research subjects and 3D animation modeling as the basis, combining with the computer and VR programming, and development of the high performance of external devices as the technology orientation, the importance and difficult point in the integration of VR animation technology and medical practice is captured, and further in-depth follow-up studies on the clinical medicine simulation system is carried out.

Both the high simulation devices which have been put into use and the use of real medical devices faced the problem that the devices are relatively large and expensive [14], and there is also a big gap with the clinical scene. The main production materials such as polyurethane and silicone are used to simulate the internal structure of the human body, however, due to the limitations in materials, storage conditions, production technology and costs, the texture of the internal walls of the organs and mucus, etc. are unable to be truly restored. Therefore, the technical requirements of the new generation VR medical simulation operating system must be small, easy to carry and at relatively low cost. At present, all countries in the world are actively improving the VR hardware devices. Thus, VR devices are showing a more optimized trend. Modern VR simulators can create realistic environments that capture minute anatomical details with high accuracy [15]. VR gastroscopy simulation operating system via three-dimensional software, MAYA, 3DMAX and other high modulus and high-definition mapping techniques restores the whole digestive tract into more realistic pictures and directly saving the cost of materials required for production with the traditional simulation devices. At the same time, it also solves the problem of difficulty in mass productions with traditional devices. The VR medical simulation operating system, through physical virtualization, provides an alternative to the high cost and rare experimental sources for medical education and experiments.

The Technical Route of Establishing the Digestive Endoscopic Simulation System

Restoration Design: Real Structure and Dynamic Simulation of Human Stomach Organs

The purpose of medical simulation devices is to solve the problems of shortages in experimental resources and that the medical students or interns are unable to carry out clinical practice individually. VR simulation operating system on the basis of traditional simulation devices can better solve this problem, saving the production costs via combination of hardware devices and software programs. Therefore, the main problem of restoration that needs to be solved is very different from the traditional simulation devices. Its key point lies in tackling the problems in digital reduction technology, that is, the restoration of patients, apparatus and clinical scene in the virtual space. In order to ensure the authenticity of the modeling and animation, in the early stage of development, the participants went to the hospital gastroscopy center to undergo field study and record of the complete surgical process. This is then combined with the photographs, images, data and other information provided by the hospital to undergo restoration of the human body and upper digestive tract.

Considering the fact that the model and animation of the traditional simulation devices combined with the physical use of 3D animation is too simple and indeed crude, the details and true dynamic level of the 3D modeling will be taken into account in the design of VR gastroscopy simulation operating system. Due to the unrestricted materials and production technology, during the virtual reality restoration, deceitness of the visual system can be achieved and a real experience is provided from the virtual. The process of human stomach organs with real dynamic simulation were as follows:

1) Information of the gastric related data, photographs and images were provided by the endoscopy center of a large teaching hospital. Related sketches were done by the researchers from the Sichuan Fine Arts Institute. Restoration of the real structure of human oral cavity, esophagus, stomach, duodenum, etc. were achieved via 3D animation technology modeling and simulation
2) Drawing of the real maps of the organ wrinkle walls and mucosal texture to achieve the restoration of human organs
3) Human organ binding was performed via 3D technology. This was coupled with 3D animation, and according to the law of movement of the human organs, restoration of the real state of motion of the simulated organ was made, such as restoration of the real situation of gastric peristalsis
4) The entire process of gastroscopic examination from the oral cavity to the stomach was produced into a full range

of interactive animation. Unity 3D is imported to create a panoramic view, achieving the goal of observing the upper digestive tract at 360 degrees without blind angles.

Tracking Design: Walking Virtual Gastroscope

Motion tracking can discriminate between the operators with different experience levels in upper gastrointestinal endoscopy. It also can be used to provide feedback regarding posture and movement during endoscopy [16]. In the virtual reality technology, the general sense of walking mainly refers to the characters walking in the virtual scene. For the VR gastroscopy simulation operating system, in addition to the user's position and movement of hands, it is also required to locate the mobility of the gastroscope camera after it enters the oral cavity and upper digestive tract [17]. Here, in order to ensure the possible necessities of the operator, the VR simulation operating system has a dual design. The operator can choose to have viewing experience during endoscopic surgery, which is, observation is performed via a monitor by the side after the gastroscope is placed inside the patient's body, or to have an endoscopic view, which is, observation of the internal condition of the upper digestive tract directly via both eyes. The following techniques were used to simulate walking:

VR Animation Programming

Various action of the operator was captured via the VR handheld device and laser positioning base station. Determination of various actions was performed via code writing by the programmers. This was combined with gastric animation to execute force feedback coding. A relatively appropriate feedback method was selected within the force feedback system supported by the VR devices [18].

Then, the front-end language and panoramic production software were combined. Code was composed for logic implementation and upon completion, was entered into the VR scene for logic tests and constantly improving its content.

VR Animation Tracking Technology

The creation of a walking camera was divided into two parts. First was walking of the operator in the virtual clinical scene. This part required tracking the operator's equipment preparation work prior to the endoscopic surgery. The second part was simulation of the endoscopic or surgical instruments from the oral cavity to the stomach via the esophagus, and undergoing 360 degrees to observe the upper digestive tract or whole surgical process, to realize the real operation experience of free walking of the virtual gastroscope in the virtual stomach scene.

Overall Design: The Real Clinical Operating Experience

Whether it is a traditional medical simulation device or a VR technology simulation device, the ultimate goal is to truly restore the clinical operating experience. For example, the design of the traditional digestive endoscopic surgery simulator focuses on the restoration of the internal structure of the human digestive tract, which is, establishment of a real human body model via a real force feedback to achieve the experience similar to the actual surgical procedure [19]. Such a design concept determines the high cost of traditional simulation devices. If it involves dozens of different cases, the number of virtual patients will also increased accordingly. The VR simulation operating system can include the common pathological features by establishing a pathology database, in which the operator can randomly select cases he wants to study or examine from the database, and this can be repeated without restrictions of time, place and case [20].

The advantage of the VR simulation system lies in its virtual operation process which can be operated without limit. VR simulators were safe, ethical and repeatable [21]. Upon completion of the restoration design and tracking design, a bridge between the user and the VR gastroscopy simulation system is needed to be established. After the following three steps, the VR gastroscopy simulation operating system would have a prototype.

Immersive Simulation Technology

First, the VR headset device was used to block the user's vision. Then, a virtual upper digestive tract was presented where the user could diagnose the possible diseases in the digestive tract via observation through the eyes. With the aid of laser tracking base station, the handheld sensor tracked the user's behavior, while the simulated gastroscopy checked the action, realizing the immersive experience of gastroscopy simulation operation. Immersive experience could replace the operator's physical operation with virtual operation in the VR system, giving the operator a real visual and auditory perception.

Realistic sense of immersion is a key element in the design of a VR system [22]. The current VR devices are more likely to cause discomfort to users at use. This is due to, the interaction between human and virtual environments appears to be contrary to the state of reality [23]. For non hardware devices, improvement can be done by in-depth study on the principle of retinal imaging, that is, distinguishing the nuances between the left and right eye images, improving the screen effects in animation production and increase the number of original animation frames, making the picture fine and real with smoother animation effect, so as to achieve the purpose of reducing the operator's sense of vertigo. In addition, according to the solution proposed by Professor Steven K. Feiner from Columbia University, the visual field of the head can be reduced by adjusting the field angle, so that the operator would have a better experience.

Creating Gastric Pathology Database

Accuraste case data was obtained from the 3A Grade Hospital. After calculation and verification, via 3D animation and computer programming techniques, a database model which correspond to a variety of gastric diseases (such as esophagitis, esophageal foreign body, esophageal varices, gastric ulcer, gastric perforation, gastric cancer, gastric polyps, gastroduodenal hemorrhage, etc.) was established.

Interactive Gastroscopy Simulation Technology and External Device Innovation

Combined with the real gastroscopic operation process, a rich model database and surgical operation animation was established. The VR operating system was imported and via combination of the gyroscope sensor, accelerometer and laser positioning sensor, the user's body movements were captured. The 360 degree mobile headset device sensor tracked the head action while the infrared tracking sensor tracked the human position. This combined with the computer real-time reading of the gastroscopic operation data, rendering the gastroscopic simulated images, and realistically reproducing the surgical process via high resolution pixel screen and refresh rate of 90 frames per second [24]. Development of 6 degrees of freedom gastroscope handle simulated real touch of the hand during gastroscopic surgery, achieving the immersive interaction between the objects in the user and virtual world.

VR allows realistic interaction with a computer-generated environment and include additional sensory information such as haptics for provision of a sense of force feedback to simulate touch [25]. The existing haptic simulation feedback technology can only provide the sensation of "yes" and "no", and unable to manipulate on strength and other properties [26]. At the same time, this article will also explore the air vortex simulation haptic. The size of the airflow vortex can be adjusted to quantitatively describe the magnitude and type of the tactile sensation, which is closer to the real tactile sensation of the texture. According to the understanding of our group, by adding the sensation of pressure to the basis of tactile sensation, a dual simulation feedback system is yet to be developed. Therefore, adding of the mechanical skeleton to the tactile feedback system does not only enable the feeling of "hitting the object", but also whether the object is "hard" or "soft", thus existed the sense of pressure of the opponent's tension, which can greatly enhance the immersive sense of virtual experience.

Restoration of gastroscopy examination or surgical process can be achieved via a series of well-designed VR gastroscopy simulation operating system, bringing the user a real operating experience. However, such technology is still yet to be enhanced and improved, mainly on the solution for the problem of the sense of vertigo and force feedback.

Conclusion: Future Prospects

VR gastroscopy simulation operating system is indeed a very good first attempt. It provides a new research direction for the combination of VR technology and clinical medicine. As far as the related research results in mainland China are concerned, the application of VR technology in medical education and experiment does have a great space of development and important research value. However, the existing research is carried out on VR hardware and software separately, and almost all software development uses the mainstream VR devices in the market as the operating platform. However, the current virtual reality devices is still unable to restore the sensory experience of the entire surgical process well enough. Subsequent development of the VR gastroscopy simulation system might consider development of combined devices, allowing users to gain real sensory experience during operation, gradually achieving the target of perfect real scene restoration in visual, tactile, force feedback and other aspects. In addition, the application of VR technology and medicine combined is not only limited to the development of gastroscopy simulation operating system. There is also a great demand in other medical specialties. Taking gastroscopy simulation operating system as the starting point, large scale development on the application of VR technology in other fields of medicine can be foreseen. Combination of virtual reality technology and clinical practice will bring great convenience for medical education and experiments.

Author's Contribution Guarantor of integrity of the entire study: Feng Jiang. Study concepts: Qianru Wang, Feng Jiang. study design: Qianru Wang, Feng Jiang. Definition of intellectual content: Qianru Wang, Feng Jiang. Literature research: Chunjiao Li. Clinical studies: Chuan Wang, Liwei Shi, Feng Jiang. Experimental studies: Chuan Wang, Liwei Shi. Data acquisition: Chunjiao Li, Zhongli Xie, Zhiguo Bu. data analysis: Chunjiao Li, Chuan Wang. Manuscript preparation: Chunjiao Li, Zhongli Xie. Manuscript editing: Chunjiao Li, Zhongli Xie. Manuscript review: Feng Jiang.

Funding This study is supported by Scientific and Technological Research Program of Chongqing Municipal Education Commission "Research on the innovation of clinical medicine application system based on VR animation technology: Taking gastrocopy simulating operating system as an example" Phased research results, Project number: KJ1708190.

Compliance with Ethical Standards

Conflict of Interest None.

References

1. Schroeder R (1993) Virtual reality in the real world: history, applications and projections. Futures 25(9):963–973
2. Gatica-Rojas V, Méndez-Rebolledo G (2014) Virtual reality interface devices in the reorganization of neural networks in the brain of patients with neurological diseases. Neural Regen Res 9(8):888–896
3. Harpham-Lockyer L, Laskaratos FM, Berlingieri P, Epstein O (2015) Role of virtual reality simulation in endoscopy training. World J Gastrointest Endosc 7(18):1287–1294
4. Wang W, Tang L, Zhao XF, Huang JS (2015) About the thinking of high simulation equipment's application on clinical medical practice teaching. Pop Sci Tech 15(5):153–154,140 (in Chinese)
5. Guze PA (2015) Using technology to meet the challenges of medical education. Trans Am Clin Climatol Assoc 126:260–270
6. Kin T, Nakatomi H, Shono N, Nomura S, Saito T, Oyama H, Saito N (2017) Neurosurgical virtual reality simulation for brain tumor using high-definition computer graphics: a review of the literature. Neurol Med Chir (Tokyo) 57(10):513–520
7. Grantcharov TP, Kristiansen VB, Bendix J, Bardram L, Rosenberg J, Funch-Jensen P (2004) Randomized clinical trial of virtual reality simulation for laparoscopic skills training. Br J Surg 91(2):146–150
8. Coleman J, Nduka CC, Darzi A (1994) Virtual reality and laparoscopic surgery. Br J Surg 81(12):1709–1711
9. Mousnier A, Kubat N, Massias-Simon A, Ségéral E, Rain JC, Benarous R, Emiliani S, Dargemont C (2007) von Hippel Lindau binding protein 1-mediated degradation of integrase affects HIV-1 gene expression at a postintegration step. Proc Natl Acad Sci U S A 104(34):13615–13620
10. Alaker M, Wynn GR, Arulampalam T (2016) Virtual reality training in laparoscopic surgery: a systematic review & meta-analysis. Int J Surg 29:85–94
11. Seymour NE (2008) VR to OR: a review of the evidence that virtual reality simulation improves operating room performance. World J Surg 32(2):182–188
12. Kundhal PS, Grantcharov TP (2009) Psychomotor performance measured in a virtual environment correlates with technical skills in the operating room. Surg Endosc 23(3):645–649
13. Hyltander A, Liljegren E, Rhodin PH, Lönroth H (2002) The transfer of basic skills learned in a laparoscopic simulator to the operating room. Surg Endosc 16(9):1324–1328
14. Qi XY, Lu W, Han FT, Liu HQ, Cao YX (2012) Researching and application of virtual simulation teaching in medical imaging equipment teaching. Chin J Med Phys 29(1):3208–3210 (in Chinese)
15. de Visser H, Watson MO, Salvado O, Passenger JD (2011) Progress in virtual reality simulators for surgical training and certification. Med J Aust 194(4):S38–S40
16. Arnold SH, Svendsen MB, Konge L, Svendsen LB, Preisler L (2015) Three-dimensional motion tracking correlates with skill level in upper gastrointestinal endoscopy. Endoscopy 47(9):825–828
17. Latypov NN, Latypov NN (1999) Method for tracking and displaying user's spatial position and orientation, a method for representing virtual reality for a user, and systems of embodiment of such methods. US. US 6005548 A.
18. Burdea GC (1996) Force and touch feedback for virtual reality. John Wiley & Sons, Inc., New York
19. Wang P, Becker AA, Jones IA, Glover AT, Benford SD, Greenhalgh CM, Vloeberghs M (2006) A virtual reality surgery simulation of cutting and retraction in neurosurgery with force-feedback. Comput Methods Prog Biomed 84(1):11–18
20. Maschuw K, Hassan I, Bartsch DK (2010) Surgical training using simulator. Virtual reality. Chirurg 81(1):19–24
21. Badash I, Burtt K, Solorzano CA, Carey JN (2016) Innovations in surgery simulation: a review of past, current and future techniques. Ann Transl Med 4(23):453
22. Gorman PJ, Meier AH, Krummel TM (1999) Simulation and virtual reality in surgical education: real or unreal? Arch Surg 134(11): 1203–1208
23. Zhang WB, Cao L, Xiong JJ (2016) The realistic challenges of virtual reality technology. Sci Sin Inform 46(12):1779–1784 (in Chinese)
24. Burdea GC, Coiffet P (2003) Virtual reality technology, 2nd edn. John Wiley & Sons, Inc., New Jersey, USA
25. Sakakushev BE, Marinov BI, Stefanova PP, Kostianev SS, Georgiou EK (2007) Striving for better medical education: the simulation approach. Folia Med (Plovdiv) 59(2):123–131
26. Zhang L, Grosdemouge C, Arikatla VS, Ahn W, Sankaranarayanan G, De S, Jones D, Schwaitzberg S, Cao CG (2012) The added value of virtual reality technology and forcefeedback for surgical training simulators. Work 41(Suppl 1):2288–2292