A Surgical Training System for Four Medical Punctures Based on Virtual Reality and Haptic Feedback

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ABSTRACT

This poster presents a surgical training system for four medical punctures based on virtual reality and haptic feedback, including a client program developed in the Unity3D game engine and a server program developed by PHP. This system provides the immersive surgery simulation for thoracentesis, lumbar puncture, bone marrow puncture and abdominal paracentesis that we call four medical punctures. Trainers or teachers can release training tasks in which trainees or students are able to learn surgery skills at a 3D visual scene. Furthermore, they will feel a sense of immediacy when putting on the head-mounted display and with the help of haptic feedback. The training records will be put into database for analysis.

Keywords: Surgical training system, virtual reality, head-mounted display, haptic feedback.

Index Terms: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual Reality; J.3 [LIFE AND MEDICAL SCIENCES]: Medical information systems; H.5.2 [Information Interfaces and Presentation]: User Interfaces—Haptic I/O

1 INTRODUCTION

Thoracentesis, lumbar puncture, bone marrow puncture and abdominal paracentesis are the basic clinical skills that medical students and residents need to obtain. Traditionally, training of these four medical punctures includes learning medical textbooks, watching surgical videos, observing the operation by the clinician and operating on plastic models or live patients.

With the rapid development of information technology, virtual reality has been widely used in all walks of life. In medical training, the application of virtual reality can save costs, enhance training effectiveness, and avoid some ethical problems. This paper presents a surgical training system for four medical punctures based on virtual reality and haptic feedback.

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2 RELATED WORK

Dimitrios Stefanidis et al. [1] reviewed the current state of simulation used in surgery and offered direction for future research and implementation of evidence-based findings. Their articles pointed out that to enable the more widespread incorporation of best practices and existing simulation curricula in surgery, effective implementation strategies need to be developed. Jaisa Olasky et al. [2] agreed that the future of simulation would depend heavily on the establishment of an agreed upon set of goals for surgical trainees. The mentioned goals include creating an immersive experience, improving ergonomic simulations, simulators that modify the program based on learner performance, safety education etc.

At present, there are some medical training systems based on virtual reality and haptic feedback. Jia Luo et al. [3] presented a new haptic and virtual reality simulator for ophthalmic surgery training. However, to the best of our knowledge, no training systems for four medical punctures based on virtual reality and haptic feedback have been published.

3 MODEL DESIGN

In order to create this training system, we design models that it requires, including human and organ models, surgical instrument models, surgical material models and surgical scene models.

3.1 Human and Organ Models

We divide the human and organ models into two groups. One is the common model that all punctures need, the other is the dedicated model for each puncture.

The common human models include patient models, clinician models and nurse models. We respectively design the organ and tissue modes for thoracentesis, lumbar puncture, bone marrow puncture and abdominal paracentesis.

3.2 Surgical Instrument and Material Models

For each of four medical punctures we design 3D surgical instrument and material models. For example, for abdominal paracentesis it includes one curved plate, two hemostats, one tissue forceps, one disinfection bowl, two disinfection cups, one abdominal puncture needle, a piece of hole towel, two or three pieces of gauze, some cotton balls, two to four sterile test tubes, one injector of 5ml, one injector of 20ml, one injector of 50ml, two pairs of sterile gloves and a long belly band etc. Some of these surgical instrument and material models could be used for other punctures. For easy to use we classify them at model library.

3.3 Surgical Scene Models

We design some 3D surgical scene models. These models include operating rooms, the patient on the table, the patient lying on the chair, the patient lying in bed and some other circumstances.

We design all above 3D models in 3D modeling tools and export the file in fbx format which can be imported into Unity3D conveniently, Fig.1 shows some of these models imported into the scene of Unity3D.

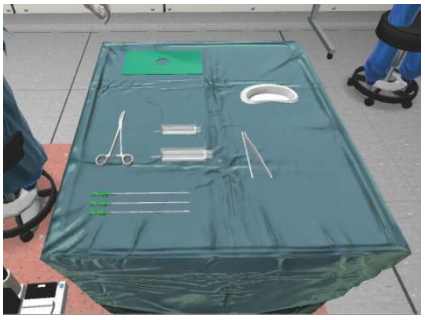

Figure 1: Some models of surgical instrument and scene.

4 Applications

We realize the surgical training system in the Unity3D game engine and develop the server program by PHP. The main functions of the system include training task release, immersive surgery simulation training and training evaluation and analysis.

4.1 Release Training Tasks

After trainers or teachers login the system by a web browser, they can release training tasks. When they release a training task, they can set the score for each step of the puncture procedure, and they are able to set the time required for the trainee to complete the training. Fig.2 shows the interface of releasing a training task.

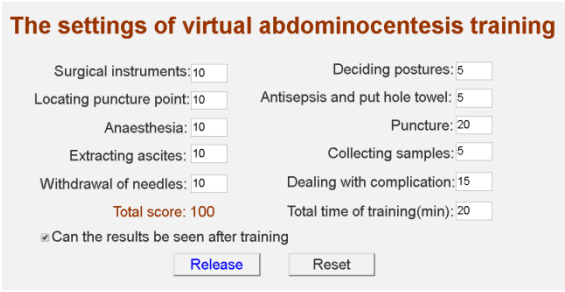

Figure 2: The interface of releasing a training task.

4.2 Immersive Surgery Simulation Training

When trainees login the system, they can freely select one of four medical punctures for training or they can view the released training tasks by trainers. When they do the released training tasks, they can put on the head-mounted display and enter a 3D surgery scene. With the help of head-mounted display and haptic feedback, they will feel a sense of immediacy. They must finish every step of the puncture procedure. Both correct and incorrect operations will be recorded and stored into database. Trainees can also watch the animation of the whole surgery procedure if they are not clear about the surgical procedure. Fig.3 shows an interface for trainees.

To perform the four medical punctures, the modeling of soft tissues is indispensable. It must be real-time and allow realistic interaction. There are two main approaches which are widely used in soft tissues modeling——Finite Element Method (FEM) and Mass Spring System (MSS). We combine the two approaches to make full use of their respective advantages.

During the training, trainees use the haptic feedback device to enhance their operating experience. According to Newton's third law of motion, when the haptic feedback device is pushed by a force, a reaction force on the opposite direction is applied to the virtual injector model. This feedback mechanism improves the reality of the interaction between feedback device and the virtual injector model.

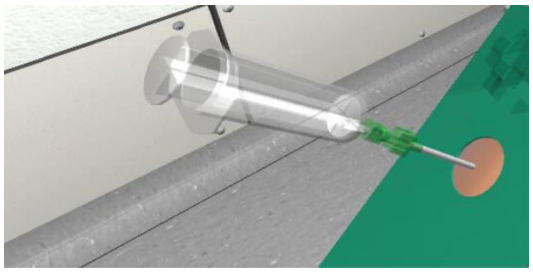

Figure 3: An interface for trainees.

4.3 Training Evaluation and Analysis

Trainers or teachers can evaluate the trainees' training effect by analyzing the data stored in the database. These data include the number of times the trainees completed the puncture procedure, the completion rate and average finished time of the trainer and some training information for all trainees. Through the analysis of these data, trainees or teachers can obtain the training of trainees and improve the future training. We have offered this system to some hospitals and medical colleges to evaluate its training capabilities.

5 Conclusion

The integration of virtual reality and haptic feedback has elevated the level of reality of four medical punctures. The haptic feedback effects convert the interaction in the 3D surgical scene to the force applied to trainees' hand. We will continue to improve our system in the future to enhance the immersive experience.

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References

[1] Dimitrios Stefanidis, Nick Sevdalis, John Paige, Boris Zevin, Rajesh Aggarwal, Teodor Grantcharov, and Daniel B. Jones. Simulation in Surgery What's Needed Next? *Annals of Surgery*, 261(5):846–853, 2015.

[2] Jaisa Olasky, Ganesh Sankaranarayanan, Neal E. Seymour, J. Harvey Magee, Andinet Enquobahrie, Ming C. Lin, Rajesh Aggarwal, L. Michael Brunt, Steven D. Schwaitzberg, Caroline G. L. Cao, Suvranu De, and Daniel B. Jones. Identifying Opportunities for Virtual Reality Simulation in Surgical Education: A Review of the Proceedings from the Innovation, Design, and Emerging Alliances in Surgery (IDEAS) Conference: VR Surgery. *Surgical Innovation*, 22(5):514-521, 2015.

[3] Jia Luo, P. Pat Banerjee, Cristian J. Luciano, Patrick Kania, Shammema Sikder, and William G. Myers. A part-task haptic simulator for ophthalmic surgical training. *2016 IEEE Symposium on 3D User Interfaces (3DUI)*, pages259–260, 2016.