ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202404_7(4).0008

Design of a Virtual Reality-Based Clinical Teaching System

Chengwu Zhang[1, *], Zhigang Hu[1], Xinzheng Wang[1] and Ling Qin[2]

[1] College of Medical Technology and Engineering, Henan University of Science and Technology, Luoyang 471000, China

[2] School of Clinical Medicine, The First Affiliated Hospital of Henan University of Science and Technology, Luoyang 471003, China

Abstract

Aiming at the problems of relative lack of clinical teaching resources and uneven quality of clinical teaching in some areas of traditional clinical teaching, this paper designs a clinical teaching system based on virtual reality technology. 3DMax software was chosen to create three-dimensional models, Unity3D physics engine as the development platform, and MySQL to build the clinical teaching case database. Calling Baidu voice technology services, combined with C# language scripting to implement the system logic, using grid simplification algorithm to optimize the three-dimensional model to reduce the system computational overhead. The system uses virtual reality technology to build the virtual environment of the ward and realize the voice dialogue interaction between the user and the system. The results of system operation show that the virtual reality-based clinical teaching system has good effects for users to familiarize with the clinical consultation process and learn relevant medical knowledge.

Keywords

Virtual reality; Clinical teaching; Voice interaction; Grid simplification.

1. Introduction

Clinical teaching usually occurs in medical institutions such as hospitals, where professional supervising doctors lead medical students to participate in medical work such as diagnosis, treatment and care of patients [1]. Clinical teaching is an important part of medical education, and its development can promote the upgrading of medical education. However, there are many problems in the actual clinical teaching process. On the one hand, there is a relative lack of clinical teaching resources in some areas, the number of teaching beds in many hospitals is insufficient, the number of supervising doctors and clinical teachers is insufficient [2], and there is a lack of new diagnostic and treatment techniques and the introduction of teaching modes, which makes it difficult to satisfy the needs of modern medical education. On the other hand, due to the differences in the clinical level of the supervising doctors themselves and the imperfections in the clinical teaching management system, the quality of clinical teaching is uneven [3], and some medical students are unable to obtain effective practice and guidance. How to allow medical students to develop individual professional practice ability in clinical teaching and promote the allocation of medical education resources requires further integration of new technologies to improve the mode of clinical teaching.

Virtual Reality (VR) integrates relevant technologies from multiple disciplines such as human-computer interaction, computer graphics, artificial intelligence, etc. [4], which can generate virtual three-dimensional scenes with high simulation and optimize the sensory experience of the experiencer. By constructing virtual scenes for specific learning tasks, users can perceive real and complex environments and learn knowledge and skills in a more immersive way [5]. Virtual reality technology has changed our perception of the world, more and more closely

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202404_7(4).0008

related to our lives. In recent years, more and more scholars have applied virtual reality technology to the medical clinical field. For example, in the field of surgical training, Luo Wei [6] and others developed a training system for abdominal operations based on virtual reality technology, which effectively improves the skill level of learners in surgery and other operations. In the field of medical rehabilitation, several studies have shown that virtual reality technology has achieved good efficacy in the rehabilitation of motor disorders caused by neurological diseases such as acquired brain injury and Parkinson's disease [7,8]. In education and training, Katelyn Stepan [9] found that the immersive learning mode based on virtual reality technology can effectively improve the efficiency of teaching. Xin Xin [10] and others experimental study showed that the application of virtual reality technology to the teaching of college internship nurse students, the theoretical scores and operational scores of the observation group of student nurses were significantly better than those of the control, which indicates that virtual reality technology mobilizes the learning enthusiasm and initiative of student nurses, and improves the effect of internship. Wang Jinyou [11] and others explored the role of virtual reality technology in urology clinical teaching, and the experimental results proved that virtual reality technology significantly improved the effect of urology clinical teaching.

The application of virtual reality technology in clinical teaching can, to a certain extent, solve the above mentioned problems existing in the current clinical teaching. Virtual reality technology can break the limitation of time and space [12], which can facilitate users to learn relevant knowledge anytime and anywhere. At the same time, the combination of excellent clinical teaching resources and virtual learning scenarios can, to a certain extent, solve the problem of uneven quality of traditional teaching and reduce the impact of human factors. Therefore, this paper designs a clinical teaching system based on virtual reality technology as an auxiliary tool for clinical teaching, providing a new teaching mode for clinical teaching.

2. Virtual Clinical Teaching System Development Process

The development of the system follows the software agile development process, which can be divided into three stages: the first stage is to analyze the system requirements, determine each functional module and collect and organize materials, mainly the mapping of model data and the collection of case information. In the second stage, 3D Max software is used to construct 3D models, including character models and item models, and then the designed models are imported into the engine in FBX file format. The third stage includes two aspects: one is to build the ward 3D scene in Unity3D, and design the layout of the lighting system, rendering, and the position of the character and item models in the ward. The MySQL database management system is utilized for the construction of the case database. Secondly, Baidu cloud service is called, and C# writes scripts to realize the voice interaction between users and the system. The detailed flow of system development is shown in Fig. 1.

3. Virtual Clinical Teaching System Design

The design goal of the virtual clinical teaching system is to provide users with a virtual environment of a hospital ward, which allows users to interact with the virtual patients of the environment by voice, so as to achieve the purpose of users' understanding and mastery of the clinical consultation process. The overall structure of the system is divided into four parts: ward scene construction, case database construction, voice interaction and user information management.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202404_7(4).0008

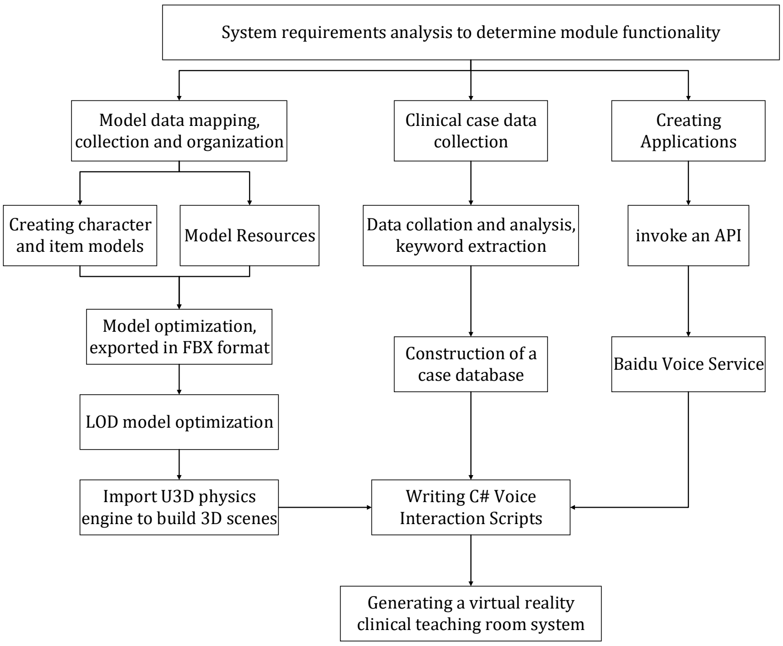


Figure 1. System development process

3.1. Ward Environment Setup

3.1.1. 3D Modeling in 3DMax

3DMax is graphics software specialized in creating 3D models, animations and digital images. When creating a 3D model, you need to plan out the shape of the model, including the body proportions and poses of the character model, and the shape and proportions of the object model. Use the base geometry provided by 3D Max to create body parts, such as the head, torso, and other parts of the character model. Modify the vertices, edges, and faces of the body part geometry to refine the details of the character. Tools such as "Edit Poly" or "Edit Mesh" allow you to make more detailed adjustments to the model, such as muscles, facial expressions, and so on. The material editor adds materials to the model, and the texture map adds texture to the model, which can make the model more realistic and textured [13], and enhance the visual effect of the model. Finally, the final rendering is performed in the "Render" panel, and the rendered model is exported in FBX file format, the interface of 3DMax model design is shown in Fig.2.

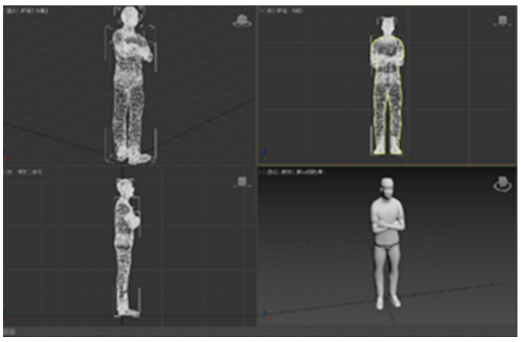


Figure 2. Three-dimensional modeling

3.1.2. Layout of Wrd Enironment

In this paper, Unity3D physics engine is chosen as the platform for running the virtual environment of the ward. Unity 3D is a professional physics engine that allows developers to carry out virtual reality development, 3D animation modeling and other functions, which can produce very realistic 3D virtual scenes [14]. The designed 3D models of characters and objects were imported into the physics engine in FBX file format.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202404_7(4).0008

In order to enhance the visual experience of the virtual ward scene, the virtual environment is arranged with reflection probes and light probes. The reflection probe can capture the reflection information of the surrounding environment, and the light probe samples the light information of the surrounding environment, and the saved reflection and light information is applied to other objects to ensure that the virtual model is more realistic, to obtain better rendering effects, and to enhance the visual quality of the virtual scene [15]. The system uses LOD (Level of Details) technique to optimize the virtual ward scene and improve the performance of the system. The LOD technique in common parlance is to allow an object to be displayed in different models at different camera distances, thus saving computational performance overhead. Therefore, one of the key points of using LOD technique is the need for models with different face count accuracy [16]. Mesh Decimation can be realized to quickly obtain multiple sets of models with different face counts, i.e., face reduction of the model to obtain different degrees of low face count models. Edge collapse (edge collapse) is an idea to achieve Incremental Decimation (Incremental Decimation), which uses triangular edge collapse for mesh simplification by combining two vertices into a single vertex [17], and for the edge mn to be collapsed, deleting the faces A and B on both sides of this edge, replacing m with n, connecting the other neighboring points of n and m, and delete m, where n is called the collapse target of m, as in Fig. 3.

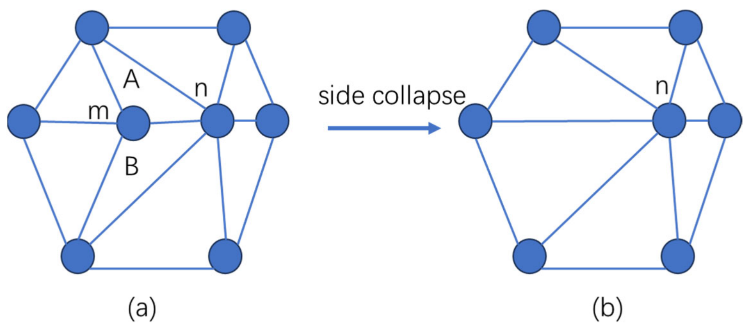


Figure 3. Simplified side collapse mesh

Edge collapse traverses all vertices in the mesh, calculates the edge collapse cost of all neighboring vertices, and then selects the neighboring point with the smallest collapse cost as its collapse target. There are two factors that can be considered when calculating the collapse cost. The first one is the length of the edges, the smaller the length of the edges indicates the smaller the model details, so the shorter edge lengths should be preferred to be removed in the simplification process. The second one is the curvature change around the point, theoretically the smaller the curvature change of the vertex, the flatter the region it is located in, and should be preferentially removed. To calculate the cost of collapse of an edge, first get the direction of the normal by the cross product of the difference of vectors between two points, compare the dot product of the normals of two faces to get the curvature value of the collapsed edge mn, and then multiply the value of the dot product by the distance between the two points to get the cost of the collapse, the calculation formula is as follows:

$$cost(m,n) = \|m-n\| \times \max_{p \in T_m} \left\{ \min_{q \in T_{mn}} \{a \div 2\} \right\} \quad (1)$$
$$a = (1 - p.normal \bullet q.normal)$$

ISSN: 2637-6067
DOI: 10.6918/IJOSSER.202404_7(4).0008

where Tm is the set of triangles that contain vertex m and Tmn is the set of triangles that contain both vertex m and vertex n. The steps for the implementation of edge collapse are as follows, and the simplified flow is shown in Fig. 4.

1) Search for relationships between vertices, triangular faces and triangular edges;
2) Calculate the collapse cost and collapse target and rank them;
3) Replace the point with the smallest collapse cost and recalculate the collapse cost and collapse target for the neighboring points to update the ordered list;
4) Determine if the current number of vertices is greater than the target number, otherwise repeat step 3.

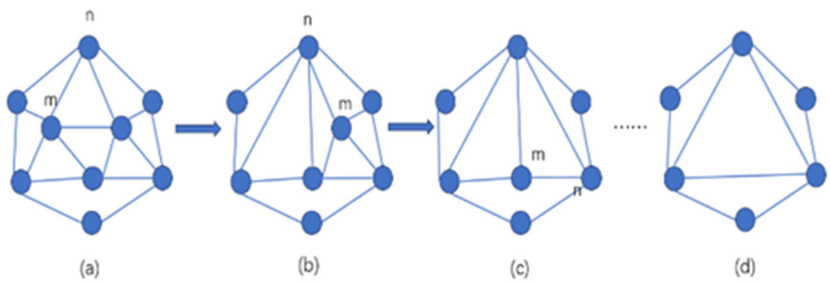


Figure 4. Mesh edge collapse process

3.2. Ward Evironment Setup

The system uses MySQL to construct the case database. MySQL is an open-source cross-platform database management system based on SQL query, which possesses the characteristics of open-source, scalability, high security, and rich community resources [18]. After field research in a local tertiary hospital ward and the exchange and cooperation of clinical chief doctors in each department, the clinical teaching and consultation process case data document was summarized and organized. The case database contains three entities: doctor, patient, and consultation record. The doctor entity includes attributes such as name, gender, job number, title, department, and area of expertise. The patient entity includes attributes such as name, gender, address, and occupation. The consultation record entity includes attributes such as date of consultation, reason for consultation, duration of condition, family members, and past medical history. There is a one-to-many relationship between the doctor and the patient, and a one-to-one relationship between the patient and the consultation record, and the instance relationship of the case database is shown in Fig. 5.

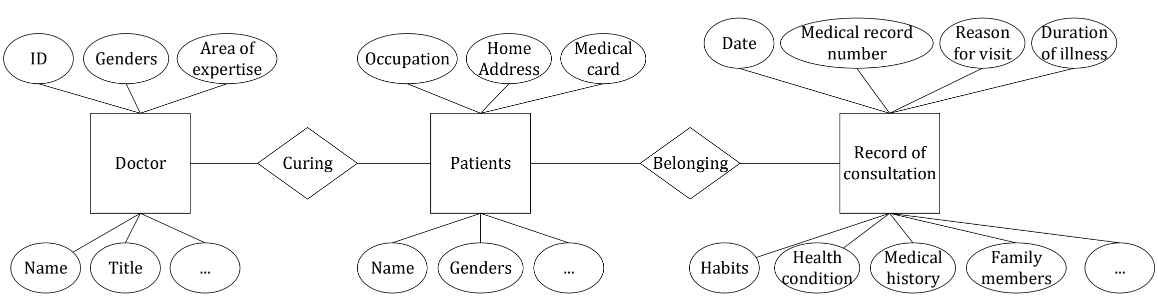


Figure 5. E-R diagram of the case database

3.3. Voice Interaction

Voice interaction is used between the user and the virtual clinical teaching system to simulate the process of clinical teaching and consultation. The voice technology service provided by Baidu Intelligent Cloud Platform is used to realize the voice dialogue between doctors and patients in the virtual scene. Baidu Intelligent Cloud Platform provides a variety of API calling

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202404_7(4).0008

methods, which can be realized by users in three ways, such as private deployment, cloud service, and installation of offline SDK. Because the HTTP-SDK method in the cloud service is deployed in a lightweight and flexible way, the user data is destroyed when it is used up, which can effectively guarantee the privacy of the data, so this paper chooses HTTP-SDK as the API calling method [19], and the detailed flow of calling Baidu's voice service is shown in Fig. 6.

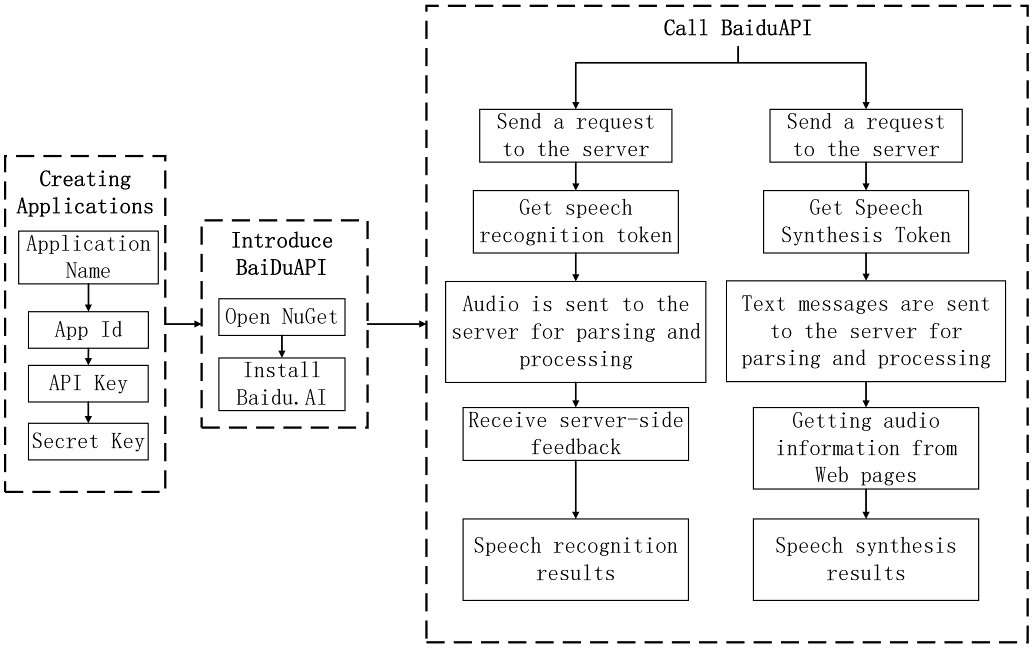


Figure 6. Calling baidu voice service

3.3.1. Speech Recognition

To create a speech recognition application in the Baidu Intelligent Cloud Platform, the platform automatically assigns the unique AppId, API Key and Secret for the project. when performing speech recognition, the C# script in the Unity3D physics engine sends a request to the Baidu cloud server to get the authorization to use Baidu's speech recognition function, sends the audio data information to the cloud server for processing, and the client The client parses the feedback results from the service and finally realizes the speech recognition function. Details of the parameters for sending and receiving feedback to the server when the system performs speech recognition are shown in Table 1.

Table 1. Details of speech recognition request/return parameters

Parameter type	Parameter name	Parameter description
request	format	Format of voice files
request	rate	Sample rate, 16000, 8000
request	cuid	Unique user identifier
request	token	Obtained access_token
request	dev_pid	Default mandarin
request	speech	Voice file binary data
request	len	Number of bytes in the local voice file
return	err_no	Error code
return	err_msg	Error code description
return	result	Speech recognition results

3.3.2. Speech Synthesis

When performing speech synthesis, a network request is sent to the Baidu cloud server to get the authorization to use the Baidu speech synthesis service, and then the text information including dialogue information, prompt information, etc. is sent to the cloud server for parsing, and the cloud server sends the specific audio information back to the customer service terminal, which ultimately realizes the function of speech synthesis. Details of the parameters sent to the server when the system performs speech synthesis are shown in Table 2.

Table 2. Details of speech synthesis request parameters

Parameter type	Default value	Parameter description
text		Synthesized text
token		Obtained access_token
cuid		Unique user identifier
ctp		Client type selection
lan		Language selection
spd	5 (medium speed)	Rate of speech, taking values from 0 to 15
pit	5 (medium tone)	Tone, value 0-15
vol	5 (medium volume)	Volume, value 0-15
person		Audio information

3.4. User Information Management

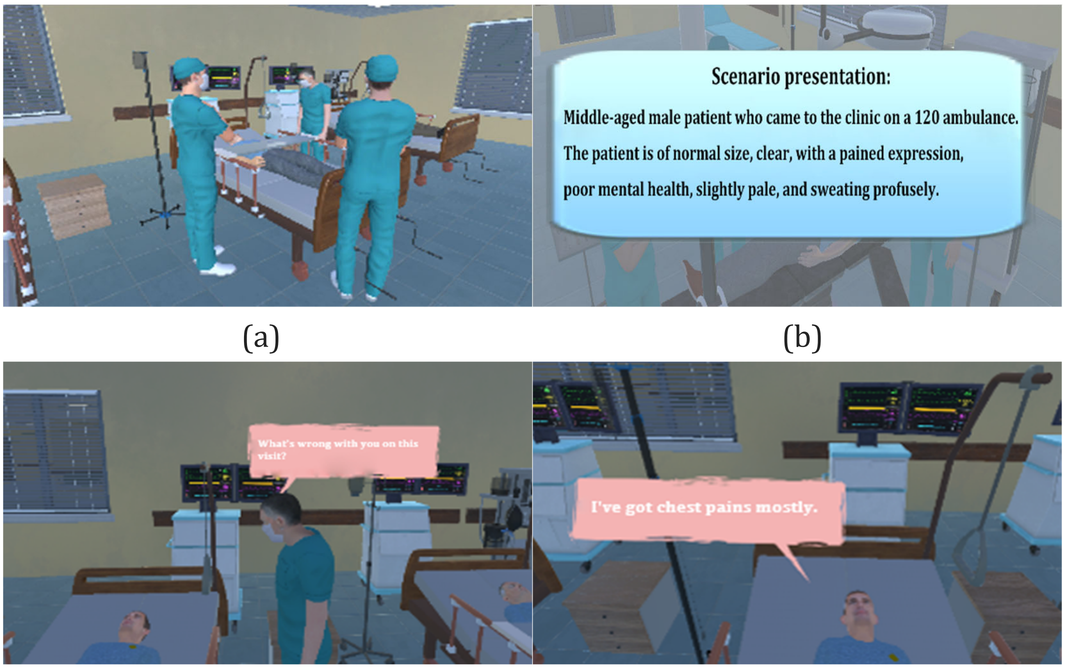
In order to be able to record the information of the users of the system, the system is designed with the user management module of the system. Considering that this system is still in the stage of optimization and improvement, the volume of user information that needs to be stored is not very large, so this system uses the PlayerPrefs class to store the user information, and it can store strings, floats, and integer values into the user's platform registration form, and this data can be run in the system to remain persistent for the duration of the system [20]. When a new user uses the system, he/she has to register first and the information is stored in the local registration table in the background processing. When logging in, the user inputs the account number and password to match with the information in the registry, and if the match is successful, the user enters the system, and if the match fails, an error message is displayed.

4. System Effectiveness Demonstration and Evaluation

4.1. System Effect Demonstration

The effect of the virtual reality-based clinical teaching system is shown in Fig. 7. After running the system, the user first needs to log in or register, and after selecting a case, the scenario of the case will appear on the screen to introduce the interface, which can help the user quickly familiarize with the case. Then voice interaction, according to the construction of the case database users simulate the doctor's point of view for the consultation process, the system simulates the patient's point of view based on the doctor's diagnosis of the corresponding answer.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202404_7(4).0008



(a) (b)

(c) (d)

Figure 7 System effect display. (a)Virtual ward scenarios; (b) Case scenarios; (c) Medical consultation; (d)Patient answer

4.2. Evaluation of System Effectiveness

The running environment of the system is: windows 11 operating system, CPU 3 GHz, RAM 8 GB, hard disk 500 GB. the LOD technique implemented by the mesh simplification algorithm based on edge collapsing can effectively reduce the number of triangular facets of the model and retain the geometrical information of the model as well as the important feature information of the model, such as topology and texture. The application effect of the mesh simplification technique is illustrated with the doctor model A as an example, as shown in Fig. 8. The number of triangular faces of the models with different qualities is shown in Table 3, which reveals that the model quality of figure (a) is the highest, the model quality of figure (b) is in the middle, and the model quality of figure (c) is the lowest. The important parameter indexes of the system operation before and after applying LOD technology are shown in Table 4, which shows that the system performance has been greatly improved after applying LOD technology. The average refresh rate of the system's screen reaches 80 frames/second, and the rendering calculation has a low latency, which indicates that the system runs relatively smoothly, and the system's smooth running effect can be ensured under the conditions of the general configuration of computer hardware environment. In summary, the system runs with good virtual scene rendering effect and can meet the needs of clinical teaching.

(a) (b) (c)

Figure 8. Model mesh simplification results. (a)High quality (b) Medium quality (c) Low quality

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202404_7(4).0008

Table 3. Model simplification effects (number of triangular faces)

Mesh quality/model	Doctor A	Doctor B	Patient
High quality	32554	31546	37370
Medium quality	21338	23675	24492
Low quality	10108	10237	11604

Table 4. Comparison of system parameters

System operating parameters	Original scene	Mesh simplification
Running average frame rate	55.6FPS	80FPS
Average frame processing time	12ms	10.2ms
Average processing time for rendering	5ms	4.3ms
Number of triangles rendered in the field of view	3.8M	2.9M
Number of fixed points rendered in the field of view	4M	3.4M

5. Conclusion

Virtual reality technology has the advantages of immersion, interactivity and imagination, and this system introduces virtual reality technology into clinical teaching, providing a new choice for exploring clinical teaching mode. By constructing a voice interactive clinical teaching system, it gives full play to the advantages of virtual reality technology that is not limited by time and space, and the teaching method based on virtual reality technology is novel and full of fun, which solves the problems of insufficient teaching resources and uneven quality of teaching on the current traditional clinical teaching in some areas to a certain extent. On the other hand, it improves the user's enthusiasm for clinical learning, combining theoretical knowledge and practice, which can consolidate and deepen the residents' or interns' understanding and memory of medical theoretical knowledge, and cultivate their scientific clinical thinking ability. The system runs stably and has a good effect on users' familiarization with clinical processes and learning of relevant professional medical knowledge.

Acknowledgments

This paper was supported by the Teaching and Research Project of the Virtual Teaching and Research Office of Engineering Innovation Education (RC013) of the Ministry of Education, and the Research and Practice Project of Higher Education Teaching Reform of Henan University of Science and Technology (2021BK054).

References

[1] LI Jian, HUANG Ji, JIANG Hao-wen et al. Requirements, norms and considerations of clinical teaching[J]. China Higher Medical Education,2018,No.262(10):18-19. (In Chinese)

[2] ZHOU Zhibo, CHEN Shi, LI Yue, HU Ya, JING Quan, WANG Qian, PAN Hui, ZHU Huijuan. Concept and discussion of standardized clinical teaching[J]. Research on Medical Teaching in Colleges and Universities(Electronic Edition),2021,11(06):9-14.

[3] Wang Zhangliang. Problems and reform countermeasures of nursing undergraduates in clinical teaching of respiratory medicine[J]. China Health Industry,2020,17(03):125-127.

[4] Wang Zhangliang. Problems and reform countermeasures of nursing undergraduates in clinical teaching of respiratory medicine[J]. China Health Industry,2020,17(03):125-127.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202404_7(4).0008

[5] Yang Li. Reflections on the use of virtual reality technology in clinical apprenticeship teaching[J]. Modern Medicine and Health,2021,37(07):1234-1236.

[6] LUO Wei, WU Mingchan. Development of laparoscopic operation training system based on virtual reality technology [J]. China Medical Equipment,2013,28(11):117-119.

[7] Albiol-Pérez Sergio, Gil-Gómez José-Antonio, Muñoz-Tomás María-Teresa, Gil-Gómez Hermenegildo, Vial-Escolano Raquel, Lozano-Quilis José-Antonio. The Effect of Balance Training on Postural Control in Patients with Parkinson's Disease Using a Virtual Rehabilitation System.[J]. Methods of information in medicine,2017,56(2).

[8] Eftekharsadat Bina, Babaei-Ghazani Arash, Mohammadzadeh Mehran, Talebi Mahnaz,Eslamian Fariba, Azari Elnaz. Effect of virtual reality-based balance training in multiple sclerosis. [J]. Neurological research,2015,37(6).

[9] Stepan, K. etc. Immersive virtual reality as a teaching tool for neu-roanatomy[J]. International forum of allergy & rhinology, 2017:1-8.

[10] XIN Xin, YU Wenjun, WAN Meiping. Evaluation of the application effect of virtual reality technology in the teaching of operating room for nurse interns in colleges and universities[J]. Journal of Nurse Advancement, 2022, 37(23): 2133-2137.

[11] WANG Jin-You, TOU Zhou-Ting, WANG Xin,et al. Application of smart teaching combined with virtual reality technology in urology clinical teaching[J]. China Case, 2023,24(1):70-72.

[12] LIU Hanghang, ZHU Zhaokun, LI Palun,et al. Application of virtual reality technology in clinical teaching of orthognathic surgery[J]. Continuing Medical Education,2023,37(5):77-80.

[13] Lin Yu. 3DMAX-based three-dimensional virtual stage scene modeling and virtual design[J]. Modern Electronic Technology,2019,42(19):103-106.

[14] Luan N. Design and realization of virtual holistic operating room interactive display [D]. Beijing: Beijing Institute of Technology,2016. (In Chinese)

[15] Huang T. Research and realization of virtual campus roaming system based on Unity3D [D]. Guangxi: Guangxi Normal University,2014.

[16] Wang Ziyi. Research on modeling composition technology and system integration method of frame structure based on BIM technology [D]. Beijing Jiaotong University,2020. (In Chinese)

[17] LUO Zhongxing, ZUO Li, LUO Kunsheng,et al. Design and realization of fully immersive VR training system for nuclear radiation monitoring[J]. Chinese Journal of Safety Science,2023,33(1):130-135.

[18] Li Yangjun. Research on open source database application based on MySQL[J]. Digital Technology and Application, 2014(06):71-72.

[19] Jiang Yi. Entry method of right source information based on Baidu Intelligent Cloud[J]. Geospatial Information,2022,20(05):145-149.

[20] Yang Huaimin, Qiu Shuwei. Design and realization of adventure game based on Unity3D[J]. Modern Computer,2023, 29(13):73-78.