SCHOOL OF SIMULATION AND VISUALISATION THE GLASGOW SCHOOL OF ART

Making an Accurate Acupuncture Feedback Platform in Virtual Teaching Environment

By Boyu Xu

The Glasgow School of Art

School of Simulation and Visualisation

MSc in Serious Games and Virtual Reality

Supervisor: Dr. Matthieu Poyade

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Abstract

Acupuncture can be an ancient art in the traditional Chinese medicine. It is difficult to teach and train for the young generation, but in recent years, there has been an increased interest in using interacted methods to enhance educational settings, especially with a growing focus on Virtual Reality(VR).

The purpose of this project is to develop and test an accurate acupuncture feedback platform in the virtual environment with immersing Virtual Reality(VR) and integrated haptics for the teaching and training in the early stage of acupuncture learning and explore a vivid and visual method to deliver the technologies of acupuncture to the young generation.

An introduction interface and the interacted methods are combined with the Virtual Reality(VR) and haptic technologies to establish concurrent and terminal feedback platform. To evaluate the interactive application, the study was conducted with ten participants who were students from GSA and the professional acupuncturists in the UK. Participants implemented feedback questionnaires at the end of testing. The overall feedback received was positive. Also, the acupuncturists took part in the calibration of the needling feedback. Due to the positive feedback, further developments could be refined on the feedback training.

Acknowledgement

I would like to show my appreciation to everyone who helped e through this process.

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Finally, I would like to thank Yifeng Wu and Zi Mu for dubbing in the project and all the participants that were involved in testing and providing feedback for the application. I would also like to thank the two professional acupuncturists for sharing their knowledge and experience throughout the testing, which helped me improve the accuracy of feedback in the application.

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Definitions and Abbreviations

1. Acupuncture - Acupuncture is a part of Traditional Chinese Medicine, it can help patients to remit the disease by using suitable needles to penetrate accurate acupoints.
2. Acupoint - Acupoint is the specific point in the body，it is useful to remit the disease by needling acupoints.
3. The main and meridian channels - The main meridian channels are the vital constituent parts of the body. Needling can penetrate the acupoint, and generate the meridian channel to make patients feel comfortable.
4. AE - Adobe After Effects
5. AI - Adobe Illustrator
6. Flash - Adobe Flash Professional
7. DoF - Degrees of Freedom
8. VR - Virtual Reality
9. App - The acupuncture application

1 Introduction

Acupuncture is a difficult part of the Traditional Chinese Medicine to both teach and train, particularly transferring the knowledge about the process of operating the acupuncture to the young generation. A case of study which performed by Pheng-Ann Heng (2006) which reviews a haptic needle manipulation simulator for Chinese acupuncture learning and training. In addition, Yuchen Jiang (2016) explored the using of Virtual Reality technology in the training of acupuncture. However, there are still improvements to be made in the teaching and training of acupuncture. There are many studies which focus on the haptic feedback force of the needling, or the virtual body in the acupuncture. These studies only point out the Virtual Reality or haptic technology independently and the rationale and accurate training of acupuncture are obscure in these professional explorations, such as using the Virtual Reality of acupuncture alone in the digital virtual human (Jun, J., et al. 2016).

The study of making an accurate acupuncture feedback platform in virtual teaching environment aims to combine the Virtual Reality and the haptic technology to create a platform to deliver the rationale of acupuncture to the youth and provide the accurate real-time and terminal feedback in the needling training. Simulation is the vital requirement of VR technology, and the application has a strong development in the simulate and visual expression. Furthermore, the accurate feedback of acupuncture is achieved by the combining of haptic technology and VR.

1.1 Rationale

The effectiveness of VR and haptic technology in the learning and training of acupuncture and delivering the knowledge of acupuncture clearly to the young generation are the vital features of the application. The rationale for the study is shown below:

1. The application can make students understand the relationship between the anatomy and acupuncture, and train the needling repeatedly.
2. The haptic technology can make students “feel” the haptic characteristics of materials and the virtual environment helps them learn the anatomy and acupoint.

3. The using of VR and haptic technology in acupuncture can not only help learners learn about the operation of acupuncture, but also create a new teaching method to save the physical materials in the teaching of acupuncture.
4. These technologies can provide a natural way to teach and train the acupuncture, it also provides a preparation for students to needle the real tissues.
5. The technologies of acupuncture can be delivered to the young generation clearly by the user-friendly introduction interface.

1.2 Aims

The aim of this research conducted is making an accurate acupuncture feedback platform in the process of teaching and training acupuncture, and exploring a modern method to deliver the knowledge of acupuncture to the youth better. The aim of the study is shown below:

1. Make the simulated and haptic teaching platform to improve the teaching and training method in the acupuncture field.
2. Develop an efficient information feedback strategy in the form of concurrent and terminal feedback to support the training and learning of acupuncture.
3. Deliver the rationale and knowledge of acupuncture to the young generation by the friendly and pellucid image information.
4. Provide repeated simulation for learning the relationship between the acupuncture and anatomy, and exercising the operation of acupuncture.

These aims will be achieved in a virtual acupuncture centre where the learners will learn the knowledge of acupuncture and perform the process of needling. Using Virtual Reality(VR) and haptic technology could make learners immerse in the operation environment, and get a real-time feedback step by step. Moreover, the learners could be free to interact in the virtual environment and achieve more effective learning results in the application. Finally, the learners could learn the rationale of acupuncture and the anatomic knowledge smoothly in the operation.

1.3 Hypothesis

The study will be useful for both learners of acupuncture and professional acupuncturists. The hypothesis for the study is shown below:

For the learner:

1. Learners with little acupuncture knowledge can learn the knowledge of acupuncture and anatomy in a friendly visual system.
2. Acupuncture knowledge can be delivered to the youth through modern imaging and interactions.
3. Through haptic feedback by haptic technology in virtual environments, learners are able to perform accurate acupuncture operations and understand the knowledge of acupuncture further.
4. Accurate concurrent and terminal feedback can help learners in understanding the needling, choose the needle and position acupoints.
5. Repeated training can help learners make a preparation for the future real acupuncture training.

For the professional acupuncturist:

1. Offer opportunities for professional acupuncturists to plan the acupuncture operation before the practical needling, through the Virtual Reality and haptic technology.
2. Help professional acupuncturists to know the disadvantage of needling using real-time and terminal feedback.

1.4 Structure of Thesis

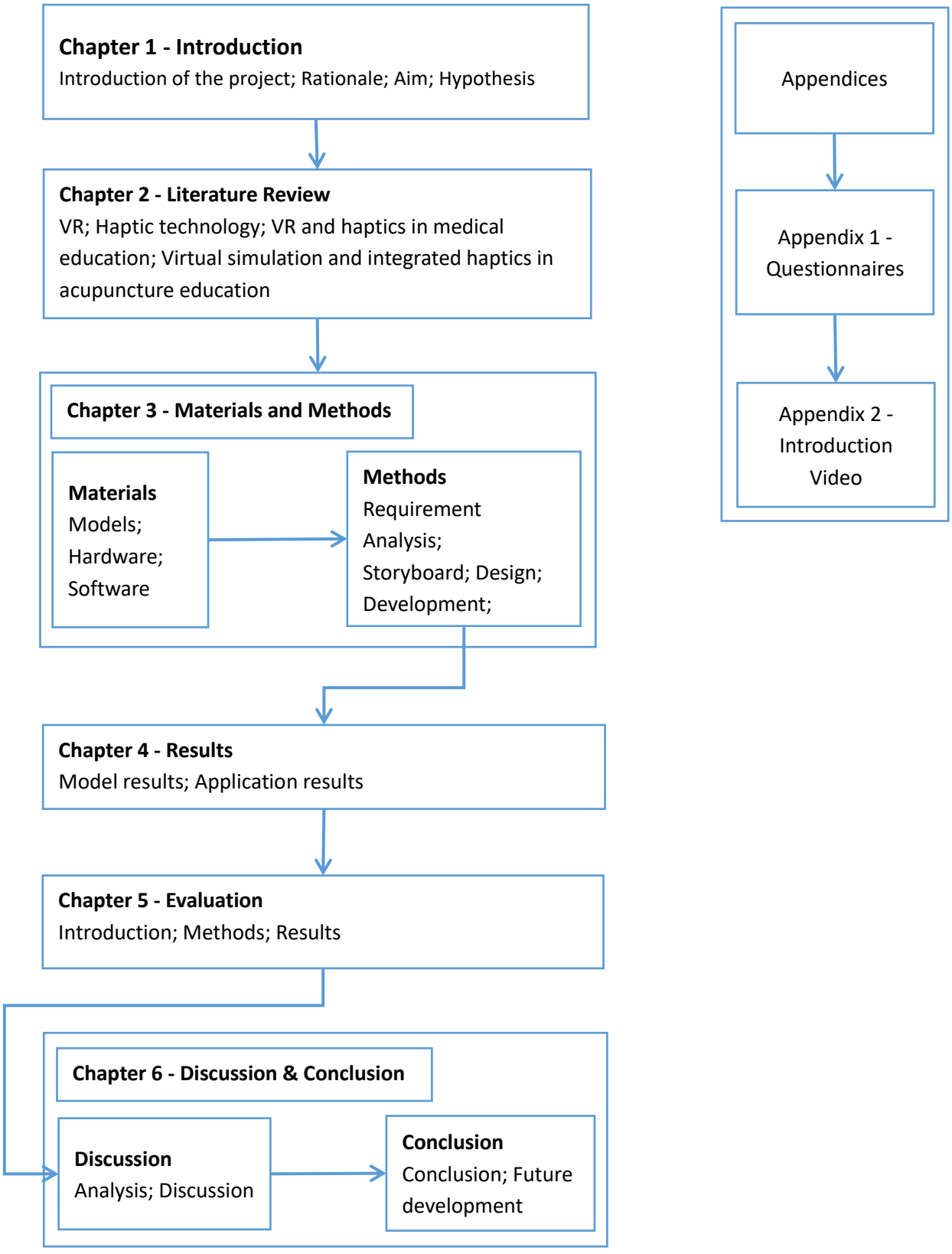


Table 1-1 Flowchart of the structure of the thesis.

2 Literature Review

2.1 Introduction

With the development of science and technology, the educational system must adapt to enhance traditional teaching methods with the blending of digital and virtual resources. There is a thesis to suggest that learning is an individual interacts with information and the environment through the development of new knowledge, skills or attitudes (SE Smaldino et al., 2004). Therefore, in the learning system, the interaction with the knowledge and environment is a vital point, and it could be particularly significant in the teaching and learning of acupuncture.

Although acupuncture has been used for thousands of years and is useful in a wide range of situation, the scientificity of acupuncture is a controversial issue (Tsuei J., 1996). However, with continuous study in acupuncture, the electrodermal screening test (EDST) and electrodermal screening device (EDSD) was put forward in 1996 (Tsuei J.J., 1996). It made the research of acupuncture combining with the solid theoretical foundation in modern physics and quantum mechanics. It meant people could understand acupuncture by actual numerical value. Besides, in 2006, students could learn and practice acupuncture in the advanced 3D interactive environment that supported by force feedback haptic and Virtual Reality technologies(Heng et al., 2006). It was the first attempt to develop a virtual human model for studying Chinese medicine (Heng et al., 2006). It was also achieving the experiential learning (Dewey, J., Lewin, K., 1984) in the teaching of acupuncture. Practice in virtual acupuncture environment could get hands-on learning.

Although current teaching methods in acupuncture have advanced a lot, some institutions are interested in paying more attention to creating better learning tool on acupuncture by different interactive ways, such as Virtual Reality and pen-force feedback tool.

2.2 Teaching and learning acupuncture

In this part, an introduction to the theory of acupuncture will be made, and the learning tools in the development of teaching in acupuncture will be illustrated.

2.2.1 Acupuncture Theory

In the traditional sense, naturalistic theories have the vital influence on the acupuncture, and the naturalistic theories are compatible with Confucianism and Taoism. Such ideas as yin-yang, qi, dampness, and wind represent East Asian conceptual frameworks that emphasize the reliability of ordinary, human sensory awareness are the cores of the acupuncture (J. Kaptchuk, 2002). In the traditional acupuncture treatment, the connection between acupuncture needles and the energy pathways of the body is described by De qi, which is an essential conventional measure standard of acupuncture treatment. The concept of De qi is discussed in the earliest Chinese medical texts, but the details phenomenon were fully described in the recent hundred years through the experiences between the acupuncturists and patients (Jian Kong et al., 2007).

In 2007, researchers reviewed the acupuncture field systematically and put forward a scale “MASS” to measure the feeling of patients when the needle penetrated the tissue of the body. Researchers hoped their efforts would enhance the rigor of acupuncture, and they introduced "Mass" to measure De qi (Jian Kong et al., 2007).

“The ‘MGH Acupuncture Sensation Scale’ (MASS) scale includes 13 descriptors: soreness, aching, deep pressure, heaviness, fullness/distension, tingling, numbness, sharp pain, dull pain, warmth, cold, throbbing, and one supplementary rows at the end for subjects to describe perceptions in their own words” (Jian Kong et al., 2007). Figure 2.1.

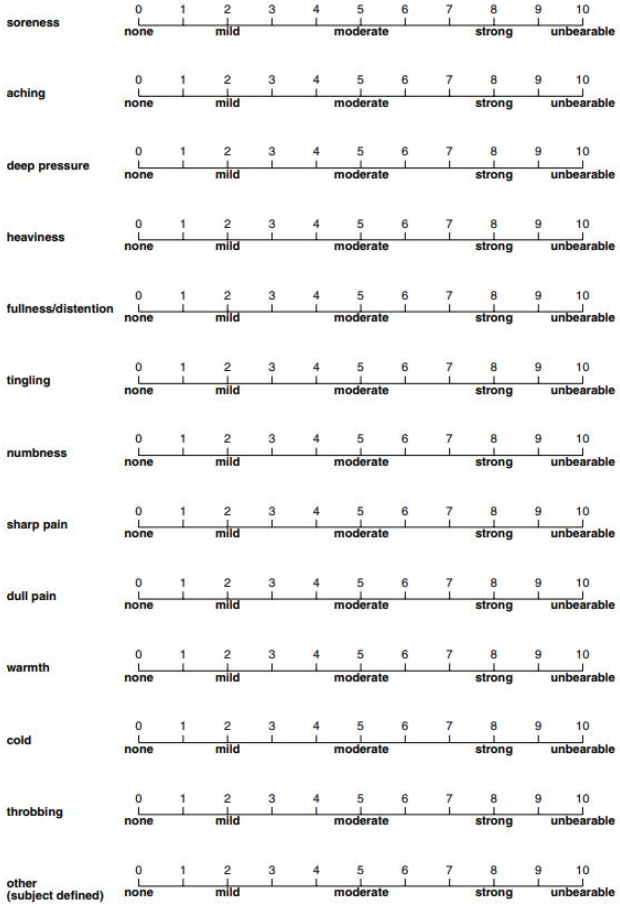


Figure 2-1 “The Massachusetts General Hospital acupuncture sensation scales (MASS). The scale includes 13 descriptors: soreness, aching, deep pressure, heaviness, fullness/distension, tingling, numbness, sharp pain, dull pain, warmth, cold, throbbing, and a subject defined” (Jian Kong et al., 2007).

Overall, in the research of modern acupuncture, researchers pay more attention to how to transfer the technology of acupuncture scientifically, and it will help the next generation to learn better. For example, The electrodermal screening test (EDST) and electrodermal screening device (EDSD) used in acupuncture in 1996, it was a connection between the quantum mechanics and acupuncture treatment (Tsuei, J., 1996).

2.2.2 Learning Tools in Acupuncture

2.2.2.1 Traditional Learning Tools

From the 3rd Century AD onwards, with the development of acupuncture in China, acupuncture became a more and more professional discipline, because of various professional books created by acupuncturists, such as *Zhenjiu Jiayi Jing* (Kan-Wen Ma, 2000).

Firstly, a book called *Zhenjiu Jiayi Jing* (A Classic of Acupuncture and Moxibustion) compiled by Huangfu Mi (214-282) between 259 and 260 (Kan-Wen Ma, 2000). It was a professional acupuncture teaching book which illustrated the name and number of points of each Channel and their exact locations, and the properties and indications of each acupoint and the methods of needling detailedly. Huangfu Mi created the book through the method which combines the theoretical knowledge and clinical experiences (Kan-Wen Ma, 2000).

Secondly, in 1023, a court physician called Wang Weiyi (approx 987-1067) wrote a book to describe the theory of acupuncture points and Channels under the order of the Song government. At the same time, he built two life-size bronze acupuncture figures cast and inscribed with Channels and points on them to aid people in understanding the knowledge of acupuncture (Kan-Wen Ma, 2000). The title of the book was Tong *Ren Shu Xue Zhen Jiu Tu Jing* (Illustrated Classic of Acupuncture and Moxibustion Points as Demonstrated on the Bronze Figure), it discussed the 359 acupuncture points detailedly, and the depth of each acupoint (Kan-Wen Ma, 2000). Following the book, the professional acupuncturists could find the detailed introduction and function of each acupuncture point. This book and the two life-size bronze acupuncture figures cast were the most important learning tools in the traditional teaching of acupuncture.

2.2.2.2 Modern Learning Methods

As far as the learning method is concerned, in the modern teaching methods of acupuncture, acupuncture is closely related to anatomy. “Treatment with acupuncture

consists of the insertion through the skin of solid needles from 15 to 50 mm in length. The depth of insertion varies from a few millimeters to several centimeters. The tip of the needle often lies in a muscle, but many recognized acupuncture points overlie other structures, including the nerves and pleura;" therefore, acupuncturists need an operating knowledge of anatomy and understanding the relationship between anatomy and acupuncture to avoid causing direct harm to the body (Elmar T. Peuker et al., 1999).

Concerning the learning system in acupuncture, the practical teaching of acupuncture followed the method of combining the theory learning and the practical training. According to the technique points of actual education, the teachers established training methods and evaluation form and listed full aspects of self-evaluation and mutual evaluation (Han, H. et al., 2016). This is a modern learning method of acupuncture to connect the theory learning and practice with the assessment.

2.3 Virtual Reality

In this part, the definition and features of VR will be described, and it also will discuss the application of VR in medical education.

2.3.1 Description of Virtual Reality

2.3.1.1 Definition of Virtual Reality

Virtual Reality is a form of technology which is coined by Jaron Lanier in 1989 to put all virtual projects under one name (Krueger, 1991). Virtual Reality is usually a combination of hardware, including computers, headsets, and motion sensors (Steuer, J., 1992). Generally speaking, in the Virtual Reality system, the user wears the stereoscopic display to connect the virtual environment and uses the sensor to carry on the interactive information transmission with the virtual environment. Image output is carried out in a stereoscopic display (Steuer, J., 1992).

With the deepening of research, people have a deep understanding of Virtual Reality(VR) from the technical level to the perceptual level. Virtual Reality has become an immersive experience, highlighting the user's individual feeling in the virtual environment. Therefore, Virtual Reality is combined with the ability of perception and interaction.

2.3.1.2 Features of Virtual Reality

About the features of Virtual Reality(VR), firstly, Virtual Reality uses computer graphics to simulate a real world in which the users can input different instructions to achieve the real-time interactivity (Grigore C. Burdea, 2003). Secondly, simulation is another vital feature of VR. VR focuses on not only seeing the images on the screen but also feeling them in the virtual environment (Burdea, 1996). Virtual Reality established the multilevel computer interface and used all of the sensory channels of the body to make a concurrent virtual environment (Codella et al., 1993). Thus, the feeling of immersion and simulation are also the features of Virtual Reality.

2.3.2 Virtual Reality in Medical Education

According to Millar's research, Virtual Reality(VR) is an excellent learning tool in the teaching and training field. Because the 3D simulator environment could help the users understanding the knowledge well and making the interactive operation. People can enter a VR world which has been established or build their VR world. The presentation and interaction of a VR world are consistent with actions in our physical world (Byrne, 1992).

VR has the incredible potential in the medical education, nowadays, more and more simulator training are established by the virtual environment to improve the skill ability of the medical students (Hoffman, H., 1995). The VR-based environment can provide a 3D visual environment for the users understanding the structure of the human tissues, and also encourage the users to interact with the virtual environment (Hoffman, H., 1995). For example, research in anesthetic simulation in 2006, these simulators combined a manikin with specific computer controls that could be manipulated in the virtual environment to provide various physiological outputs (Bradley P., 2006). It was an accurate and repeated operation training equipment to help students do the anesthetic simulation. Also, in 2009, researchers developed the ‘Karlsruhe Endoscopic Surgery Trainer,' which is a VR technology-based training system for laparoscopic surgery (Kuhn, Ch. et al., 2009). The VR training system taught surgeons new procedures and determined their ability level before they operated on patients.

2.4 Haptic Technology

In this part, the description of the haptic device and the application of haptic technology in medical education will be illustrated.

2.4.1 Haptic Device

“The word haptics, believed to be derived from the Greek word haptesthai, means related to the sense of touch. In the psychology and neuroscience literature, haptics is the study of human touch sensing, specifically via kinesthetic (force/position) and cutaneous (tactile) receptors, associated with perception and manipulation. In the robotics and virtual reality literature, haptics is broadly defined as real and simulated touch interactions between robots, humans, and practical, remote, or simulated environments, in various combinations” (Handbook of Robotics, Siciliano, 2016).

The user can experience tactile sensation in the environment and feel the feedback of tactile force interactively. Besides, the user also can feel the tactile performance in the operating environment (Handbook of Robotics, Siciliano, 2016).

Figure 2-2 shows the haptic loop. It is composed of a haptic device, a controlled computer environment, and an interactive platform.

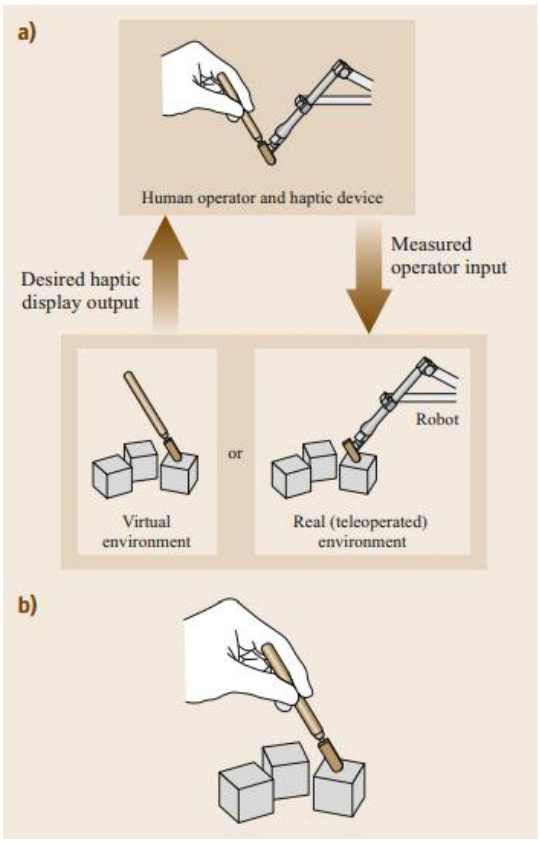


Figure 2-2 The haptic loop (Handbook of Robotics, Siciliano, 2016).

Firstly, the tactile device tests the operator's input force through the haptic device's force feedback which is produced by the user's input. Second, the input information is connected to the virtual environment. In the virtual environment, the input force information has an impact on the overall virtual environment. At the same time, the tactile device interacts with the real environment, and the tactile force transmits the tactile information to the user. Finally, the user feels the tactile force feedback on the tactile device. This complete haptic loop repeats itself in the haptic system (Handbook of Robotics, Siciliano, 2016).

2.4.2 Haptic Technology in Medical Education

The haptic technology can be used for people to train some skills to combine with the virtual display, which need the hand-eye coordination, such as the surgical training (Maharashtra, 2015). The haptic device has a broad application within virtual medical training applications, and mainly, it can be used to help doctors to plan an operation and train skills (Coles, T.R. et al., 2010). For example, in 2012, the researchers established an intravenous simulator incorporating virtual reality and haptics device technologies (Jung Eun-Yang et al., 2012). It was a haptic training aid used by medical and nursing colleges with IV arms designed for IV injection PE. Furthermore, in the example, the researchers also evaluated the simulator training. The virtual and haptic simulator training method could help the students learn injection skills well and complete injections quickly (Jung Eun-Yang et al., 2012).

Also, nowadays, the patient safety is becoming more and more concerned, in particular, considering the medical process and technology (Coles, T.R. et al., 2010). Safe practice of operation becomes more and more critical, and the operator needs to respond correctly to both visual and haptic actions. Therefore, medical simulator becomes a more accepted tool to train the process of operation. For example, in 2001, the researcher made an exploration of graphical and haptic simulation of the laparoscopic common bile duct (Basdogan, B., 2001). The researcher simulated a surgical procedure that involved inserting a catheter into the cystic duct using a pair of laparoscopic forceps. In this research, the user could be trained to grasp and add a flexible moving catheter into the deformable cystic duct in a virtual environment. In the process of training, the user could see the related images on the computer screen and feel the haptic feedback.

2.5 Virtual Simulation and Integrated in Acupuncture

Simulation-based learning is an effective learning method for the learning and training of acupuncture. In the traditional teaching method of acupuncture, in 1027, Wang Weiyi established two bronze real-size statutes for teaching acupuncture and surface anatomy. It was a useful attempt at simulated learning (Proceedings of the Saudi Health Simulation Conference 2018, 2018). The following lists three examples about the research combining the virtual simulation and integrated haptics in acupuncture.

Firstly, in 2006, using the virtual reality technology, researchers developed an intelligent virtual environment for the study and training of acupuncture in China. This was the first step in improving the overall virtual environment for the study of Chinese medicine. Students could learn and practice acupuncture in an advanced 3D interactive virtual environment that supported by a force feedback interface for acupuncture. Therefore, students could not only "see" but also "feel" virtual patients (Heng et al., 2006). Figure 2-3 Needle puncture on the acupoint Sanyinjiao (Heng et al., 2006). Figure 2-4 User interface and operation situation of the research (Heng et al., 2006).

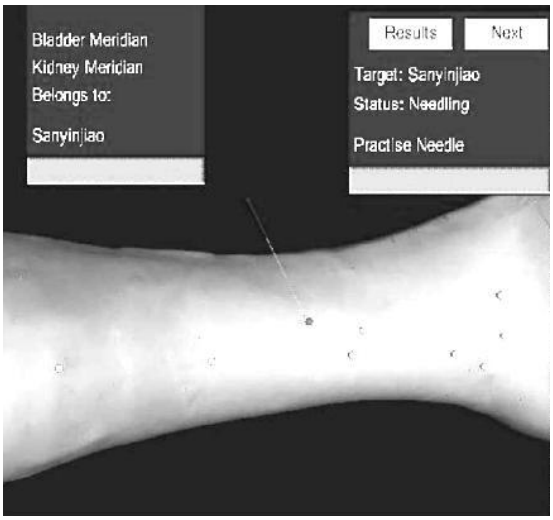


Figure 2-3 Needle puncture on the acupoint Sanyinjiao (Heng et al., 2006).

Figure 2-4 User interface and operation situation of the research (Heng et al., 2006).

In the research, it was an attempt combining the acupuncture with the simulator haptic technologies. It pointed out the data analysis of force in the acupuncture and thought the system had a reasonable force feedback result (Heng et al., 2006).

Secondly, in 2014, researchers made a study to compare and measure the force of penetrating the six acupuncture points and establishing a platform to simulate the needling force. Also, the doctors of Korean medicine made an evaluation and feedback about the accuracy of the needling force (Lee In-Seon et al., 2014). It was a haptic simulation for acupuncture needle manipulation, which pointed out the biomechanical forces of six human acupoints. Figure 2-5 shows the changing of the power in haptic simulation for acupuncture.

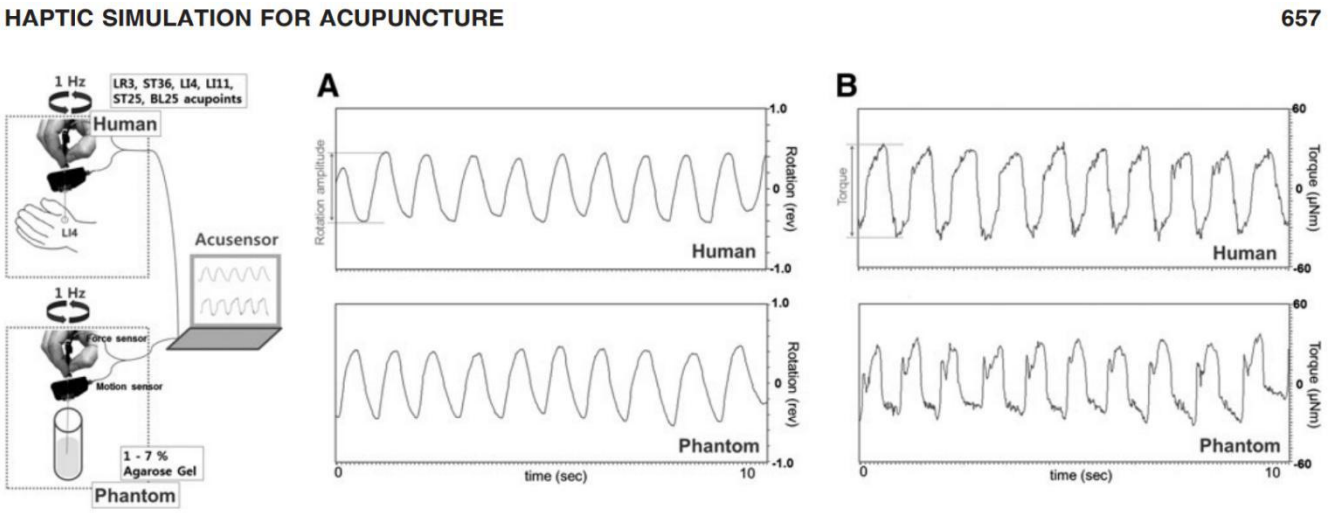


Figure 2-5 The changing of the force in haptic simulation for acupuncture (Lee In-Seon et al., 2014).

Thirdly, in 2016, the three-dimensional structure of acupoint anatomy was integrated into the teaching of acupuncture manipulation. Combined with the implementation and application of the acupuncture and moxibustion in digital virtual human (Jiang et al., 2016). Figure 2-6. In this research, on the one hand, based on VOXEL-MAN (Karl Heinz Hohne,1984) Figure 2-7 virtual human development platform, researchers finished the three-dimensional browser redevelopment of the science of acupuncture and moxibustion of Shu acupoint, which provided visual perception for people. On the other hand, based on modern biomechanics theory, researchers established models for graphics and image processing technology and force feedback technology. The

stress process of the structure of each layer in the acupuncture point area was given to people in the sense of touch by the manner of virtual reality and force feedback (Jiang et al., 2016)。

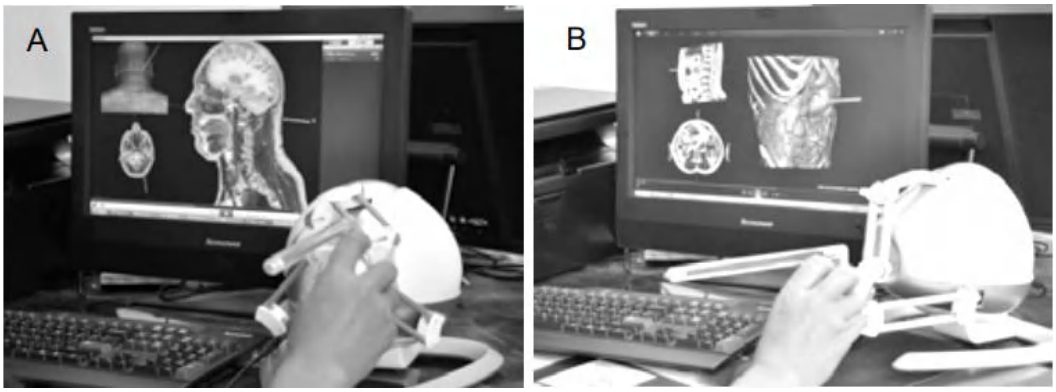


Figure 2-6 The simulator needling training situation (Jiang et al., 2016)

Figure 2 -7 The Voxel-Man System (Voxel-Man, 1984).

Figure 2-7 shows the Voxel-Man System, which was established by 3D visualization of tomographic images from CT. The reference address is https://www.voxel-man.com/about/.

2.6 Conclusion

First of all, the discussed above refers to two main parts, the simulator and haptic technologies in medical education and the application of simulation and haptics in acupuncture. As I mentioned before, establishing the simulated and haptic training system is an effective and modern method to teach and exercise the operation of medical knowledge. It not only can make the learners "see" the medical rationale but also help them "touch" the practical exercising.

The VR anatomical learning and haptic acupuncture training are combined in the project. The application focuses on two parts, firstly, deliver the knowledge of acupuncture and anatomy to the next generation clearly and visually. Secondly, making an accurate acupuncture feedback platform to train the acupuncture. Therefore, it is essential to get the tactile feedback correct, or it will provide the incorrect training for the learners.

3 Materials and Methods

3.1 Materials

In this part, the physical contents of the project will be illustrated, and these materials are divided into three sections, the image and model of medical information, the hardware and the software.

3.1.1 Medical Image Information and models

3.1.1.1 Image Information

The image information used in the project consists of open resources which could be found in books and papers. The following is a table with the information that has been used to organize the anatomical structures within the project.

Image Information	Description	Reference
Human anatomical image: Thorax	Understanding the female thoracic structure. Figure: 3-1-1	These images are from Netter's clinical anatomy. Images are published in a book called *Atlas of Human Anatomy*, authored by Netter (Netter, F., 2011).
Human anatomical image: Forearm	Understanding the structure of the forearm, especially the muscles forming. Figure: 3-1-2	

Table 3-1 Illustrating the information of image and reference.

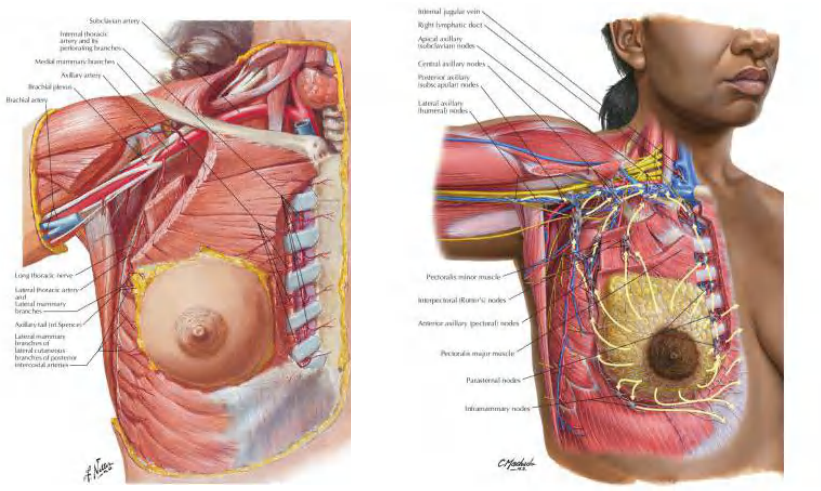


Figure 3-1-1 Human anatomical image: Thorax (*Atlas of Human Anatomy,* 2011).

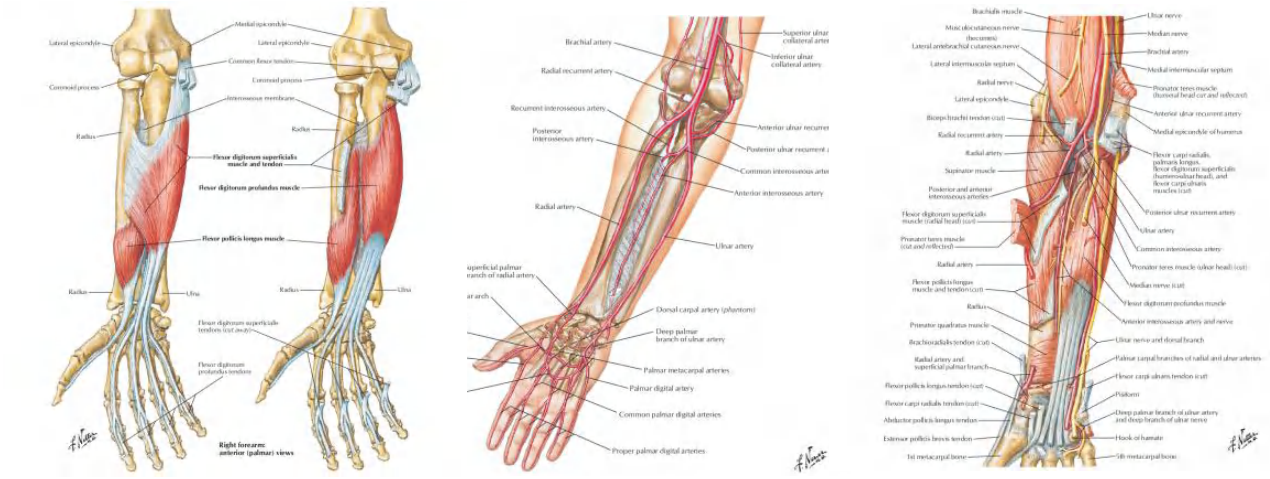


Figure 3-1-2 Human anatomical image: Forearm (*Atlas of Human Anatomy,* 2011).

3.1.1.2 Models

A part of models used in the project consists of open resources which were bought to online ANATOMY MODELS STORE. The following is a table with the information that has been used to organize models within the application.

Model Information	Description	Reference
Human Female Anatomy Complete 3D Model Pack	Models of correct structure and proportion in body systems. Figure: 3-2-1	The model could be bought to online ANATOMY MODELS STORE, and the following is the online address. https://www.plasticboy.co.uk/store/MAYA-Rigged-Human-Female-Anatomy-Complete-V07.html

Table 3- 2 Illustrating the information of models and reference.

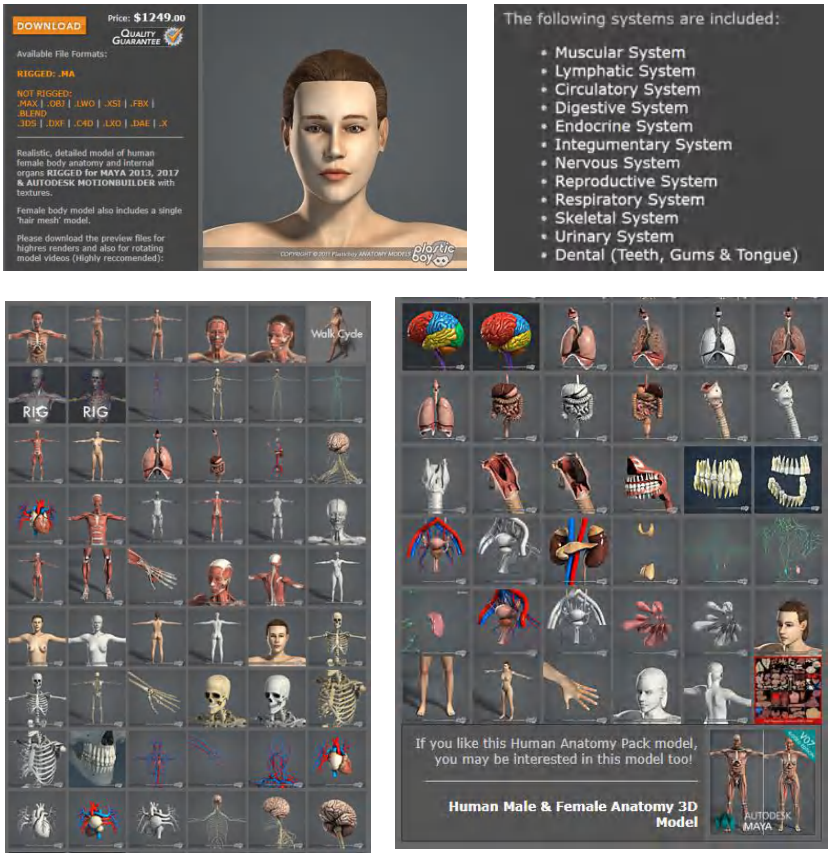


Figure3-2-1Human Female Anatomy Complete 3D Model Pack (ANATOMY MODELS STORE, 2011).

The Glasgow School of Art supplies the hardware of the project. Hardware requirements must be met the running of the application and the development of the plan. Table 3-3 lists the specific requirements of the computer to run the virtual environment by HTC Vive and Phantom Omni. Furthermore, the detailed equipment description will be mentioned in Table 3-4 and Table 3-5.

3.1.2.1 Computer Requirement

In the following two tables, the first table is the minimum requirement for the computer to run the application. And the second one is the configuration of the computer to show the demo in GSA.

Table 3-3 listing the specific requirements of the computer in the project.

Recommend Computer Spaces	**Description**	**Reference**
Graphics	NVIDIA® GeForce® GTX 1060 or AMD Radeon™ RX 480, equivalent or better	The configuration of computer is mentioned on the website of HTC Vive (HTC, 2015). The following is the address of the website. https://www.vive.com/uk
Processor	Intel® Core™ i5-4590 or AMD FX™ 8350, equivalent or better	
Memory	4 GB RAM or more	
Video out	HDMI 1.4, DisplayPort 1.2 or newer	
USB ports	1x USB 2.0 or better port	
Operating system	Windows® 7 SP1, Windows® 8.1 or later, Windows® 10	

Table 3-3-1 The minimum requirement for the computer to run application (HTC, 2015).

Computer Spaces	Description	Reference
Graphics	NVIDIA GeForce GTX 1080	The configuration of computer is mentioned on the website of MSI (MSI, 2017). The following is the address of the website. https://uk.msi.com/
Processor	Intel® Core™ i7-7820HK CPU @ 2.9GHz	
Memory	16.0GB	
OS	Windows 10	

Table 3-3-2 The configuration of the computer to show the demo in GSA (MSI, 2017).

3.1.2.2 HTC Vive Detailed Description

HTC Vive is the critical equipment to achieve the virtual environment. In this part, the detailed information of HTC Vive will be illustrated, and it contains the structure, the data, the description and the reference to each piece of the equipment.

Structure	Information	Description	Reference
Headset	- Adjustable straps and interchangeable inserts - Front-facing camera - Eye relief adjustments - Fits most glasses (HTC Vive, 2015)	The virtual environment could be shown by the headset. Figure 3-4-1.	The detailed description of each part of the equipment is open resource on HTC Vive website (HTC Vive, 2015). https://www.vive.com/uk
Controller	- Designed exclusively for VR - Intuitive controls and gestures - Realistic HD haptic feedback (HTC Vive, 2015)	People could track or move objects in the virtual environment by the controller; it means the controller is the tool to achieve interaction between the virtual environment and	

		learners. Figure 3-4-2.	
Base Stations	- 360-degree play area tracking coverage - Wireless syncing - Fits standard threaded mounting points (HTC Vive, 2015)	It builds the 3D space to run the application. The minimum space is 1.5m * 2m. Figure 3-4-3.	

Table 3-4 the detailed description of HTC Vive (HTC Vive, 2015).

Figure 3-4-1 Headset (HTC Vive, 2015)

Figure 3-4-2 Controller (HTC Vive, 2015)

Figure 3-4-3 Base Stations (HTC Vive, 2015)

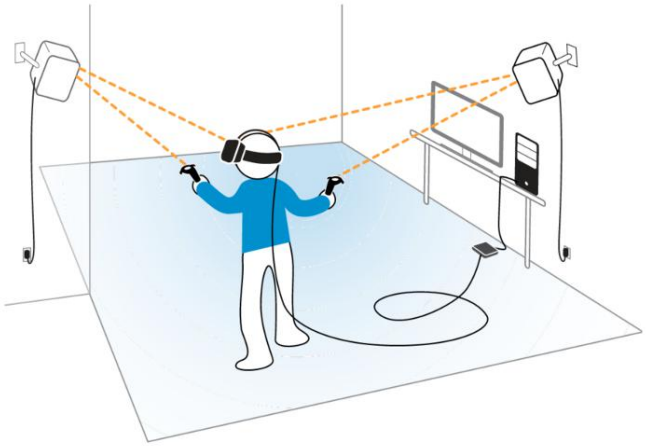


Figure 3-4-4 HTC Vive Playing Space (HTC Vive, 2015)

3.1.2.3 Phantom Omni Detailed Description

The Phantom Omni is a commercial, portable haptic device with Six Degrees of Freedom (DoF) developed by Sensable Technologies. It is widely used in various applications, including simulation, training, machine interface design, mapping and dozens of other applications (SensAble, 1994).

Table 3-5 lists detailed information of the haptic. Table 3-6 illustrates the Six Degrees of Freedom (6DoF) in the haptics.

3.1.2.3.1 The information of Phantom Omni

Model	**The Phantom Omni Device**	**Reference**
Force feedback workspace	~6.4 W x 4.8 H x 2.8 D in > 160 W x 120 H x 70 D mm	The device evolved from research done by Thomas Massie and Dr. Kenneth Salisbury at MIT (SensAble, 1994). The following website address could find the more information and resources. www.sensable.com/support-overview.htm
Footprint Physical area the base of device occupies on the desk	6 5/8 W x 8 D in ~168 W x 203 D mm	
Weight (device only)	3 lb 15 oz	
Range of motion	Hand movement pivoting at the wrist	
Nominal position resolution	> 450 dpi ~ 0.055 mm	
Backdrive friction	<1 oz(0.26 N)	
Maximum exertable force at nominal (orthogonal arms) position	0.75 lbf. (3.3 N)	
Continuous exertable force (24 hrs.)	> 0.2 lbf. (0.88 N)	
Stiffness	X axis > 7.3 lb/in (1.26 N/mm) Y axis > 13.4 lb/in (2.31 N/mm) Z axis > 5.9 lb/in (1.02 N/mm)	

Inertia (apparent mass at tip)	~0.101 lbm. (45 g)	
Force feedback	x,y,z	
Position sensing [Stylus gimbal]	x, y, z (digital encoders) [Pitch, roll, yaw (± 5% linearity potentiometers)]	
Interface	IEEE-1394 FireWire® port: 6-pin to 6-pin*	
Supported platforms	Intel or AMD-based PCs	
OpenHaptics® SDK compatibility	Yes	

Table 3-5 The detailed description of Phantom Omni (SensAble, 1994).
https://www.virtalis.com/wp-content/uploads/phantom_omni_spec.pdf

Figure 3-5-1 The modeling of Phantom Omni (SensAble, 1994).

3.1.2.3.2 Six Degrees of Freedom (6DoF) in Phantom Omni

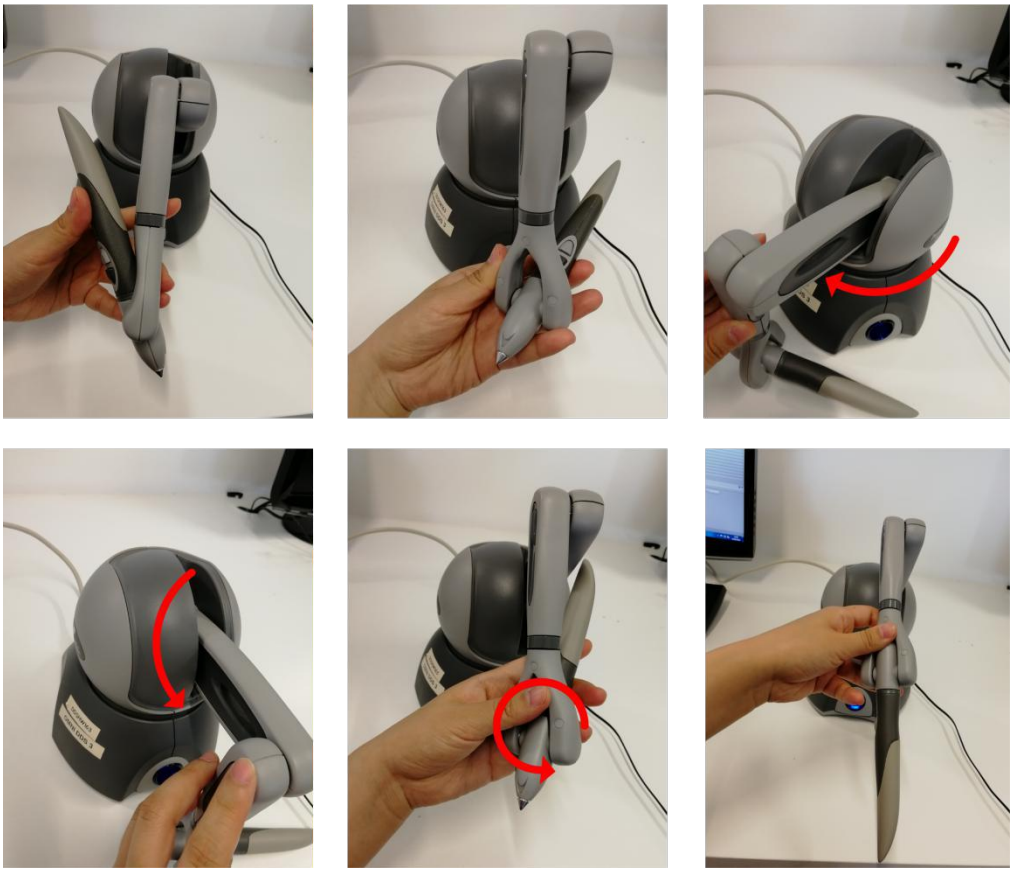


Table 3-6 The Six Degrees of Freedom (6DoF) in the haptic device.

3.1.3 Software

Table 3-7 is a list of software that has been used to establish the application. The list includes the software to build the programming in the project and the 3D model software to create the virtual environment. Besides, image and video software are used to construct the interacted interface and the introduction video.

Software	Description	Reference
3DS Max	Cutting the 3D modeling and changing the texture.	https://www.autodesk.co.uk/products/3ds-max
Maya	Cutting the 3D modeling and changing the texture.	https://www.autodesk.co.uk/products/maya
Adobe Photoshop	User interface	https://www.adobe.com
Adobe Illustrator	User interface; Type design; Logo design; Storyboard and so on.	https://www.adobe.com
Flash	Designing the introduction video.	https://www.adobe.com
Adobe After Effects	Designing the introduction video.	https://www.adobe.com
Goldwave	Editing the audio.	https://www.goldwave.com
Unity 3D	Organizing the virtual environment; Programming the functions with C#; Combining the Steam VR and Haptic Plugin.	https://unity3d.com/cn
MonoDevelo (in-build to Unity 3D)	Scripting with C#, in-build into Unity 3D.	https://www.monodevelop.com
SteamVR Plugin	Steam VR Plugin is fixed into the Unity 3D to build the simulated environment.	https://assetstore.unity.com/packages/templates/systems/steamvr-plugin
VRTK - VR Toolkit Plugin	VR Toolkit Plugin is used to establish the button interaction in the virtual environment.	https://assetstore.unity.com/packages/tools/vrtk-virtual-reality-toolkit-vr-toolkit-64131
OpenHaptics Plugin	OpenHaptics Plugin is fixed into the Unity 3D to establish the integrated haptic interaction.	https://assetstore.unity.com/packages/essentials/tutorial-projects/unity-5-haptic-plugin-for-geomagic-openhaptics

Table 3-7 List of software used for the application, including a description of their use.

3.2 Methods

The following flowchart shows an overview of the design process for the application.

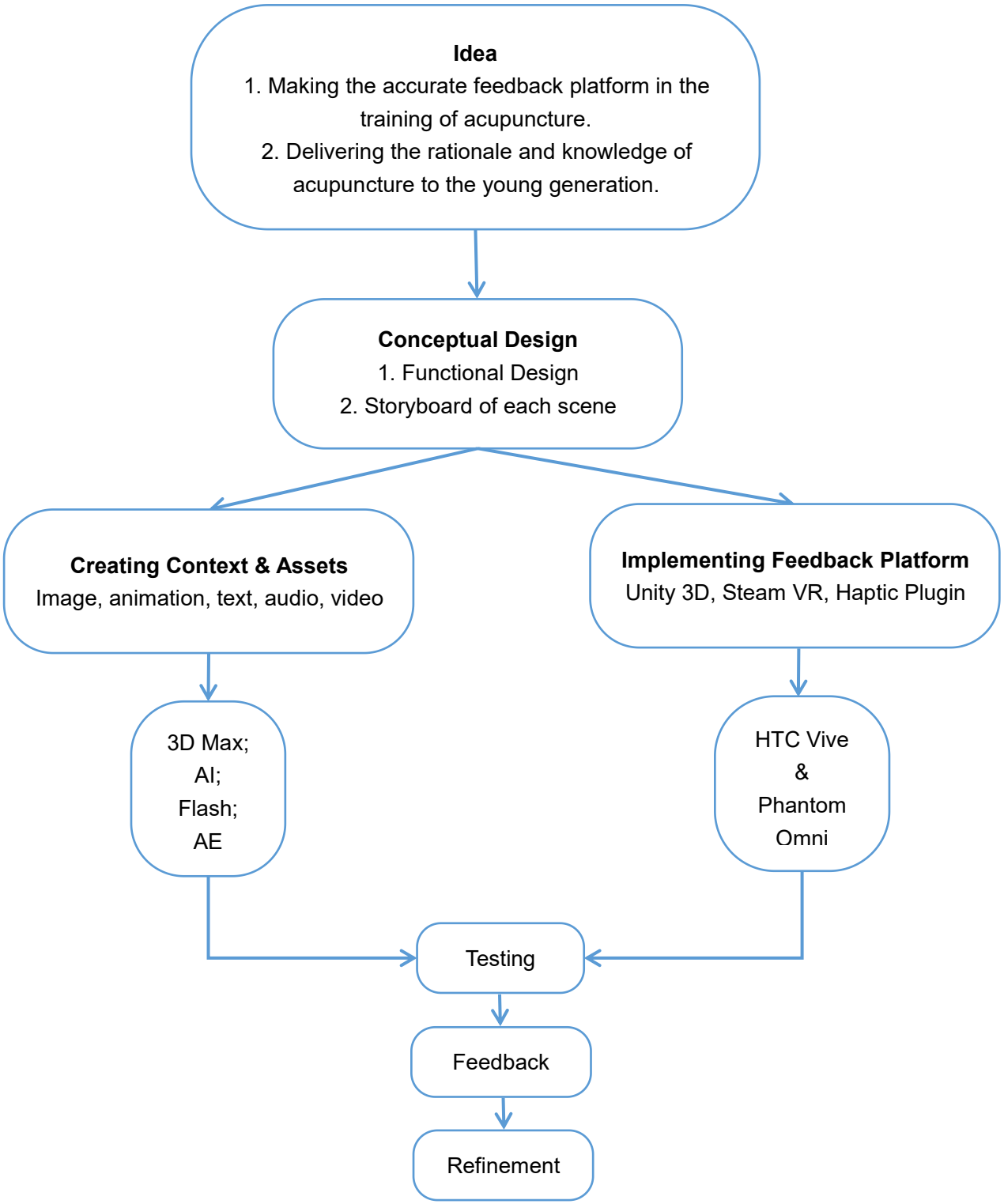


Table 3-8 Flowchart of the design process for the application.

3.2.1 Requirements

Table 3-9 and Table 3-9-1 show an overview of the functional requirements of the application.

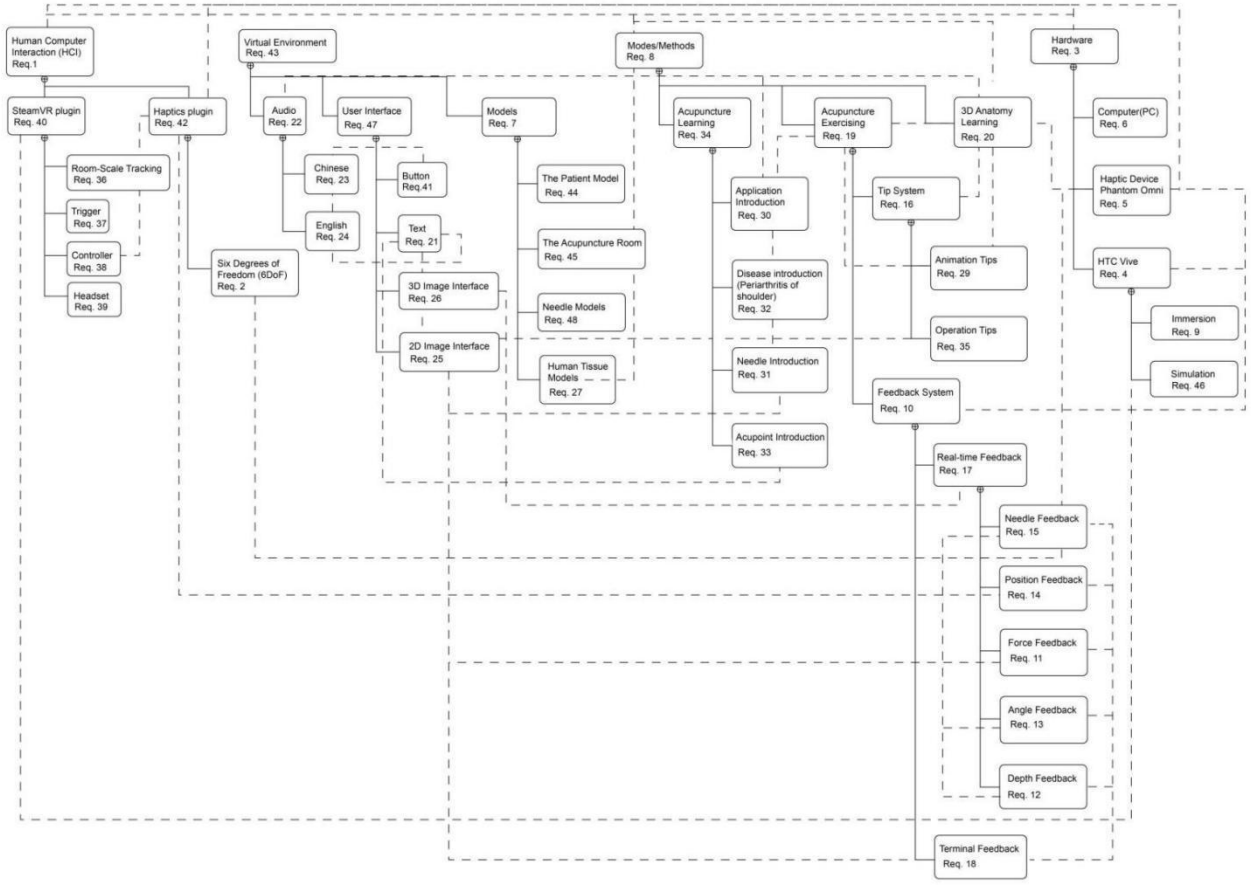


Table 3-9 Requirement Diagram -- Haptic-Enabled Virtual Reality Acupuncture Teaching and Training Platform.

Requirement Number	Requirement Name	Description	Rationale	Parent	Children	Related Req.	Verification	Order
1	Human-Computer Interaction(HCI)	The system must achieve the unity and harmony between the application and users.	The concept of interaction contains the communication between the hardware and software with human and the cognitive and emotional aspects of the user's experience. The interaction can be divided into the tangible and intangible two aspects (Laurel, B., Joy Mountford S., 1990).	-	40.42	3	In the project, the user will have a fluent interaction between the equipment and software. Also, the user will achieve a comfortable and friendly operation feeling.	Compulsory
2	Six Degrees of Freedom (6DoF)	6DoF must be provided for users in the system.	The rigid body is free to change position as forwarding/backward (surge), up/down (heave), left/right (sway) translation in three perpendicular axes, combined with changes in orientation through rotation about three perpendicular axes, often termed yaw (normal axis), pitch (transverse axis), and roll (longitudinal axis).(Srivastava, M.K., 2017) In the object, it has the	42	-	5	In the application, hand movement pivoting at the wrist by Phantom Omni. This includes the moving and tracking in six different directions in the 3D space.	Compulsory

			accurate tracking following the six directions. It also provides flexible methods of interaction **(Req. 1)**.					
3	Hardware	Suitable hardware equipment is provided to run the project.	The hardware is the fundamental condition to run the application. It contains the appropriate computer requirements **(Req.6)**, HTC Vive **(Req.4)**and Phantom Omni **(Req.5)**.	-	6.4.5	1	The user will use HTC Vive to see the virtual environment, and the Phantom Omni (Haptic device) to achieve the interaction between the virtual environment and users.	Compulsory
4	HTC Vive	The system contains the headset, controllers and base stations.	HTC Vive is a virtual reality(VR) device to establish the connection between the real world and the virtual environment **(Req.43)**. It provides an immersive experience **(Req.9)**.	3	9.46	40.43	The user wears HTC Vive equipment to experience the application. And the user will see the immersive world by the headset.	Compulsory
5	Phantom Omni	The system allows the user to build the interaction between the virtual environment and themselves.	Phantom Omni is a haptic feedback device. The user could experience 6DoF when using the device to penetrate the skin. Furthermore, the user will experience the different force **(Req.11)**, angle **(Req.13)**, position **(Req14.)** by the device. The	3	-	42.19	The user will get accurate feedback from it, and the Phantom Omni is the object to get the user interacts.	Compulsory

			device is the key point to achieve the user interaction **(Req.1)**.					
6	Computer (PC)	The system is the clear condition about running the object on PC.	Computer requirements mention the minimum requirements to run the object smoothly. It contains the computer requirements with HTC Vive **(Req.4)** and Phantom Omni **(Req.5)**.	3	-	-	The project can only run if the computer meets minimum configuration requirements.	Compulsory
7	Models	All models are used to establish the virtual environment.	Models are divided into three kinds. The first part is the model of the acupuncture room **(Req.45)**, the second one is the patient model **(Req.44)**. Thirdly, it is the colorful needle models **(Req.48)**. Finally, it is the human tissue models **(Req.27)**.	43	44.45..48.27	-	All models are used in the virtual environment. Therefore, the user will see them when they wear the headset.	Compulsory
8	Methods / Modes	The system has four different methods to learn and exercise acupuncture.	Firstly, the user will understand the points of acupuncture **(Req.34)**, and learn the relationship between the acupuncture and the anatomy **(Req.20)**. Furthermore, the user could exercise the operation of	-	34.19.20	3.1.43	The application will be constituted by these four methods, and the user could learn and exercise acupuncture following by the system.	Compulsory

			acupuncture **(Req.19)**, and get real-time feedback **(Req.17)** and the terminal feedback **(Req.18)**.					
9	Immersion	The application provides an immersive environment to make the user experience better operation system, and immersive interaction.	Immersive experience hopes the user could feel the real world in a virtual environment **(Req.43)**. And the user could do the operation of acupuncture and learn anatomy and acupuncture in the virtual environment.	4	-	43	The user could make interaction within the virtual environment by the equipment.	Compulsory
10	Feedback system	The feedback system could be divided into two types. The first one is real-time feedback and the second one is terminal feedback.	The real-time feedback **(Req.17)** means the user could see the operation of acupuncture directly and get the 3D image feedback in the process of exercising. The user records a terminal image about every part of one acupuncture point after the operation. Finally, the user could get terminal feedback **(Req.18)** and evaluation by the professional acupuncturist after the total treatment operation.	19	17.18	5	The user could get the real-time and terminal feedback in the process of operation and after the whole operation. At the end of the application, the user also will get an evaluation and level of the total exercising.	Compulsory

11	Force feedback	The system provides the feedback about the force of each acupoint.	The force feedback of operation could be shown by a 2D chart interface **(Req.25)**.	17.18	-	25	The user will get feedback in the process of operation.	Compulsory
12	Depth feedback	The system provides the feedback about the depth of acupoint.	The depth feedback of operation could be shown by a 3D internal structure interface **(Req.26)**.	17.18	-	26	The user will get feedback in the process of operation.	Compulsory
13	Angle feedback	The system provides the feedback about the angle of penetration.	The angle feedback of operation could be shown by a 3D image interface **(Req.26)**.	17.18	-	26	The user will get feedback in the process of operation.	Compulsory
14	Position feedback	The system provides the feedback about the position of acupoint.	The position feedback of operation could be shown by a 3D image interface **(Req.26)**.	17.18	-	26	The user will get feedback in the process of operation.	Compulsory
15	Needle feedback	The system provides the function of choosing needle in the application.	For the user to learn the knowledge of different needles.	17.18	-	25	The needle feedback makes the user learn the accurate information of the needle and choose the correct one to do the operation.	Compulsory
16	Tip system	The tip system provides a reminder to the	The audio reminder **(Req.22)** could be provided in the whole application. And an	19	29.35	22	The user could use the application smoothly with these tips. And the user	Good to have

		user about the information of the correct acupoint in the application.	animation tip **(Req.29)** about the specific acupoint should be provided before the operation.				also could get a better preparation before the acupuncture exercising.	Compulsory
17	Real-time feedback	The real-time feedback system has five parts, the choice of the needle, the position, depth, angle and force feedback of each acupoint.	The real-time feedback has six parts, needle feedback **(Req.15)**, position feedback **(Req.14)**, force feedback **(Req.11),** angle feedback **(Req.13)** and depth feedback **(Req.12)**.	10	15.14.11 . 13.12	5.42	The user will get real-time feedback in the process of operation.	Compulsory
18	Terminal feedback	The terminal feedback system is contained by two parts.	The terminal feedback has two parts, the acupoint terminal feedback, and the operation terminal feedback.	10	-	15.14.1 1. 13.12	The user will get terminal feedback in the process of operation.	Compulsory
19	Acupuncture exercising	The system is the main function of the application.	The aim of acupuncture exercising is remitting disease**,** learning the operation of acupuncture, establishing the needling feedback platform **(Req.16)**.	8	16.10	1.3.43	The user will exercise the operation of acupuncture by haptic device.	Compulsory
20	3D anatomy learning	The aim of the system is to learn the knowledge of anatomy by 3D images.	The 3D anatomy learning could be divided into two types, the first is acupoint anatomy**(Req.29)**, and the second is human tissue anatomy**(Req.35)**.	8	-	16.47.2 2	The user could learn the 3D anatomy knowledge directly and accurately in the process of exercising.	Compulsory Good to have

21	Text	The text is a method of information expression in the application.	The system will help the user to operate the application, and it has two languages, Chinese **(Req.23)** and English **(Req.24)**.	47	-	23.24.35	the system will help the user to operate the application friendly.	Compulsory
22	Audio	Audio is a method of information expression in the application.	The system will help the user to operate the application, and it has two languages, Chinese **(Req.23)** and English **(Req.24)**.	43	23.24	20.34	the system will help the user to operate the application friendly.	Compulsory
23	Chinese	Chinese is one of the optional language systems in the application.	The system could have two parts, the first is text **(Req.21)** and the second is audio **(Req.22)**.	22	-	21	The user could get the Chinese information in the process of application.	Optional
24	English	English is one of the optional language systems in the application.	The system could have two parts, the first is text **(Req.21)** and the second is audio **(Req.22)**.	22	-	21	The user could get the English information in the process of application.	Optional
25	2D image interface	The 2D image interface will be shown to express the terminal result of each acupoint.	The 2D image interface provides the correct position of each acupoint.	47	-	47.34.20	The result of the operation of the user will be shown on the 2D image interface.	Compulsory
26	3D image interface	The 3D image interface will be shown to express the real-time feedback.	The 3D image interface shows the real-time feedback of operation.	47	-	47.34.20	The process of operation will be shown on the 3D image interface.	Compulsory
27	Human	Models	It will help the user to	7	-	34.19.2	The user will see the	Compulsory

	tissue models		understand the rationale and knowledge of acupuncture and anatomy.			0	model in the process of penetration.	
28	Tip system	The tip system could be divided into two types.	The tip system is divided into two types, the animation tip **(Req.29)** and the operation tip **(Req.35)**.	19	29.35	20.34	The user could use the application smoothly with these tips.	Compulsory
29	Animation tips	The animation tip could help the user to do the training of acupuncture.	The acupoint tip appears at the beginning of the operation. It will help the user to know which acupoint need to penetrate. The accurate operation demo will help the user to learn the correct operation.	16	-	34.20	The user will get useful information from these tips.	Good to have
30	Application introduction	The system will help the user know the knowledge points in the application.	It contains the needle introduction **(Req.25)**, the disease introduction, the acupoint introduction **(Req29.)**, the acupuncture introduction and the anatomy introduction **(Req.20)**.	34	-	22.29	The user will know the detailed information about the acupuncture and anatomy.	Compulsory
31	Needle introduction	The system is the introduction of needles.	It is a text **(Req. 21)** introduction about needles.	34	-	21	The user will know the detailed information about the needles.	Compulsory
32	Disease introduction (Periarthritis of the	The system is the introduction of periarthritis of the shoulder.	It is a video introduction about the disease.	34	-	22.29	The user will know the detailed information about the periarthritis of the shoulder.	Good to have

	shoulder)							
33	Acupoint introduction	The system is the introduction of acupoint.	It is audio **(Req.22)** and animation tip **(Req.29)** introduction about the acupoint.	34	-	22.29	The user will know the detailed information about the acupoint.	Good to have
34	Acupuncture learning	The system is the introduction of acupuncture.	It is audio **(Req.22)** and image **(Req.47)** introduction about the acupuncture.	8	30.32.3 1.33	22.47	The user will know the detailed information about the acupuncture.	Good to have
35	Operation tips	The operation tip could help the user exercise the needling smoothly.	The system provides tips for the user in the acupuncture exercising **(Req.19)**.	16	-	22.47	The user will follow these operation tips in the process of operation.	Compulsory
36	Room-scale tracking	The system is the space of the virtual environment.	It contains the HTC Vive **(Req.4)**.	40	-	3.4	The user could move in the space.	Compulsory
37	Trigger	The system provides the method to achieve the choice function in the application.	It is a configuration of HTC Vive.	40	-	4	The user could use the trigger to choose buttons.	Compulsory
38	Controller	The system helps the developer to do the project.	The system helps the developer to make the development of functions.	40	-	42	The user will experience the controller in the process of operation.	Compulsory
39	Headset	It is a part of HTC Vive	It is a configuration of HTC Vive **(Req.4)**. The system is the equipment to make a	40	-	4.43	The user could see the virtual environment by the headset.	Compulsory

			connection between the real world and the virtual environment **(Req43)**.					
40	SteamVR plugin	The project is established based on the system.	It is the software to do the project.	1	36.37.38.39	4	The developer does the project by the learning of the plugin.	Compulsory
41	Button	The system provides a friendly interaction to make the user achieve more effective learning results.	The system is a part of user interface **(Req.47).**	47	-	16.34.20	The user could run the application smoothly and learn the rationale and knowledge of acupuncture by click the button.	Compulsory
42	Haptics plugin	The project is established based on the system.	It is the software to do the project.	1	2	5	The developer does the project by the learning of the plugin.	Compulsory
43	Virtual environment	The system establishes the total learning environment of the application.	it is constituted by the models**(Req.7)**, user interface**(Req.47)** and audio**(Req.22)**. It provides the running environment of the application.	-	22.47.7	1.3	The user could use the application through two devices in the virtual environment.	Compulsory
44	The patient model	The system focuses on building a realistic needling environment.	It is a part of the virtual environment **(Req.43)**.	7	-	34.19	It helps the user to feel realistic in the virtual environment.	Compulsory
45	The acupuncture	The system establishes a	It is a part of the virtual environment **(Req.43)**.	7	-	-	It helps the user to feel realistic in the virtual	Compulsory

	room	realistic needling environment.					environment.	
46	Simulation	The system points out the reality to make the user perform a true acupuncture training.	It provides real and accurate feedback of acupuncture in the application. It connects with the HTC Vive **(Req.4)** and Phantom Omni **(Req.5)**.	4	-	43	The user could feel a real acupuncture training in the virtual environment.	Compulsory
47	User interface	The system provides a comfortable interaction to the user.	It makes the application has a comfortable interaction. It is a part of HCI **(Req.1)**.	43	41.21.26.25	1	The user could run the application following the UI system.	Compulsory
48	Needle models	The systems combine with the needle feedback.	It provides a system of choosing needles and gets needle feedback **(Req.15)**.	7	-	15	The user could understand different types of the needle in the system.	Compulsory

Table 3-9-1 Table for the Application Requirements.

3.2.2 Design and Development

In this part, the process of design and the development of the project will be described step by step.

3.2.2.1 Storyboard of Application

After laying out the functional requirements of the application, the storyboard of the application is sketched to illustrate the design of the application.

Firstly, it is the Scene 01 - Start Menu. Figure 3-10-1.

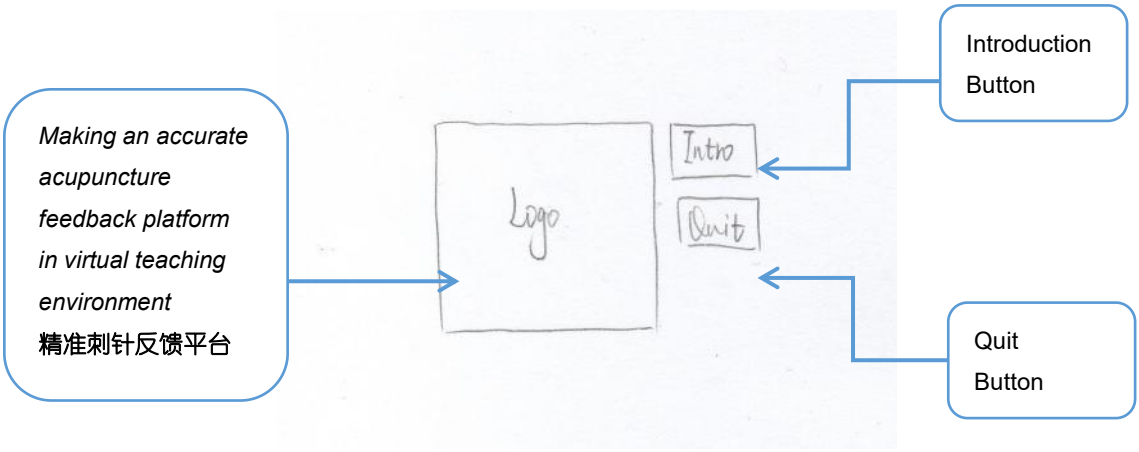


Figure 3-10-1 The sketch of the start menu.

1. The title of the application is *Making an accurate acupuncture feedback platform in virtual teaching environment*. The application has the two language system, English, and Chinese. Two languages can help more learners to understand the rationale of acupuncture.
2. The introduction button can connect with the introduction scene.

Secondly, it is the Scene 02 - Introduction. Figure 3-10-2

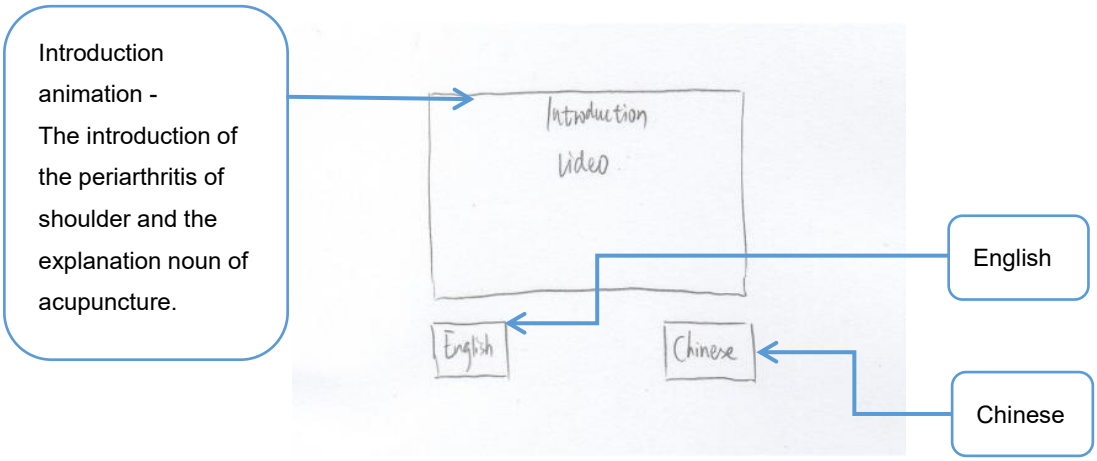


Figure 3-10-2 The sketch of the introduction interface.

1. Introduction animation is designed and made by myself; it contains two parts, the introduction of the periarthritis of shoulder and the explanation noun of acupuncture.
2. The user can choose a language to begin the acupuncture training.

Thirdly, it is the Scene 03 - Acupuncture Training Interface. Figure 3-10-3

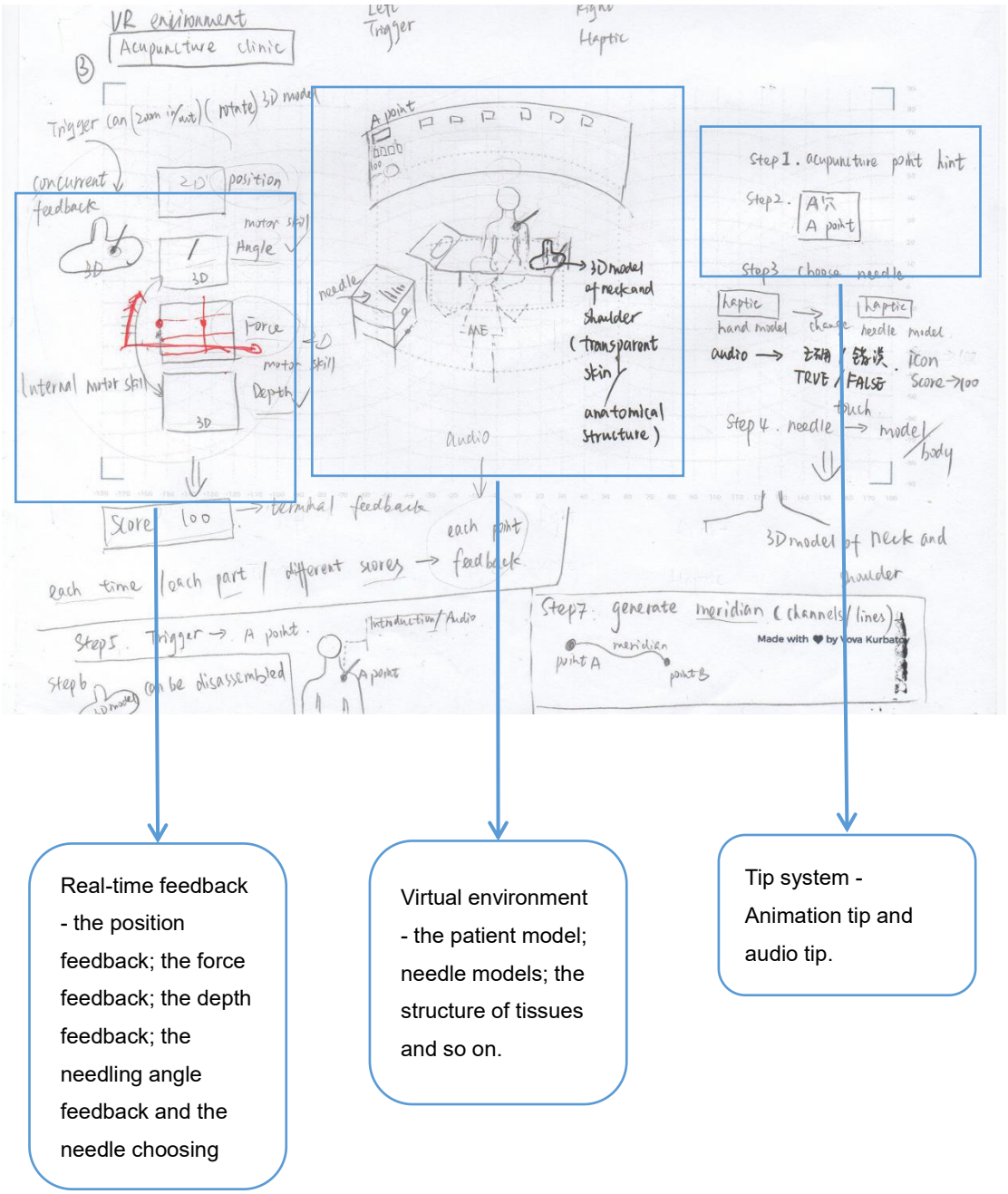


Figure 3-10-3 The sketch of the acupuncture training interface.

1. The virtual environment is constituted with the patient model, needle models, and the anatomical structure.
2. Real-time feedback will be shown on the Canvas in the virtual environment. The learners can get the concurrent feedback when they needle the anatomical model.
3. In the application, the user will see the animation tip before training, and these tips will help the user know the position of the acupoint.

Fourthly, it is the Scene 03 - Acupuncture Training Interface. Figure 3-10-4

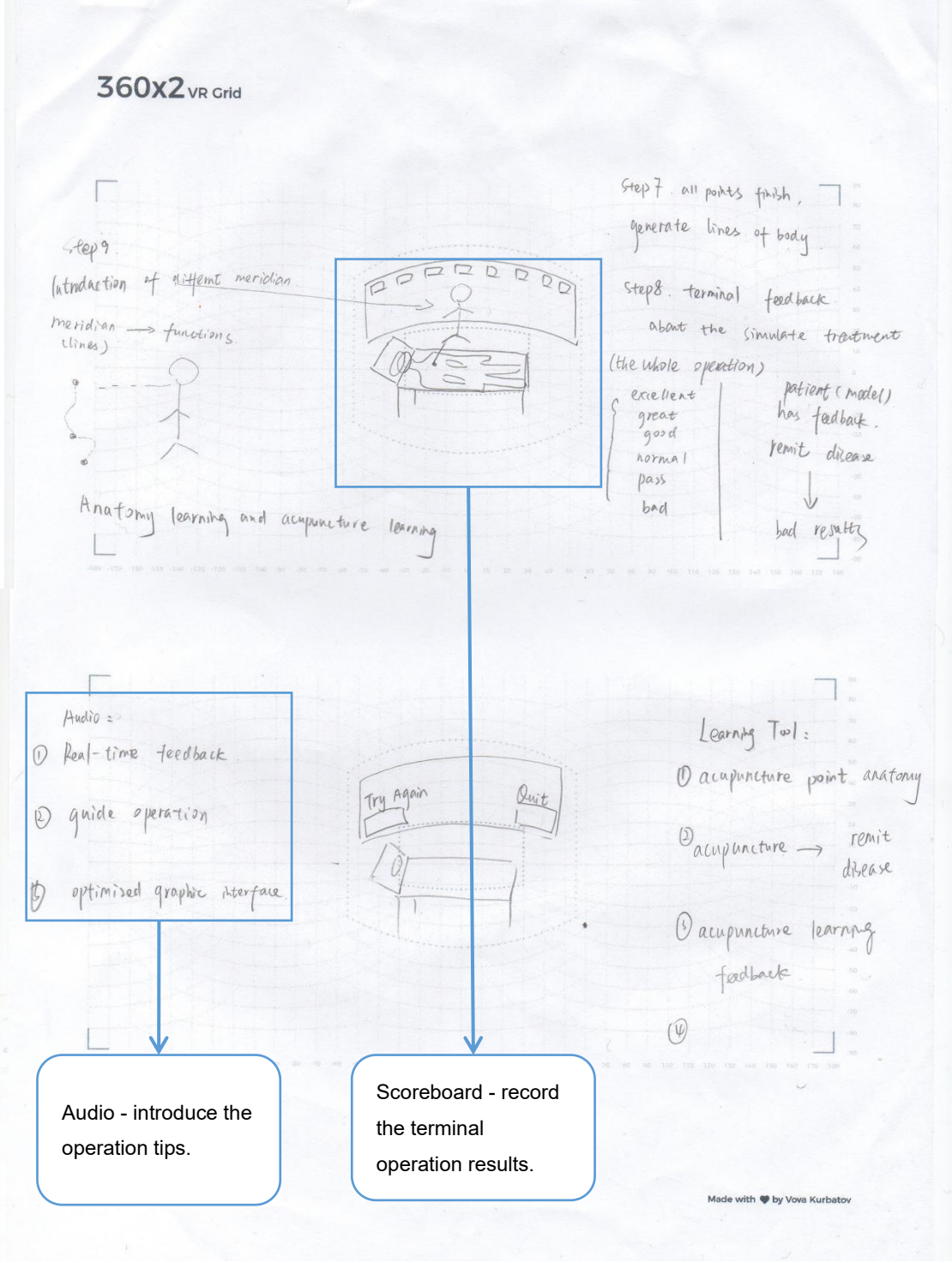
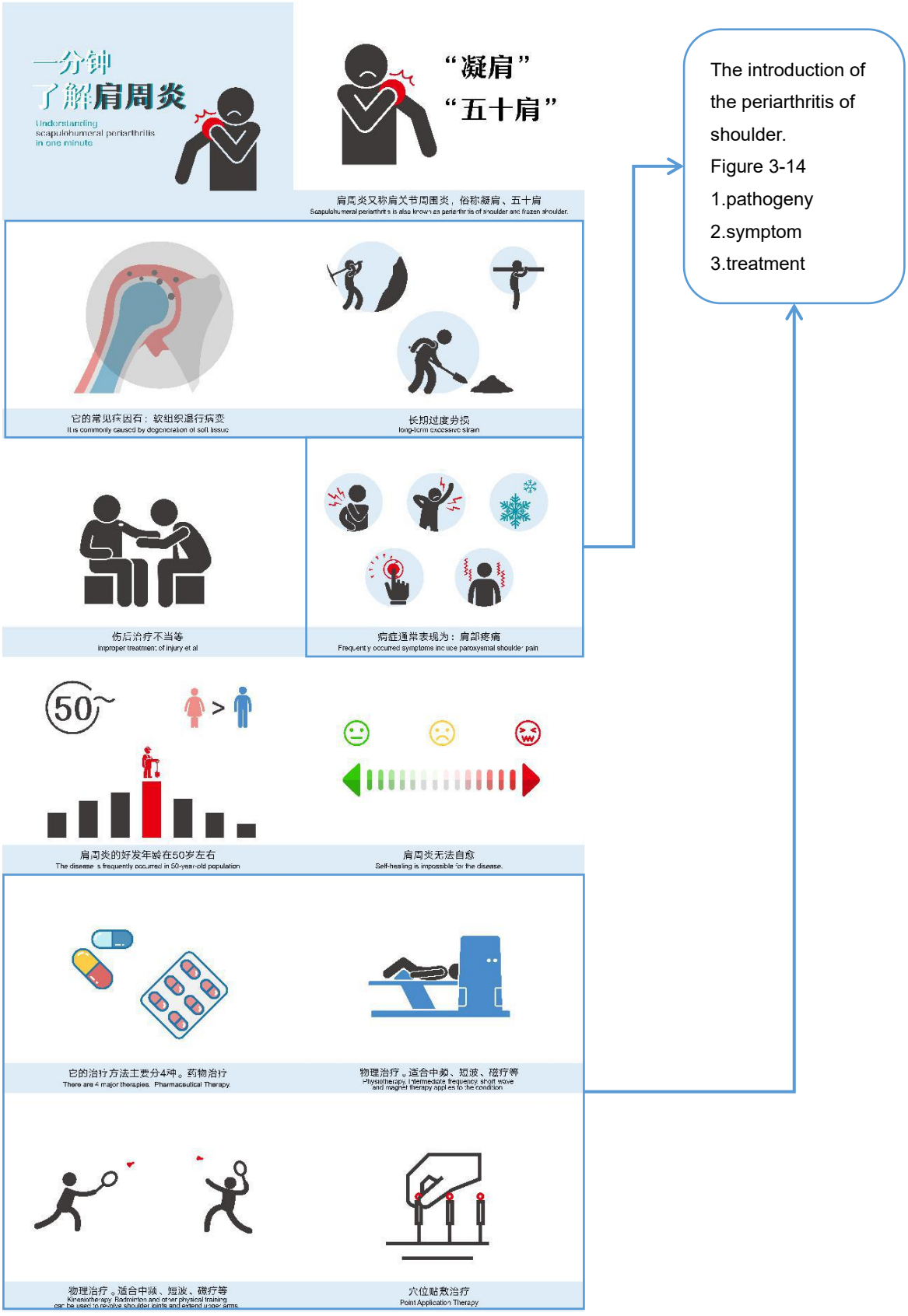


Figure 3-10-4 The sketch of the acupuncture training interface.

1. The audio is included in the introduction of the application and the tip system.
2. The terminal feedback results will be recorded on the scoreboard.

3.2.2.2 Storyboard of Introduction Interface



The introduction of the periarthritis of shoulder.
Figure 3-14
1.pathogeny
2.symptom
3.treatment

Figure 3-10-5 The storyboard of the introduction of the periarthritis of shoulder.

Figure 3-10-5 shows the storyboard of the main pages and illustration ideas for the introduction of the periarthritis of shoulder. The storyboard is designed through the software Illustrator. In the introduction, the user can understand the pathogeny, symptom, and treatment of the disease.

Furthermore, in the introduction interface, the user also can achieve the information about the professional acupuncture term. Figure 3-10-6.

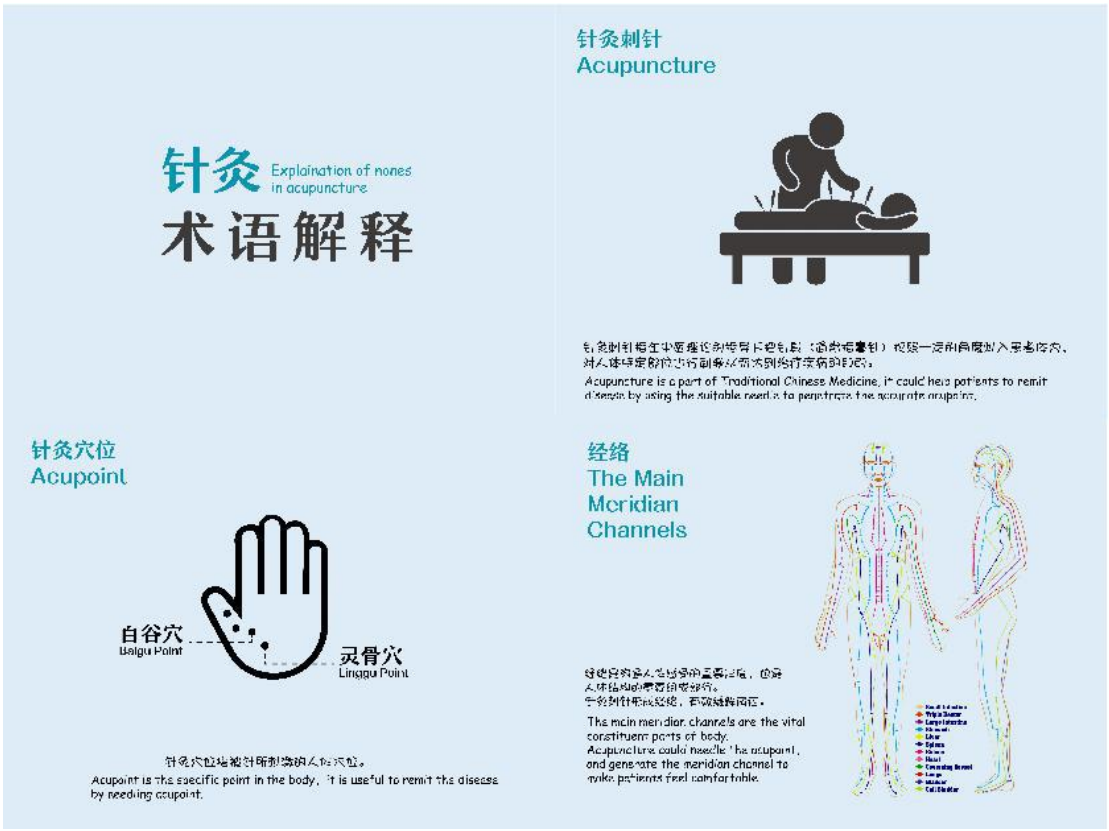


Figure 3-10-6 The storyboard of the professional acupuncture term.

Figure 3-10-6 shows the storyboard of the professional acupuncture term. In this part, the user can understand the common acupuncture term, and it is preparation before the acupuncture training.

3.2.3 Creating Context and Assets

The organizing of 3D modeling and the designing of introduction animation will be illustrated in this part.

3.2.3.1 3D Modelling

Firstly, the original 3D modeling within the project was open resources which were bought to online ANATOMY MODELS STORE. (Chapter 3.1.1.2) Figure 3-11-1

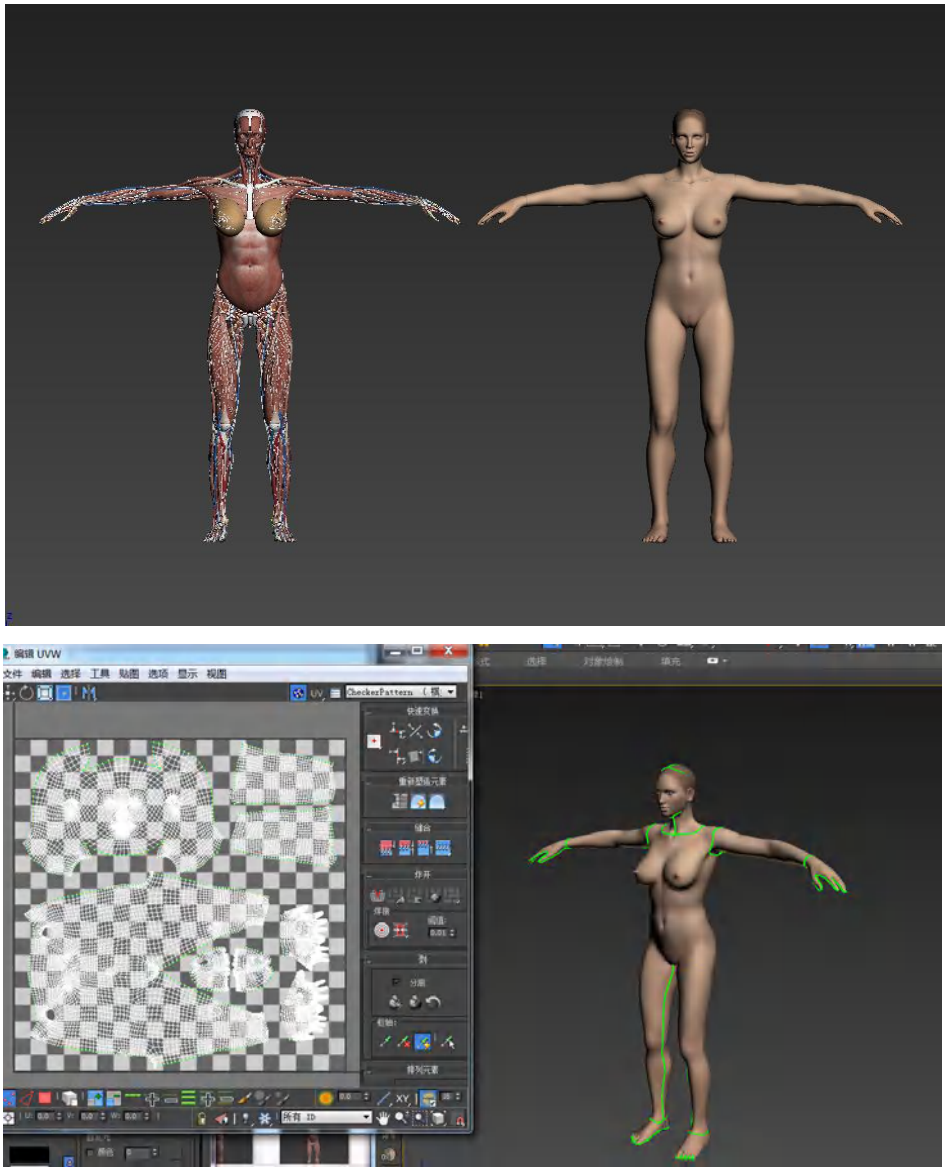


Figure 3-11-1 3D modeling - open resources in online ANATOMY MODELS STORE Human Female Anatomy Complete 3D Model Pack (ANATOMY MODELS STORE,

2011)

Secondly, change the material of the skin to make it as a translucent model through the software 3D Max. Figure 3-11-2 The original model. Figure 3-11-3 the changed model. Figure 3-11-4 the whole model with the translucent material.

Figure 3-11-2 The original model (ANATOMY MODELS STORE, 2011)

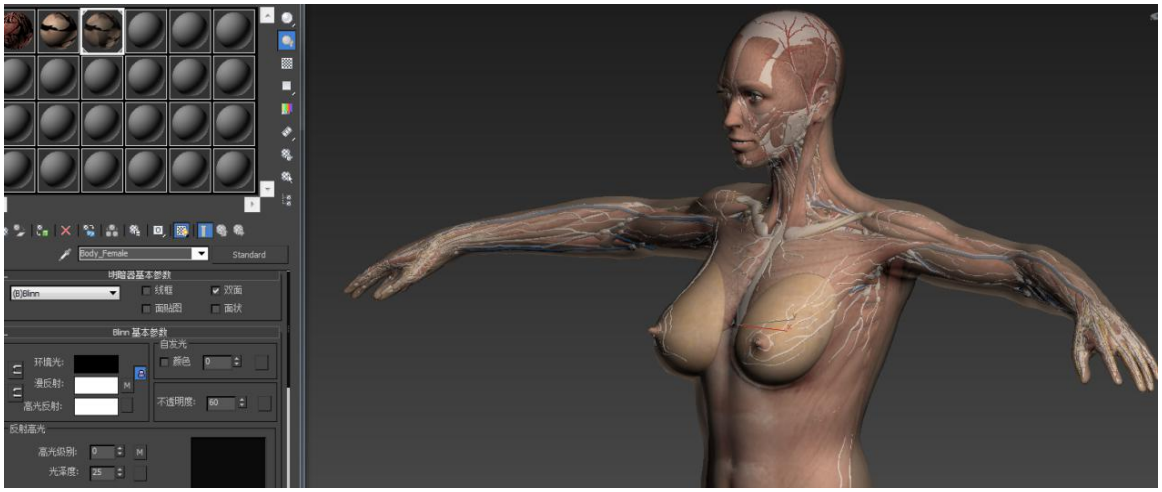


Figure 3-11-3 The changed model - using the translucent material on the skin

Figure 3-11-4 The whole model with the translucent material.

Thirdly, because the topic of the application is the treatment of the periarthritis of shoulder, I will cut the model to retain the shoulder part and the arm part by 3D Max to make the user see the anatomy clearly and understand the rationale of acupuncture.
Figure 3-11-5 Cut function.
Figure 3-11-6 The cutting shoulder model. Figure 3-11-7 The cutting arm model.

Figure 3-11-5 Cut function.

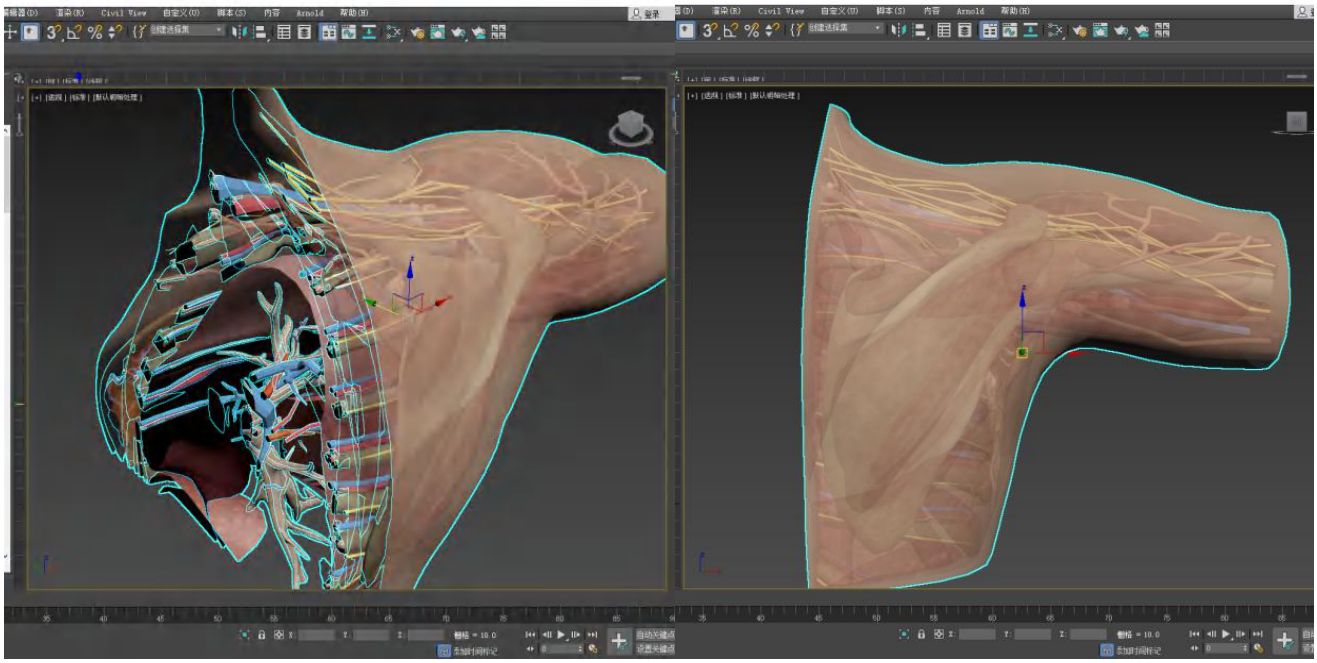
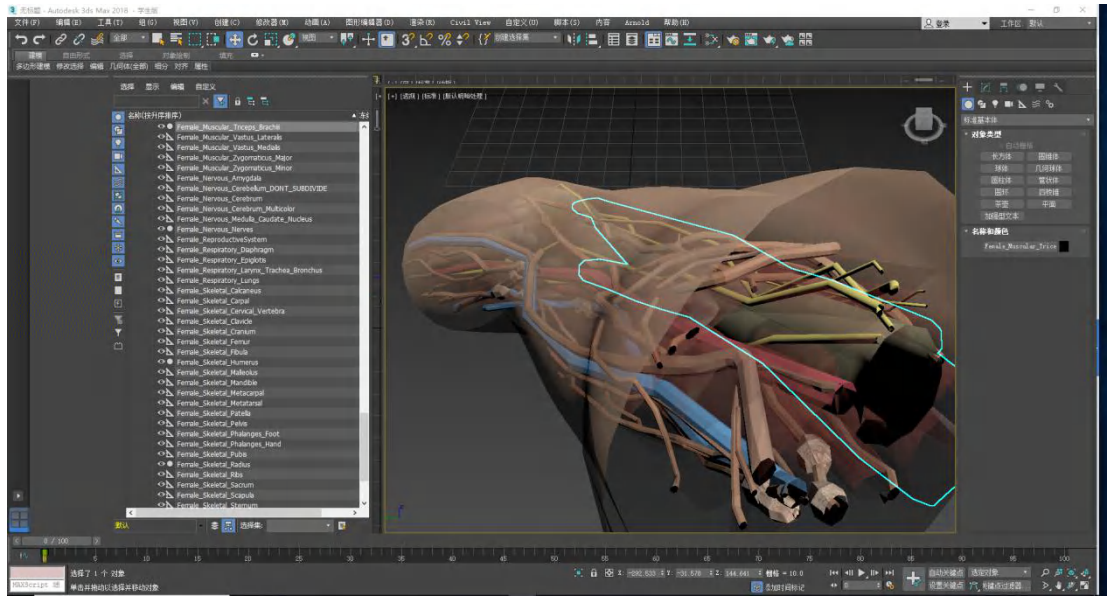


Figure 3-11-6 The cutting shoulder model.



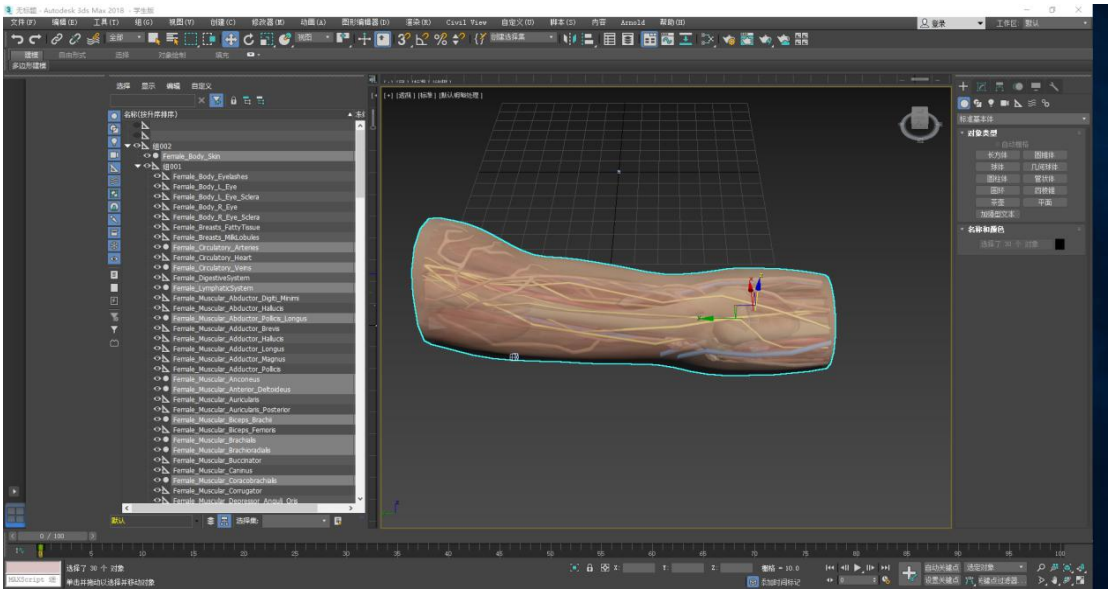


Figure 3-11-7 The cutting arm model.

.

3.2.3.2 Introduction Animation

Firstly, according to the storyboard (Chapter 3.2.2.2), the animation about the introduction of the periarthritis of shoulder and the acupuncture will be designed by software Flash.

Figures 3-12-1, 3-12-2.

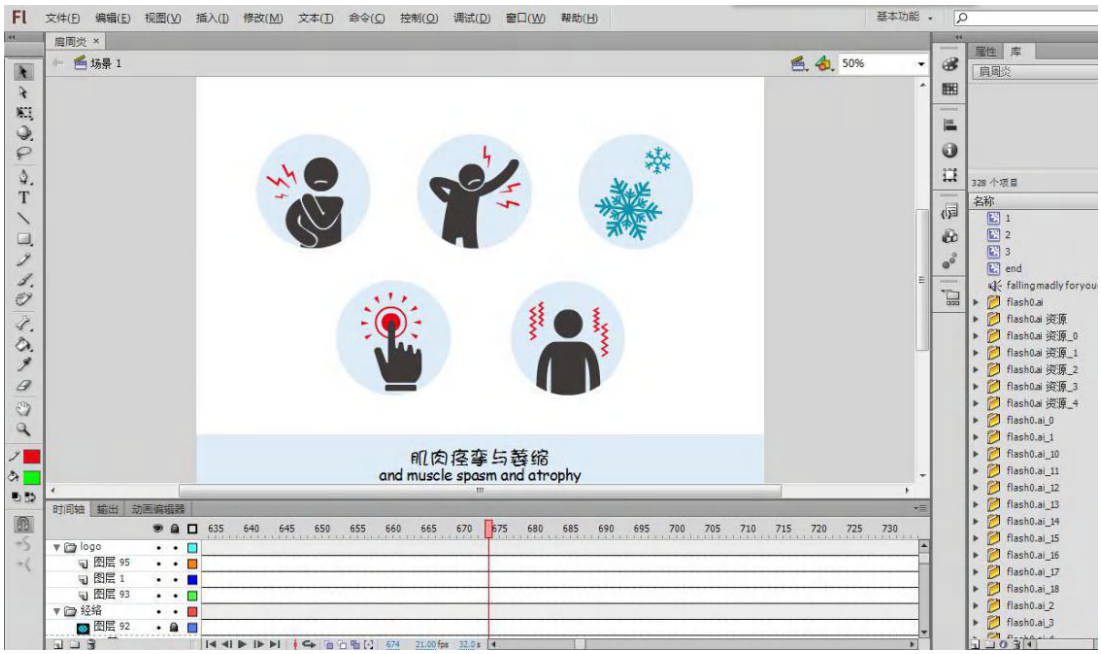


Figure 3-12-1 The process of designing the animation.

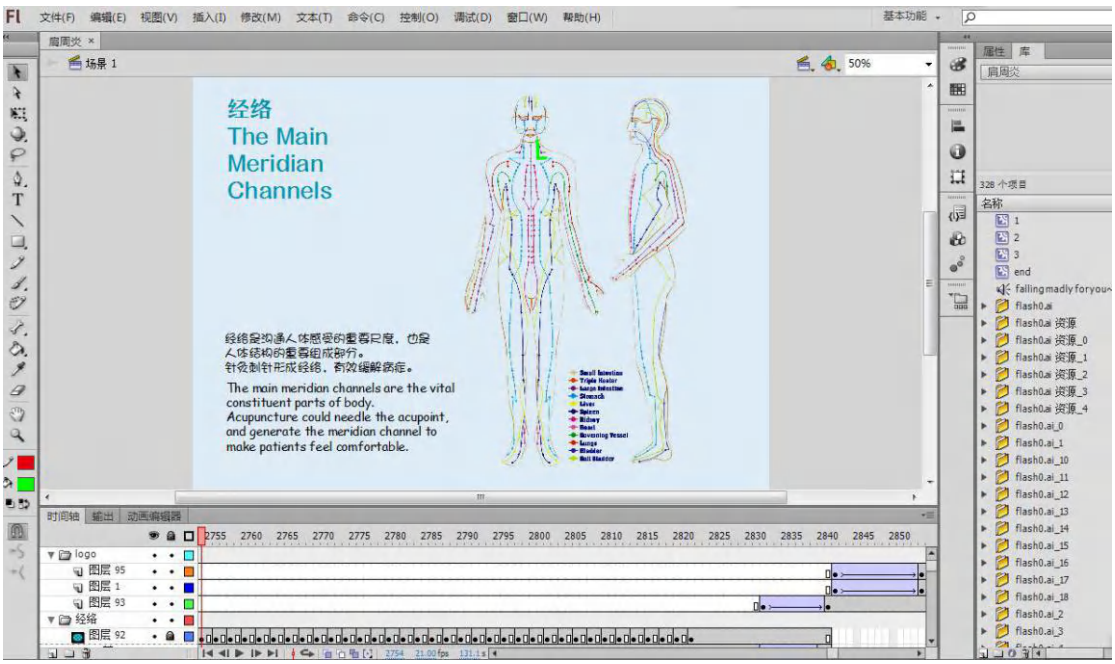


Figure 3-12-2 The process of designing the animation.

Thirdly, transform the file format of the animation and fix it in Unity 3D. Figure 3-12-3. Transform the animation into Unity step by step.

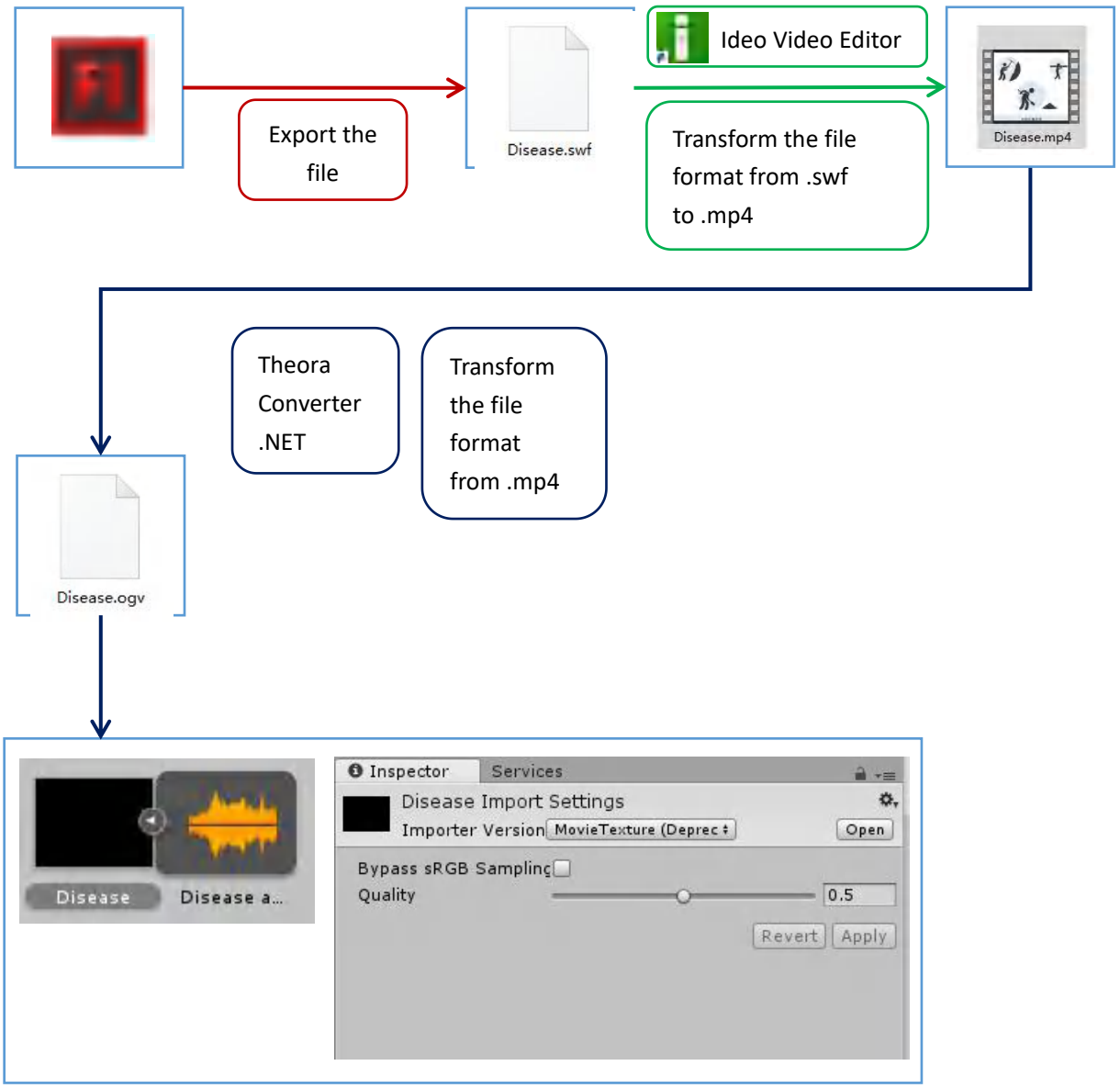


Figure 3-12-3 Transform the animation into Unity step by step.

The file format called .ogv is the only one which can run in Unity, so I need to transform the file format and import it in Unity. The ogv file is an image animation which has the separate audio.

3.2.4 Configuration for the Application

In this part, it will illustrate the configuration of the application, and some requirements when the user experiences the application.

HTC Vive's room-scale needs to be set at first. Figure 3-13-1 shows the room-scale to establish the virtual environment.

Figure 3-13-1 The room-scale to establish the virtual environment.

In the space, the user needs to prepare a desk, a chair and a suitable computer connecting with the HTC Vive and haptic device (Phantom Onmi). The user needs to sit on the chair to operate the equipment. Therefore, the virtual environment must be oriented in such a way that the user is seated. It is a vital point to experience the application. Figure 3-13-2 The correct experience situation.

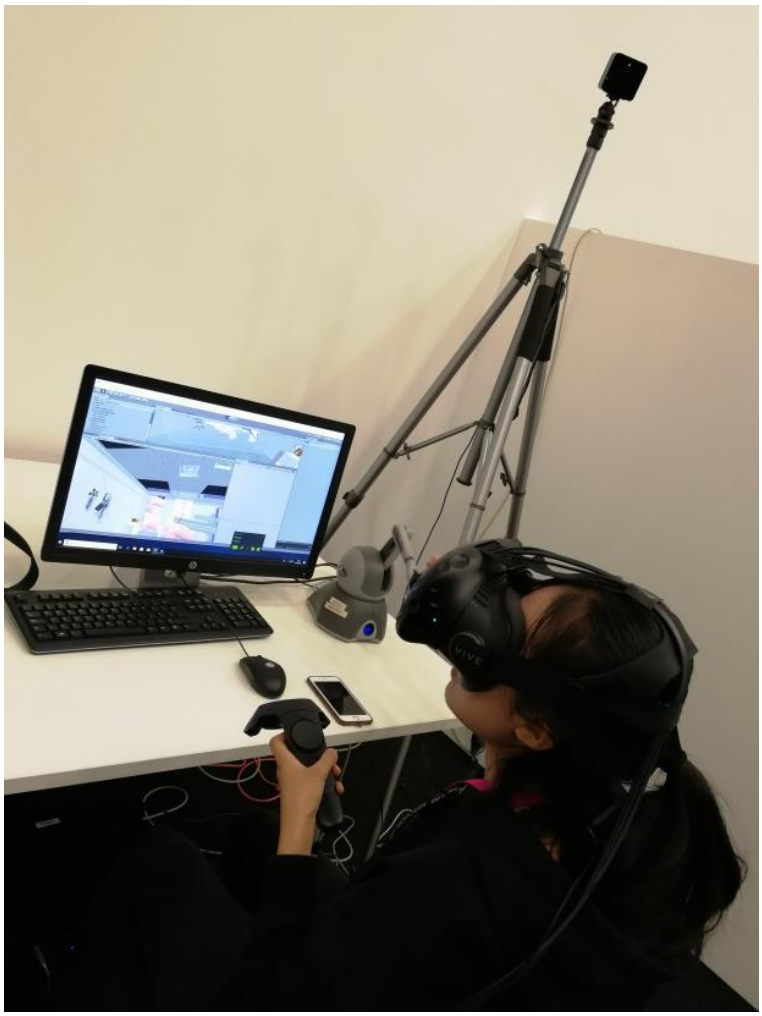


Figure 3-13-2 The correct experience situation.

3.2.5 VR Environment

In this part, it will discuss the programming connecting with the application in the environment, and the implementing of the virtual environment.

3.2.5.1 Programming of the Application in Virtual Environment

To establishing the virtual environment and interaction with HTC Vive, the headset and two controllers need to be set first. Figure 3-14-1 Setting the headset and controllers.

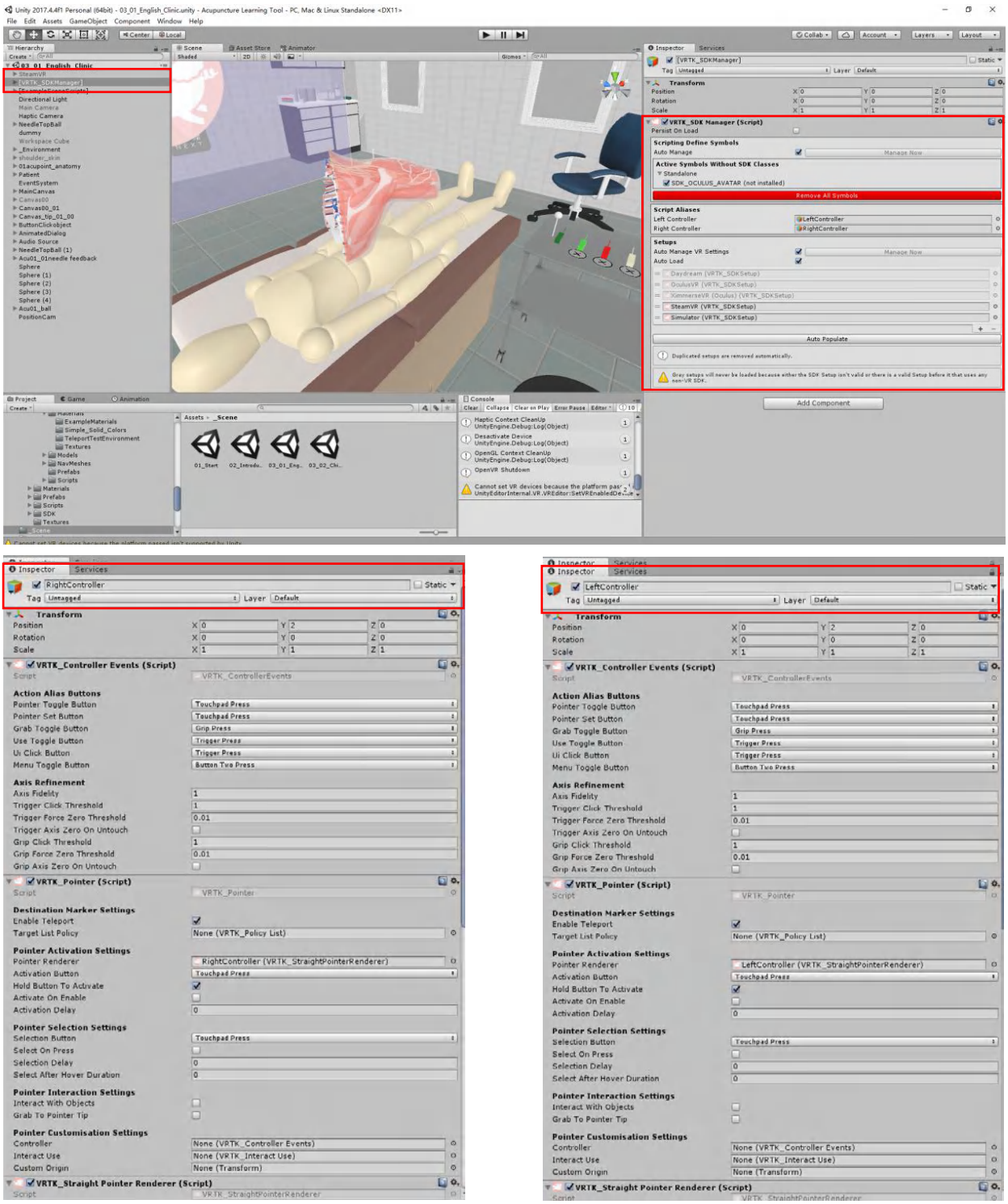


Figure 3-14-1 Setting the headset and controllers.

Only if the headset and controllers are set, the virtual environment can be connected with HTC Vive, and the user can use controllers to do the interaction. After that, the clicking button function will be described in the virtual environment with HTC Vive.

The function in VR - Building Canvas in the virtual environment and using the controller to click the button.

Firstly, Building Canvas in VR - Figure 3-14-2

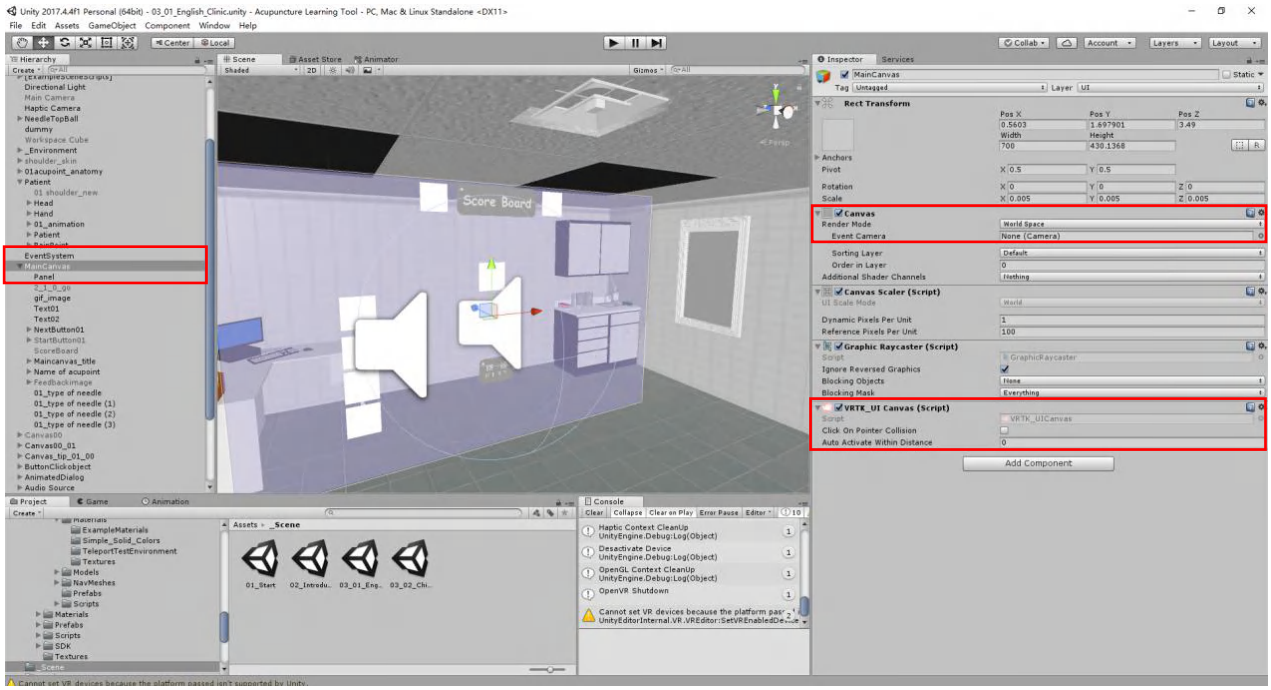


Figure 3-14-2 The vital points about establishing the Canvas in VR.

Canvas is the indispensable part to achieve the button function. In VR, the key point is to change the Canvas in world space state.

Secondly, understanding the using function of the controller. Figure 3-14-3

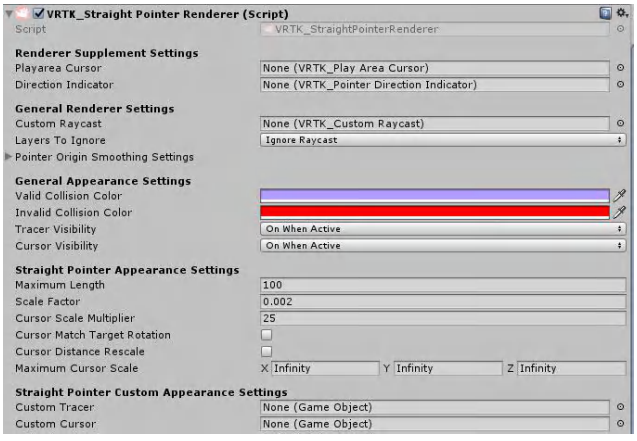


Figure 3-14-3 The function of the controller.

Figure 3-14-4 Plugin - VR Toolkit.

The function of the controller can be built by a Plugin called VRTK - VR Toolkit.
It is a useful plugin to achieve the button function in VR. Figure 3-14-4 VRTK - VR Toolkit
https://assetstore.unity.com/packages/tools/vrtk-virtual-reality-toolkit-vr-toolkit-64131

Also, the clicking button scripting is also needed to be fixed. Figure 3-14-5 The scripting of button clicking. Figure 3-14-6 Arranging the scripting on the specific button.

“Button_Onclick(){}” is the essential function of the scripting.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;

public class NextButton01 : MonoBehaviour {

    // Use this for initialization
    public GameObject false01;
    public GameObject false02;
    public GameObject false03;



    public GameObject true01;
    public GameObject true02;
    //public GameObject true03;

    // Use this for initialization
    void Start () {

    }

    public void Button_Onclick(){

        false01.SetActive (false);
        false02.SetActive (false);
        false03.SetActive (false);

        true01.SetActive (true);
        true02.SetActive (true);
        //true03.SetActive (true);


    }

    // Update is called once per frame
    void Update () {

    }
}

```

Figure 3-14-5 The scripting of button clicking.

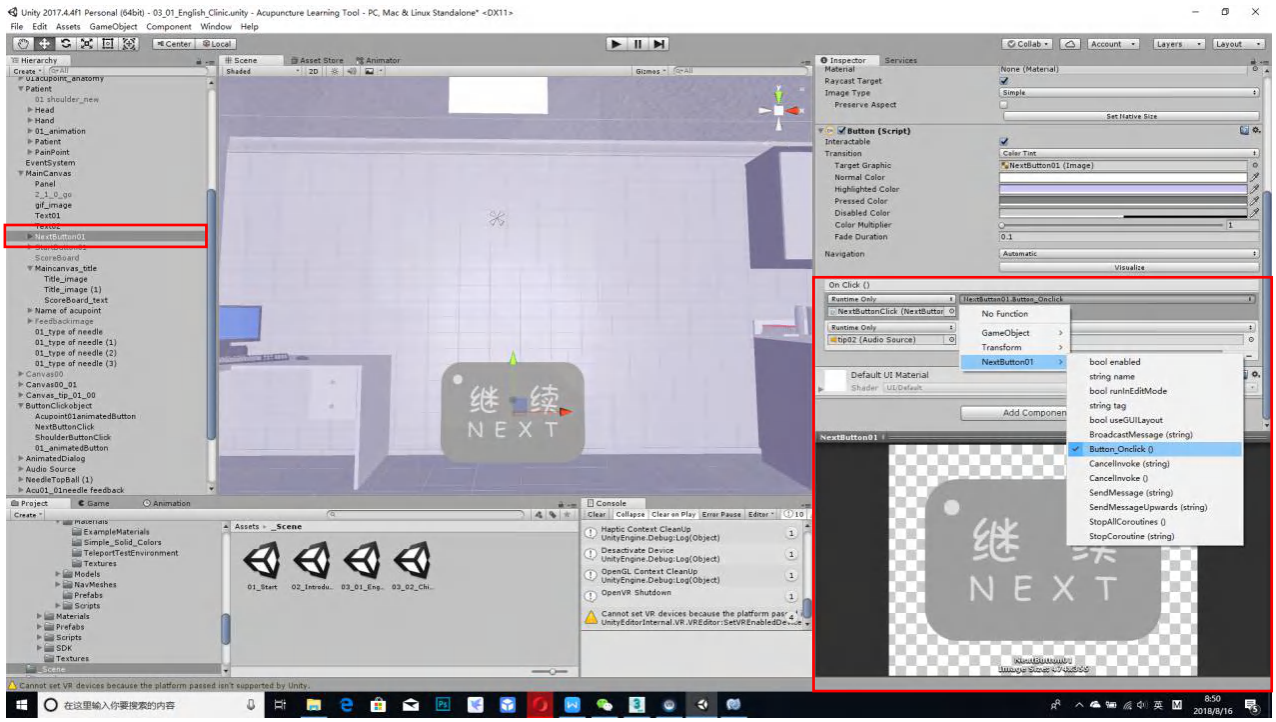


Figure 3-14-6　Arranging the scripting on the specific button.

3.2.5.2 Implementing Virtual Environment

Firstly, the prototype of the application has four scenes. Figure 3-15-1

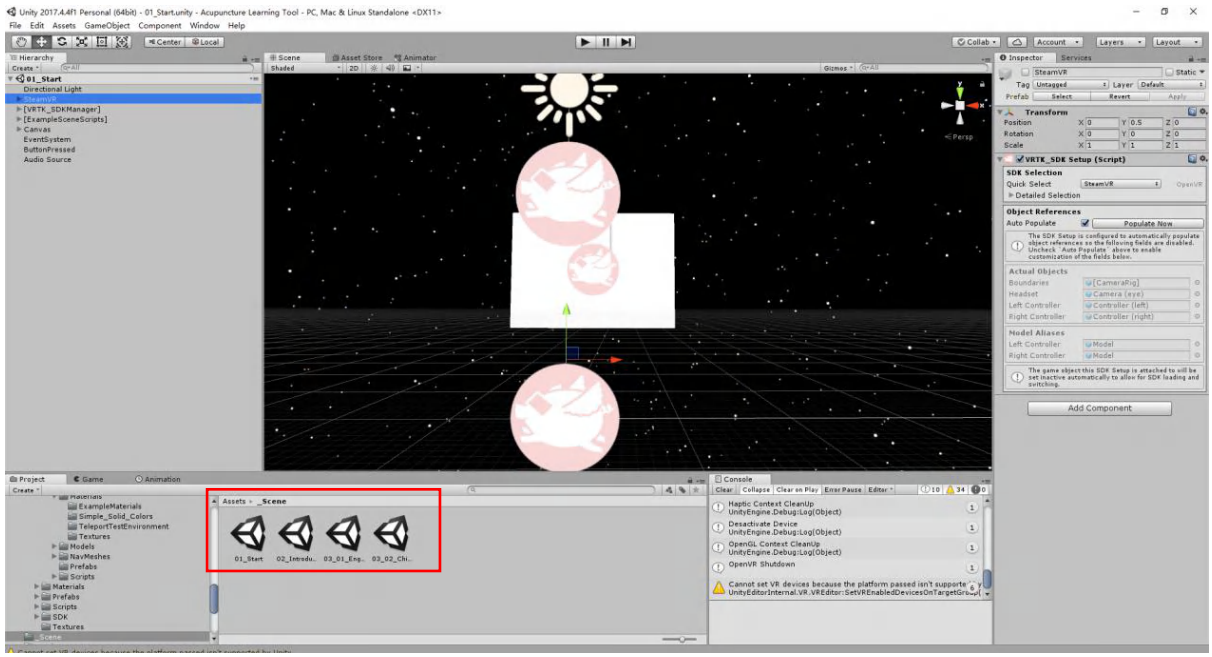


Figure 3-15-1 The prototype of the application has four scenes. Start; Introduction;

English acupuncture training; Chinese Acupuncture training.

Secondly, the virtual environment will be established. The first step, the designer needs to find a suitable position to arrange the VR camera. Figure 3-15-2. The second step, organize the suitable models in the virtual environment. Table 3-9-2.

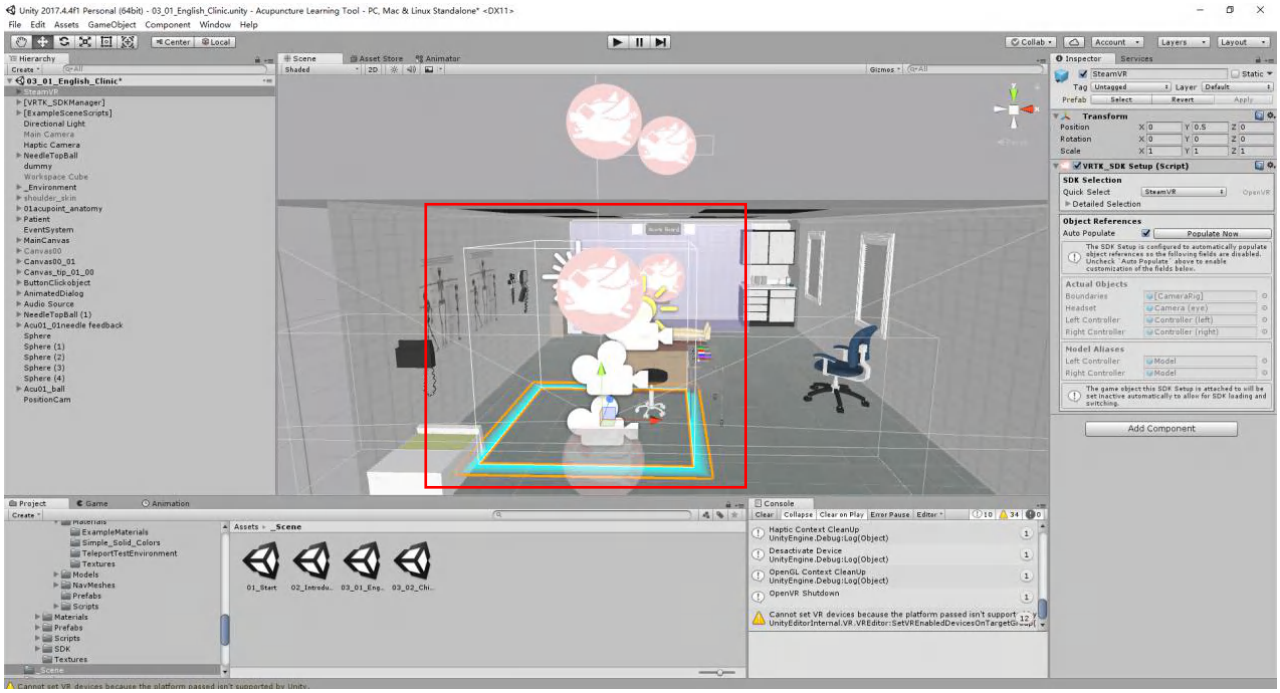


Figure 3-15-2 Arranging the VR camera.

Table 3-9-2 shows that the models used within the virtual environment consist of open resources which were bought to online UNITY ASSET STORE.

Model Information	**Description**	**Reference**
Doctor's Office	Models have many hospital elements can be used to build an acupuncture clinic. Figure: 3-15-3	The model could be bought to online UNITY ASSET STORE; the following is the online address. https://assetstore.unity.com/packages/3d/props/interior/hospital-doctor-s-office-65226

Table 3-9-2 Illustrating the information of models and reference.

Figure 3-15- 3 Doctor’s Office models (UNITY ASSET STORE, 2017).

Thirdly, in the virtual environment, the animation tips about the acupoint is also an element in the virtual environment. Figure 3-15-4. The animation tips cannot only remind the user about the position of the acupoint but also add interest to the application.

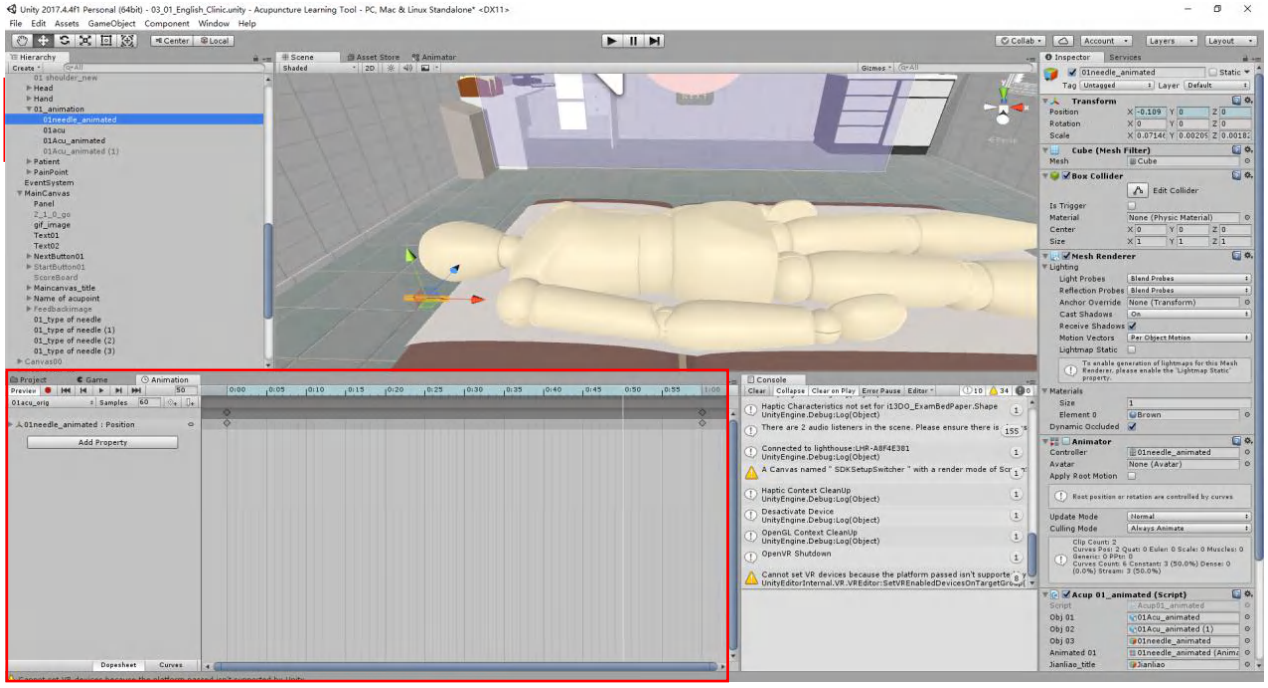


Figure 3-15-4 The animation tip on the brown needle.

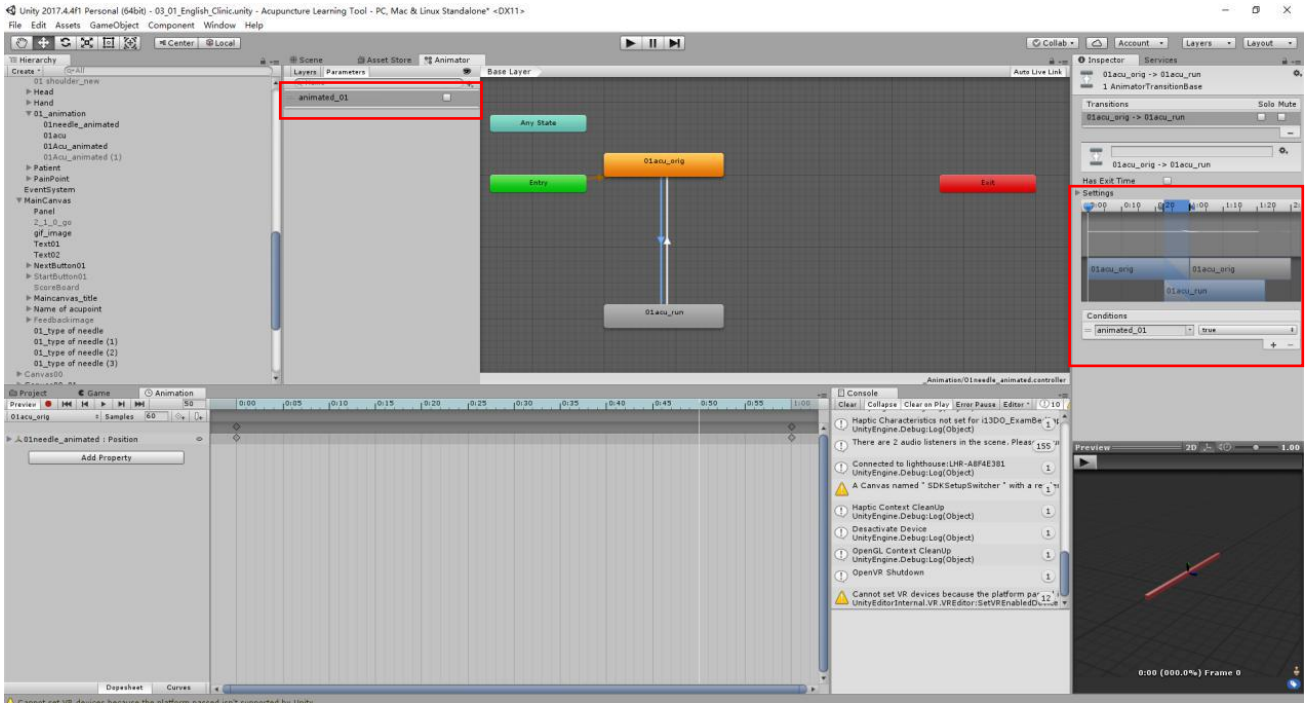
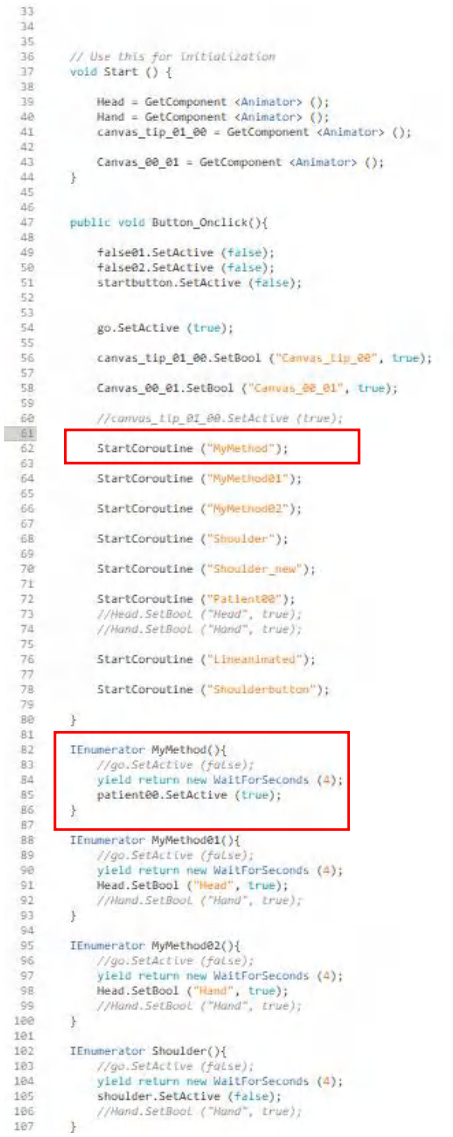


Figure 3-15-5 The animator on the brown needle.

Figure 3-15-5 shows the animator on the needle. The animator uses the bool function, and it is useful for the designer to use the animation on scripting. If the designer wants to run the animation, will use “animated_01 = true”.

Finally, scripting to make the process of operating smoothly is also a mentionable point in the virtual environment.

In the application, “How to run many elements in order?” is confused the designer. The method to arrange many elements is using the function “IEnumerator(){}.” Figure 3-15-6.



```
33
34
35
36  // Use this for initialization
37  void Start () {
38
39      Head = GetComponent <Animator> ();
40      Hand = GetComponent <Animator> ();
41      canvas_tip_01_00 = GetComponent <Animator> ();
42
43      Canvas_00_01 = GetComponent <Animator> ();
44  }
45
46
47  public void Button_Onclick(){
48
49      false01.SetActive (false);
50      false02.SetActive (false);
51      startbutton.SetActive (false);
52
53
54      go.SetActive (true);
55
56      canvas_tip_01_00.SetBool ("Canvas_tip_00", true);
57
58      Canvas_00_01.SetBool ("Canvas_00_01", true);
59
60      //canvas_tip_01_00.SetActive (true);
61
62      StartCoroutine ("MyMethod");
63
64      StartCoroutine ("MyMethod01");
65
66      StartCoroutine ("MyMethod02");
67
68      StartCoroutine ("Shoulder");
69
70      StartCoroutine ("Shoulder_new");
71
72      StartCoroutine ("Patient00");
73      //Head.SetBool ("Head", true);
74      //Hand.SetBool ("Hand", true);
75
76      StartCoroutine ("Lineanimated");
77
78      StartCoroutine ("Shoulderbutton");
79
80  }
81
82  IEnumerator MyMethod(){
83      //go.SetActive (false);
84      yield return new WaitForSeconds (4);
85      patient00.SetActive (true);
86  }
87
88  IEnumerator MyMethod01(){
89      //go.SetActive (false);
90      yield return new WaitForSeconds (4);
91      Head.SetBool ("Head", true);
92      //Hand.SetBool ("Hand", true);
93  }
94
95  IEnumerator MyMethod02(){
96      //go.SetActive (false);
97      yield return new WaitForSeconds (4);
98      Head.SetBool ("Hand", true);
99      //Hand.SetBool ("Hand", true);
100 }
101
102 IEnumerator Shoulder(){
103     //go.SetActive (false);
104     yield return new WaitForSeconds (4);
105     shoulder.SetActive (false);
106     //Hand.SetBool ("Hand", true);
107 }
```

Figure 3-15-6 The scripting to make many elements in the application run in order.

In the application, the scripting means the current operation will wait a few seconds. The designer can change the waiting seconds to arrange the different operation in order.

3.2.6 Haptic Interaction

In this part, the programming about the accurate feedback platform will be explained detailedly. Besides, the feedback prototype with the haptic device will be implemented.

3.2.6.1 Programming of the Application in Haptic Interaction

To achieving the real-time feedback platform, first of all, the rationale of the Plugin need to be understood. A suitable needle model should be connected with the Plugin; it will move the position and rotate followed the haptic device. Figure 3-16-1 Figure 3-16-2 Figure 3-16-3.

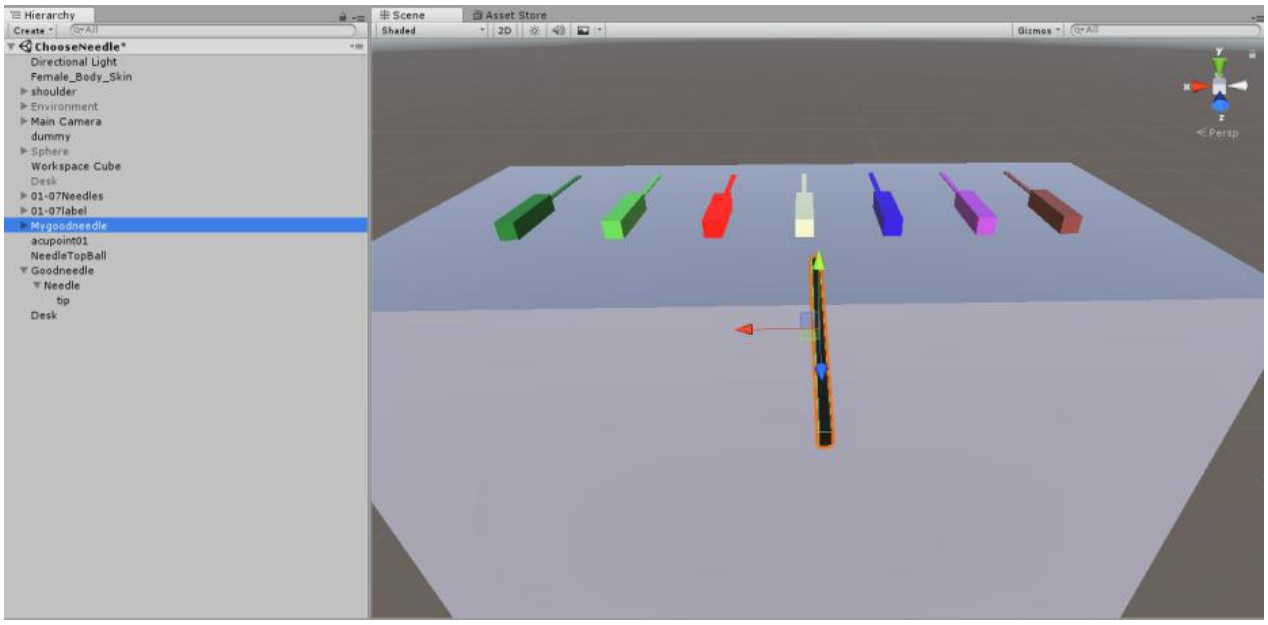


Figure 3-16-1 shows “MygoodNeedle” in the environment.

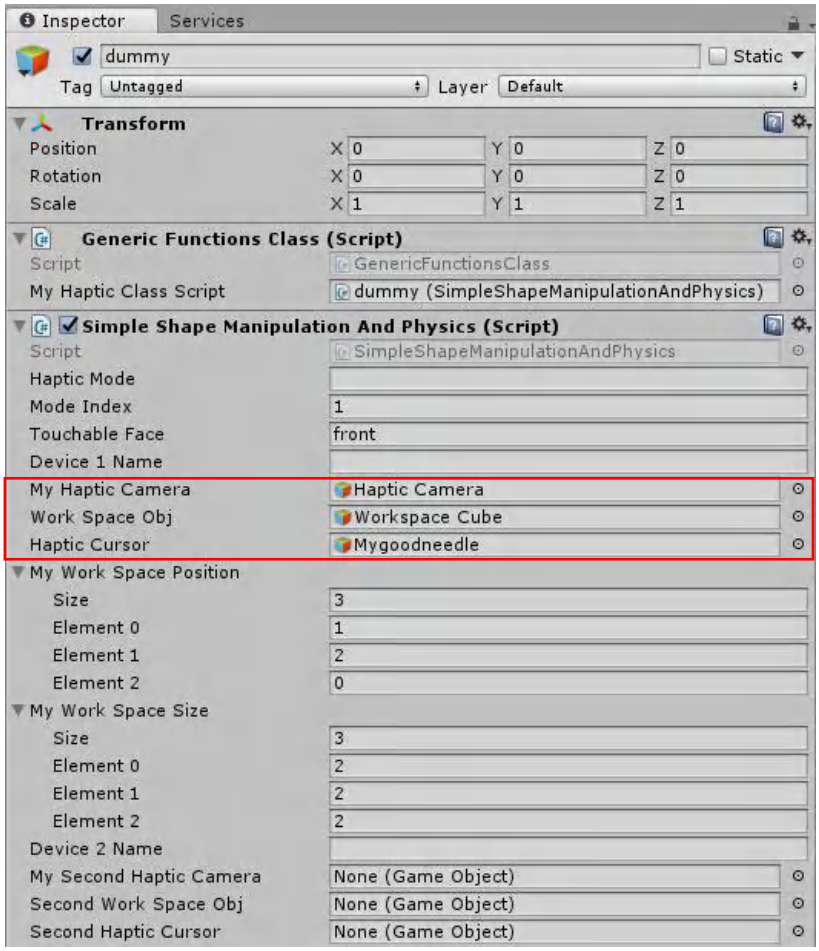


Figure 3-16-2 shows the excellent needle model has been connected with the haptic device.

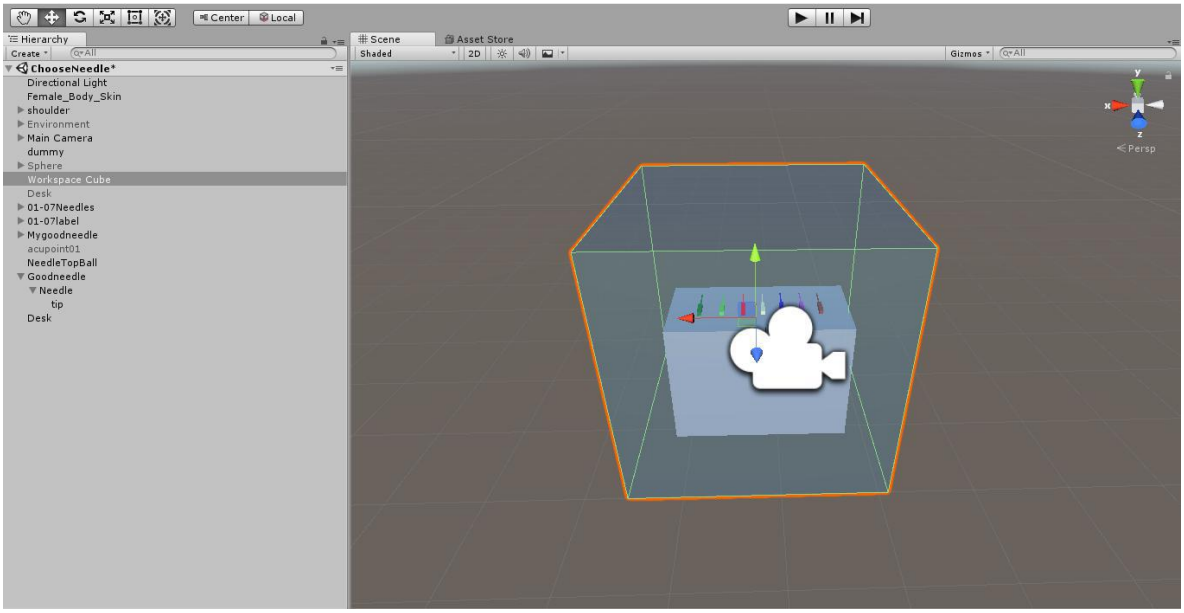


Figure 3-16-3 shows the moving space of the haptic device.

After fixing the fundamental haptic plugin, three main scripting in the feedback platform will be mentioned.

1. The first function - scripting the choosing needle function and understanding the use of buttons on Phantom Omni.

Firstly, the choosing needle scripting is based on the function “OnTriggerEnter(){}” and “OnTriggerExit(){}”. Figure 3-16-4

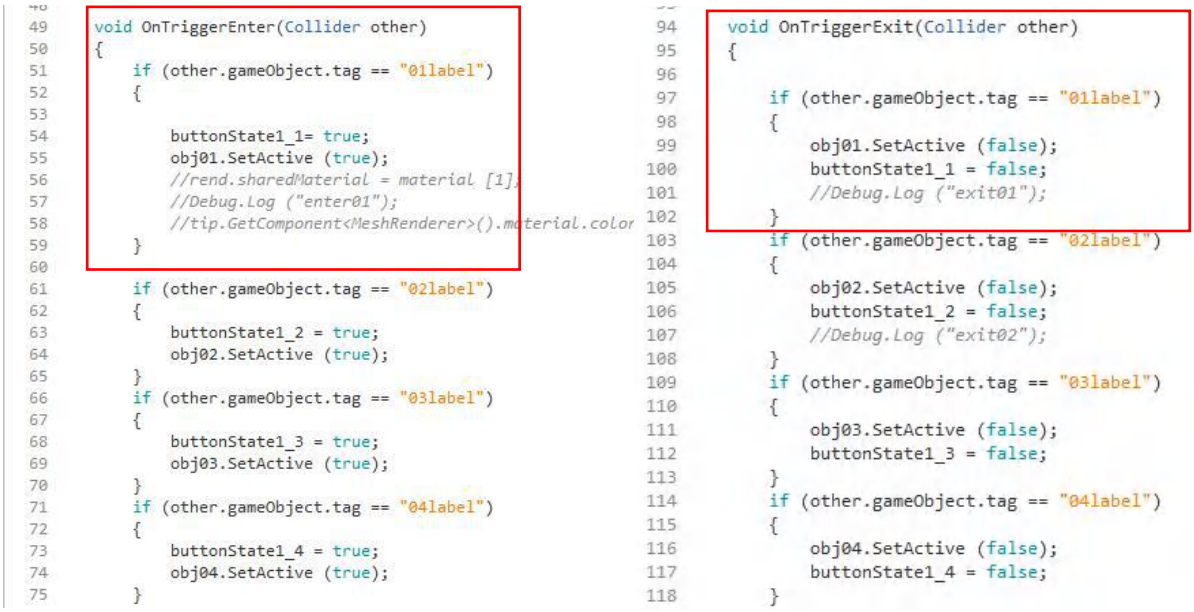


Figure 3-16-4 The scripting achieves the collision detection. “OnTriggerEnter” means the device touches the needle model. “OnTriggerExit” means the device leaves the needle model.

In the scripting, the haptic device can get collision detection, and make the relevant response. In the application when the haptic device touches the needle model, the needle introduction will be shown. Figure 3-16-5

Figure 3-16-5 The function prototype of choosing the relative needle.

Secondly, understanding the use of buttons on Phantom Omni can achieve the needle chosen the correct color. It means “MygoodNeedle” can change the color when the user clicks the button to Phantom Omni. Figure 3-16-6 Figure 3-16-7 Figure 3-16-8

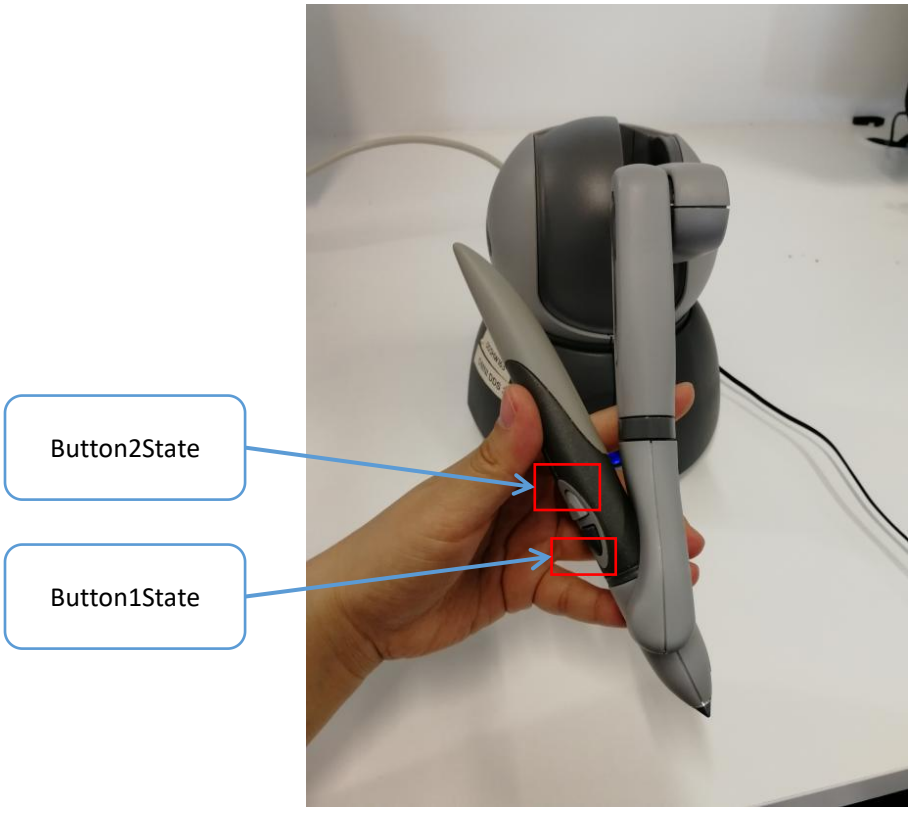


Figure 3-16-6 shows the two buttons on the haptic device.

```
public class Label : MonoBehaviour {


    public Material[] material;
    Renderer rend;

    public GameObject obj01;
    public GameObject obj02;
    public GameObject obj03;
    public GameObject obj04;
    public GameObject obj05;
    public GameObject obj06;
    public GameObject obj07;

    public bool buttonState1_1;
    public bool buttonState1_2;
    public bool buttonState1_3;
    public bool buttonState1_4;
    public bool buttonState1_5;
    public bool buttonState1_6;
    public bool buttonState1_7;

    public bool buttonState2;
```

```
void Update () {

    //buttonState1 = PluginImport.GetButton1State ();
    buttonState2 = PluginImport.GetButton2State ();

    if (buttonState2 == true)
    {
        rend.sharedMaterial = material [0];
    }

    if (buttonState1_1== true&& PluginImport.GetButton1State())
    {
        rend.sharedMaterial = material [1];
      //  tip.GetComponent<MeshRenderer>().material.color = Color.yellow;
        //Debug.Log ("button1_1");
    }

    if (buttonState1_2== true&& PluginImport.GetButton1State())
    {
        rend.sharedMaterial = material [2];
        //Debug.Log ("button1_2");
      //  tip.GetComponent<MeshRenderer>().material.color = Color.green;
    }
```

Figure 3-16-7 shows the scripting about using the button to change the color. “GetButton1State(){}” is a bool function to activate the using of the Button1 on the haptic device.

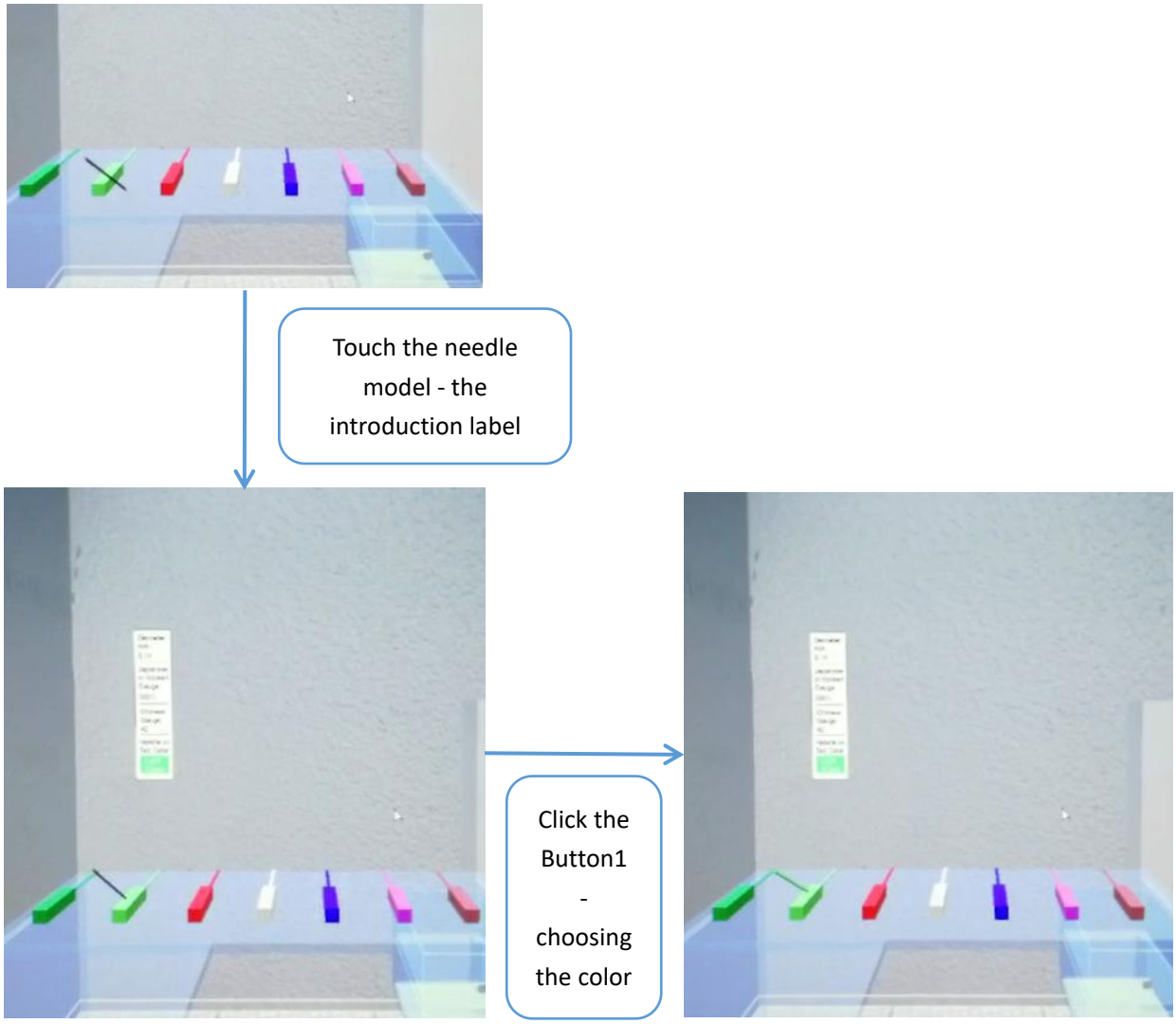


Figure 3-16-8 shows the prototype of the choosing needles.

2. The second function - Real-time feedback.

The core of the function is the application of the Render Texture. Figure 3-16-9 shows the step achieving the real-time feedback.

Firstly, creating a render texture in assets.

Secondly, creating a camera to target the position where needs the real-time feedback, and fix the render texture under the camera.

Thirdly, showing the render texture on Canvas.

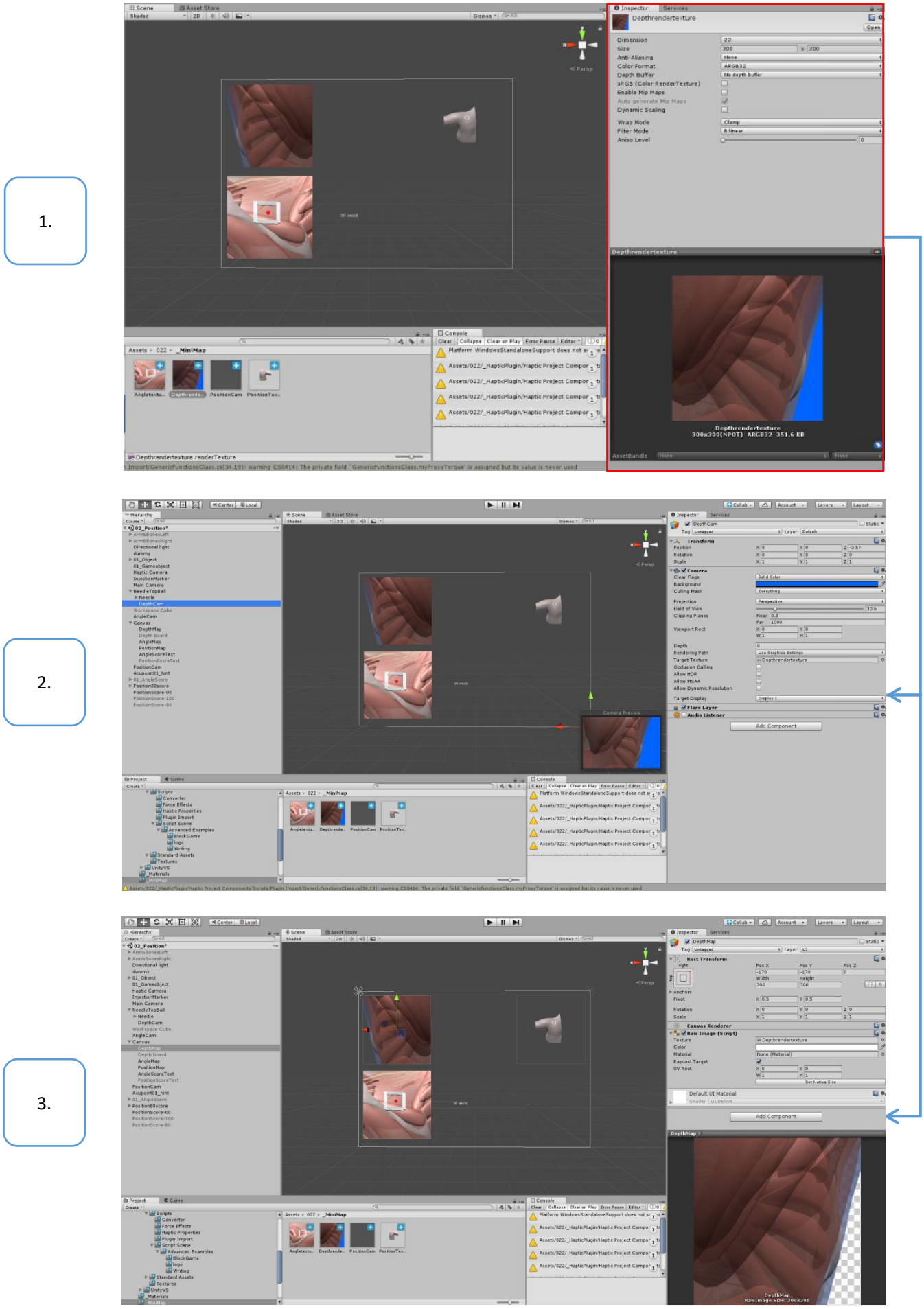


Figure 3-16-9 The process of creating the real-time feedback texture on Canvas.

3. The third function - Recording the terminal feedback on the scoreboard.

The function can be divided into two parts, the first is recording the feedback texture, and the second is showing the recorder on Canvas.

Firstly, the scripting of saving the texture to a fixed path. Figure 3-16-10 Figure 3-16-11

```
18  private void Awake(){
19      instance = this;
20      myCamera = gameObject.GetComponent<Camera>();
21  }
22  // Use this for initialization
23  /*void Start () {
24
25  }*/
26
27  private void OnPostRender(){
28      if (takeScreenshotOnNextFrame) {
29          takeScreenshotOnNextFrame = false;
30          RenderTexture renderTexture = myCamera.targetTexture;
31
32          Texture2D renderResult = new Texture2D (renderTexture.width, renderTexture.height, TextureFormat.ARGB32, false);
33          Rect rect = new Rect (0, 0, renderTexture.width, renderTexture.height);
34          renderResult.ReadPixels (rect, 0, 0);
35
36          byte[] byteArray = renderResult.EncodeToPNG ();
37
38          System.IO.File.WriteAllBytes (Application.persistentDataPath + "/CameraScreenshot01.png", byteArray);
39          Debug.Log ("Texture saved to: " + Application.persistentDataPath + "/CameraScreenshot01.png");
40
41          //fileSave = new FileStream(Application.dataPath + "/Save/"+filename,FileMode.Create);
42
43
44          //WWW =new WWW("file://"+ Application.dataPath+"/CameraScreenshot.png");
45          //yield return WWW;
46
47          //image.mainTexture = WWW.texture;
48
49          Debug.Log ("Saved CameraScreenshot.png");
50
51          RenderTexture.ReleaseTemporary (renderTexture);
52          myCamera.targetTexture = null;
53
54
55      }
56
57  }
58
59  private void TakeScreenshot(int width, int height){
60      myCamera.targetTexture = RenderTexture.GetTemporary (width, height, 16);
61      takeScreenshotOnNextFrame = true;
62  }
63
64
65  public static void TakeScreenshot_Static(int width,int height){
66      instance.TakeScreenshot (width, height);
67  }
68
```

The size and type of the saved texture

The path of the saved texture

Figure 3-16-10 shows the size, type, and path of the saving texture.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class GameHandler : MonoBehaviour {

    // Use this for initialization
    private void Start () {

    }

    // Update is called once per frame
    private void Update () {


        if (PluginImport.GetButton1State ()) {

            ScreenshotHandler.TakeScreenshot_Static (512, 512);


        }

    }
}

```

Figure 3-16-11 shows pressing the Button2 on the haptic device and then the texture saved.

Secondly, creating a new image on Canvas to load the saved texture. Figure 3-16-12 Figure 3-16-13

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine .UI;
using System.IO;

public class LoadTexture : MonoBehaviour {


    public Image myImage;
    Texture2D myTexture;
    int width = 512;
    int height = 512;


    // Use this for initialization
    void Start () {
    }

    // Update is called once per frame
    void Update () {
        /*if (Input.GetKeyDown (KeyCode.Space)) {
            Invoke ("GetImage", 1f);
        }*/

        if (PluginImport.GetButton1State ()) {
            Invoke ("GetImage", 1f);
        }
    }

    void GetImage() {

        byte[] bytes = File.ReadAllBytes(Application.persistentDataPath + "/CameraScreenshot01.png");
        Texture2D texture = new Texture2D(width, height, TextureFormat.RGB24, false);
        texture.filterMode = FilterMode.Trilinear;
        texture.LoadImage(bytes);
        Sprite sprite = Sprite.Create(texture, new Rect(0,0,width, height), new Vector2(0.5f,0.0f), 1.0f);

        GetComponent<Image>().sprite = sprite;
    }
}

```

Figure 3-16-12 shows the scripting of loading the saved texture from the fixed path.

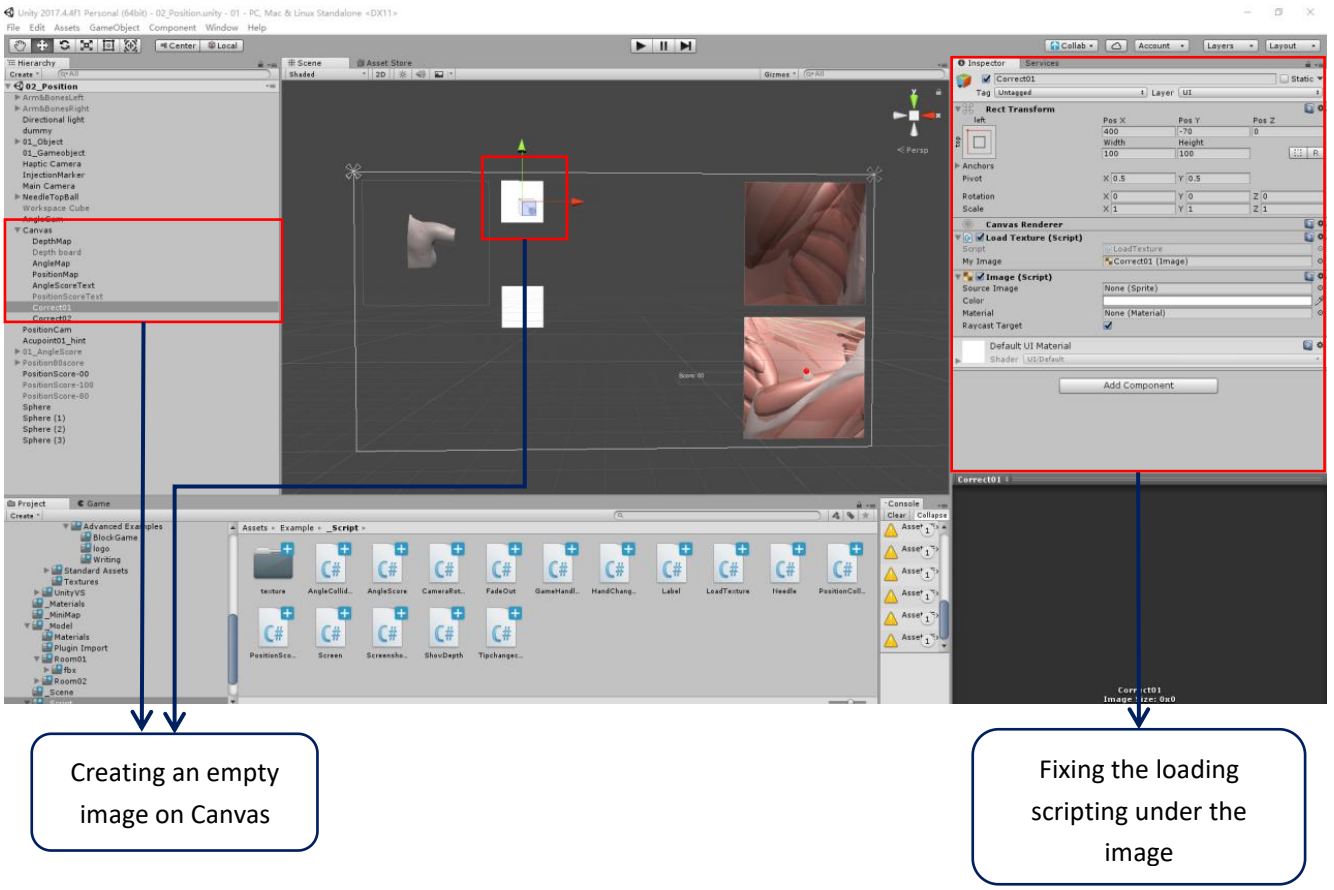


Figure 3-16-13 shows the image on Canvas which shows the saved texture.

Create an image to load the saved texture on Canvas and fix the loading scripting under the image.

3.2.6.2 Implementing the Feedback Platform Prototype

The feedback platform is composed of the real-time feedback and recording the terminal feedback on Canvas. Figure 3-17-1 shows the real-time feedback prototype.

Figure 3-17-2 shows the saving and loading the terminal results.

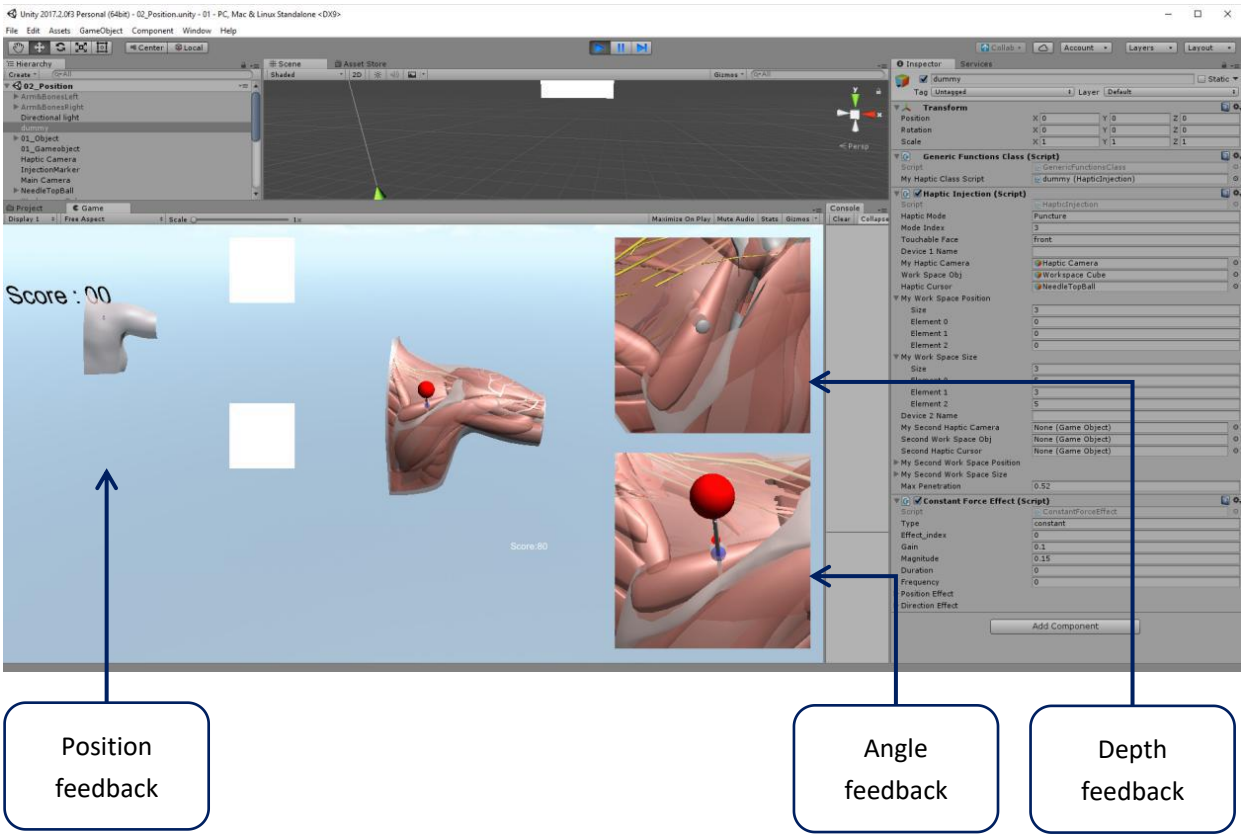


Figure 3-17-1 shows the concurrent feedback, and reflect the real-time texture on Canvas; it includes the position of acupoint, the angle of the needle and the depth of needling.

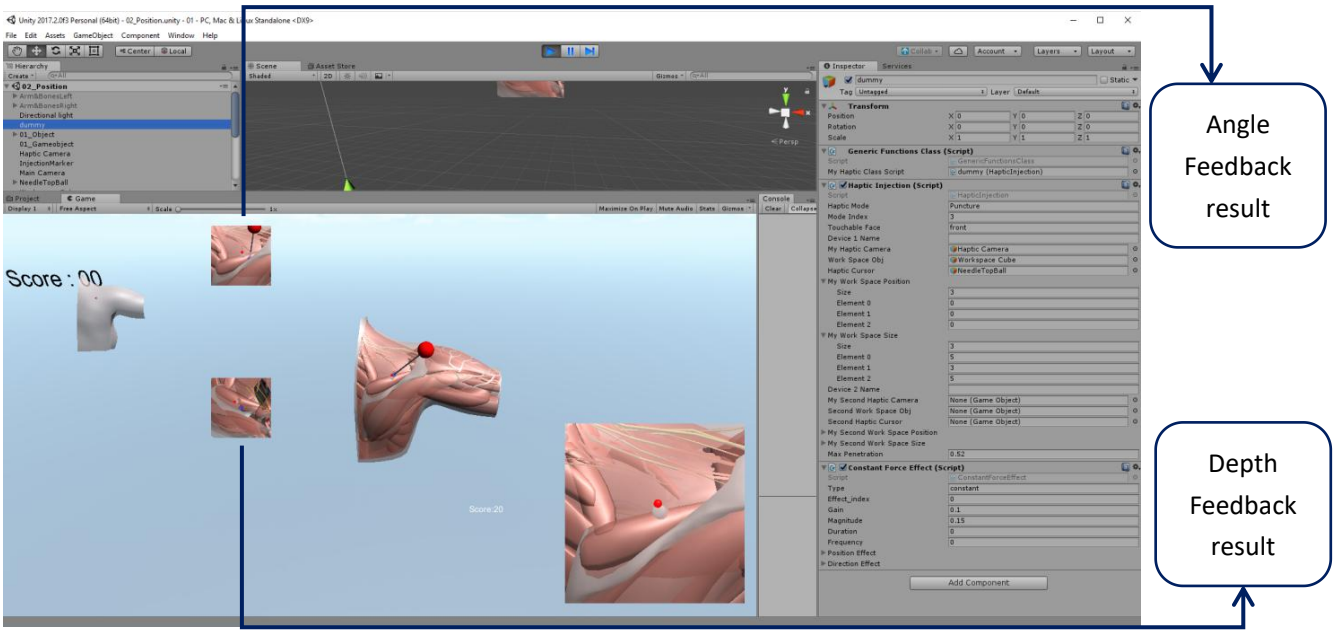


Figure 3-17-2 shows loading the saved texture on Canvas.

3.2.7 Final Design of the Application - Combining VR and Haptic technology

In this part, the virtual and haptic technology will be combined in the development of the application. Figure 3-17-3 Figure 3-17-4

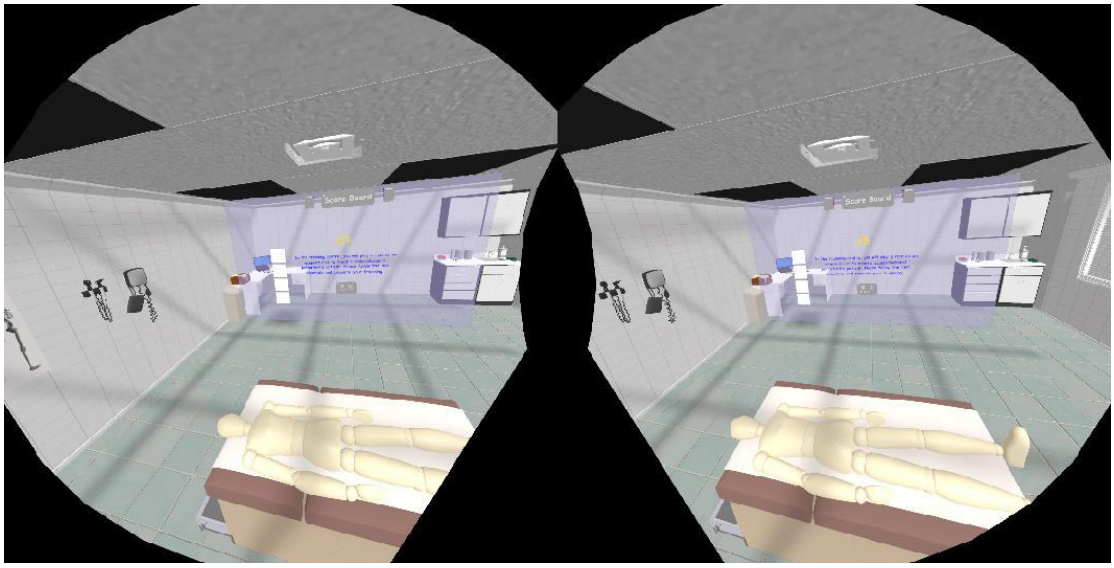


Figure 3-17-3 shows the environment of the application in HTC Vive.

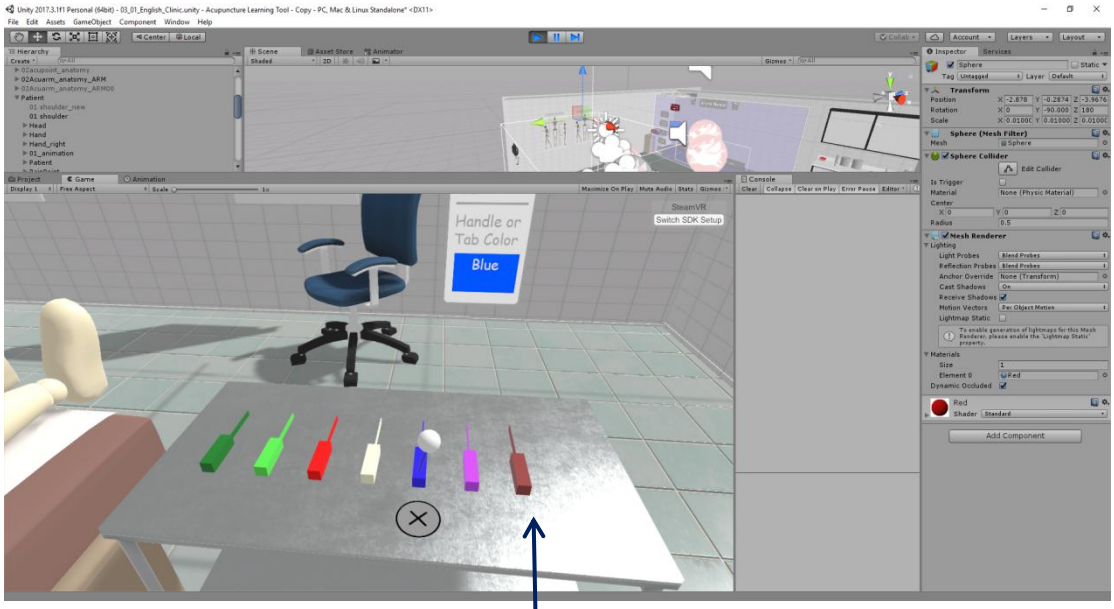


Figure 3-17-4 shows the haptic development in the virtual environment.

4 Results

In this part, the results of the application will be illustrated clearly. It contains the whole introduction animation, every scene of the application and the total training of acupuncture.

The application is a platform to provide the accurate feedback of acupuncture; it is developed by two devices, HTC Vive and Phantom Omni. The user can learn the rationale of acupuncture and train the needling skills on the application.

4.1 Introduction Animation

The introduction of the periarthritis of shoulder and the acupuncture will be arranged before the acupuncture training (as seen in Appendix 2). Figure 4-1 shows the animation images of the introduction of the periarthritis of shoulder run in the application. Figure 4-2 the introduction animation in VR. Figure 4-3 shows the animation images of the introduction of the acupuncture run in the application.

Figure 4-1 The animation images about the introduction of the periarthritis of shoulder.

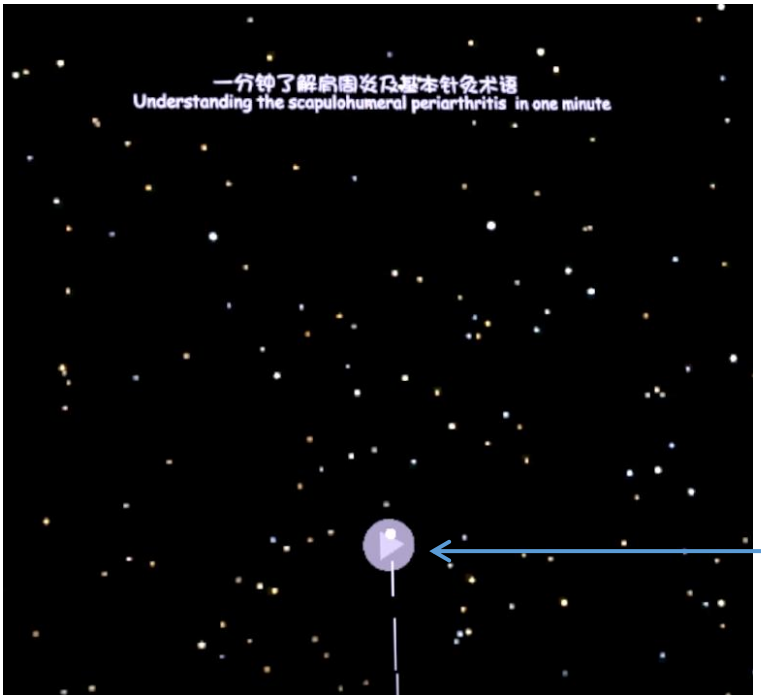


Figure 4-2 The introduction animation in VR.

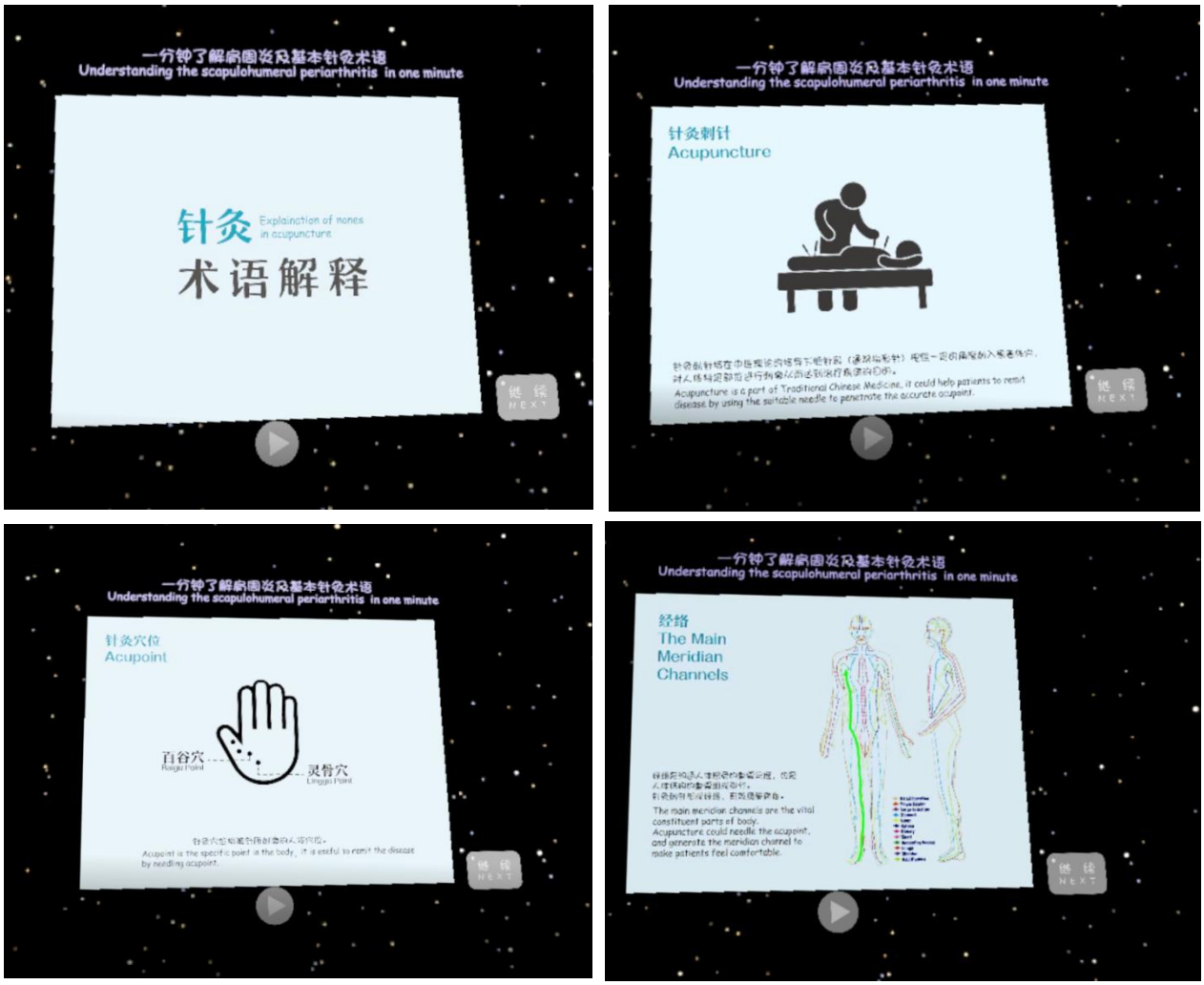


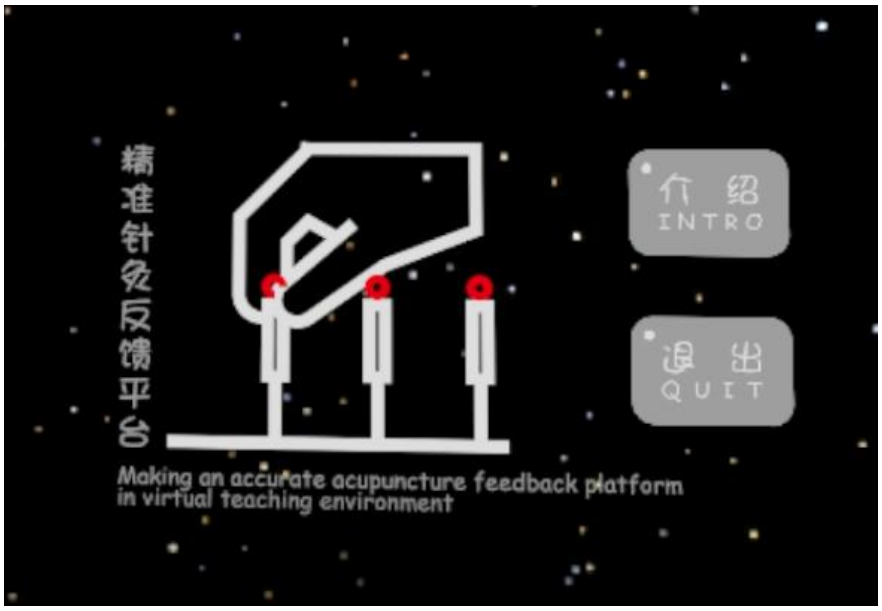
Figure 4-3 The animation images about the introduction of the acupuncture.

Because the acupuncture training is treating the periarthritis of shoulder, the introduction of the periarthritis of the shoulder is needed to understand before training.

“Acupuncture,” “Acupoint,” “The Main Meridian Channels” these three nouns are professional vocabularies in the acupuncture training. Therefore, the explanation of professional dictionaries is necessary for the introduction interface. It can help the user understand the knowledge of acupuncture better.

4.2 Application Results

4.2.1 Start and Introduction



Start

Figure 4-4 The start interface.

Introduction

Figure 4-5 The introduction of the periarthritis of shoulder and the acupuncture.

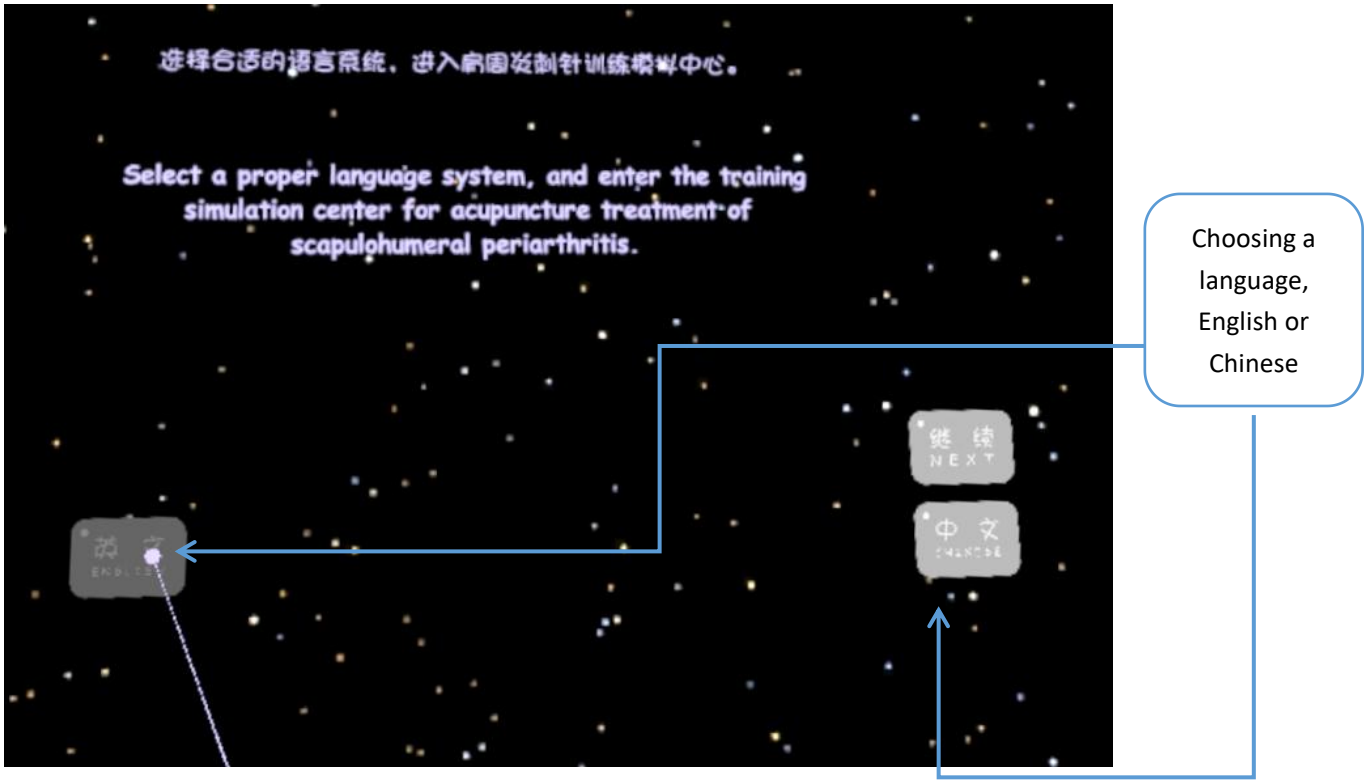


Figure 4-6 Choosing a language to enter into the acupuncture training centre.

In the introduction interface, the user can choose a suitable language to run the needling training smoothly; the language text system is consistent with the audio system.

4.2.2 Accurate Needling Training

In the needling training scene, firstly, the animation and introduction will be shown in the virtual environment. Figures 4-7, 4-8, 4-9. Secondly, the user can run the acupuncture training followed by the hint animation of acupoint. Figure 4-10. Also, the real-time feedback of needling will be shown on the Canvas in the virtual environment. Figures 4-11, 4-12, 4-13, 4-14.

Figure 4-7 The introduction of acupuncture training centre.

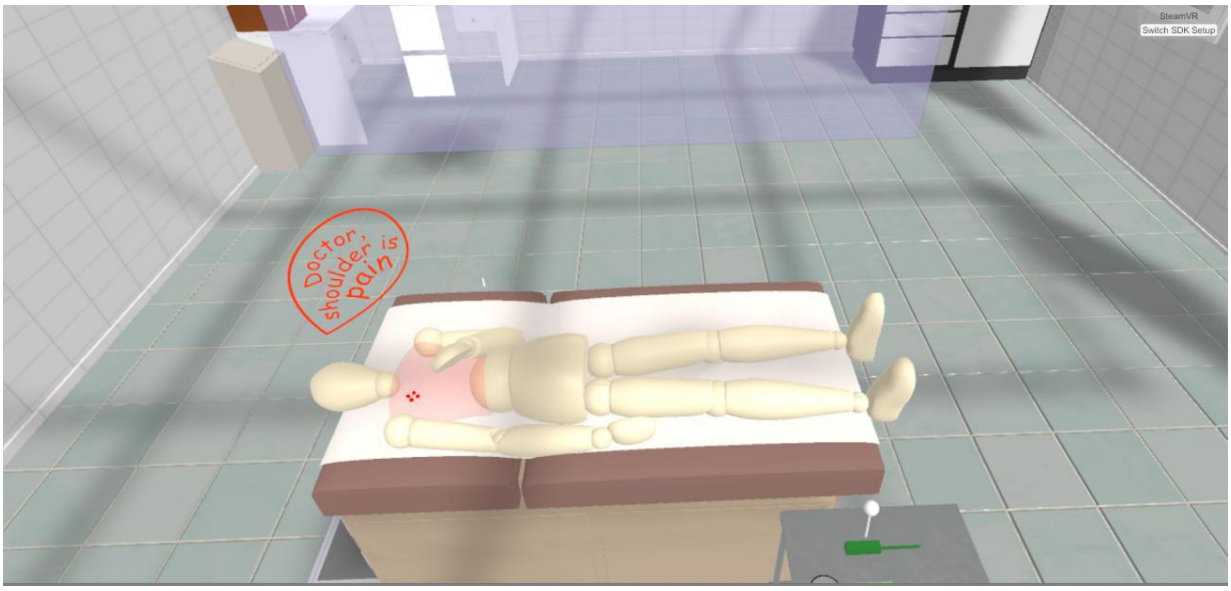


Figure 4-8 The animation of the disease.

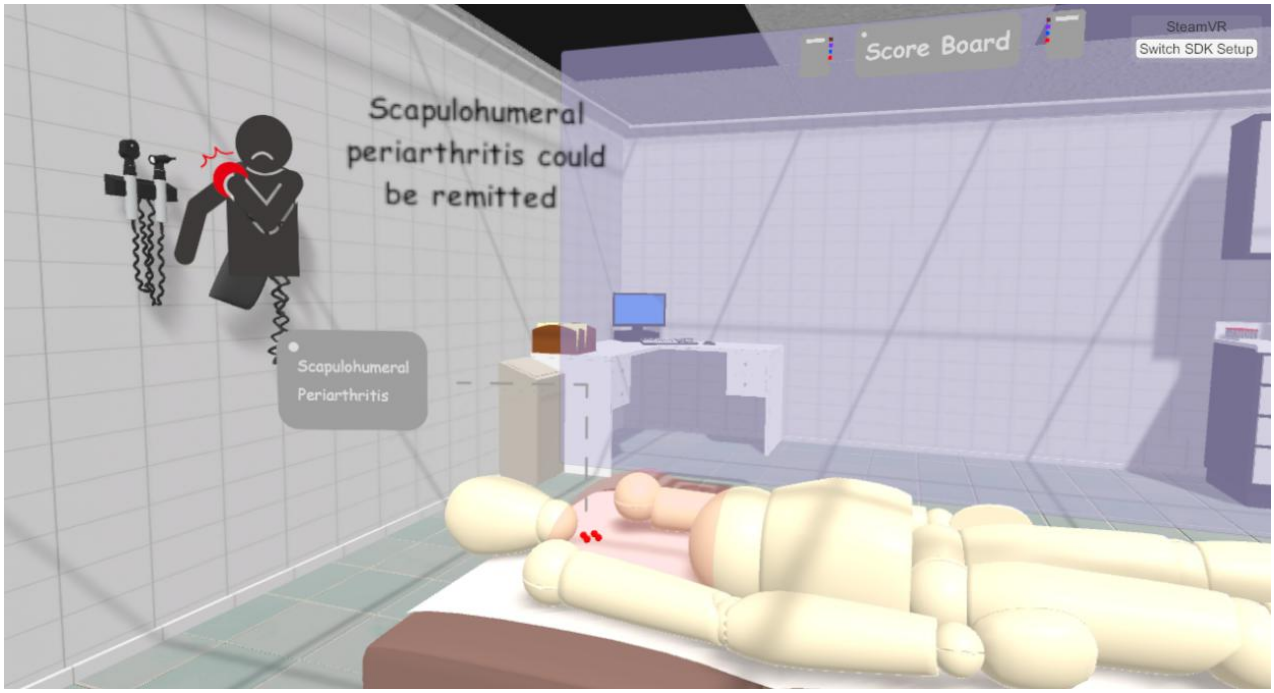


Figure 4-9 The introduction of the disease.

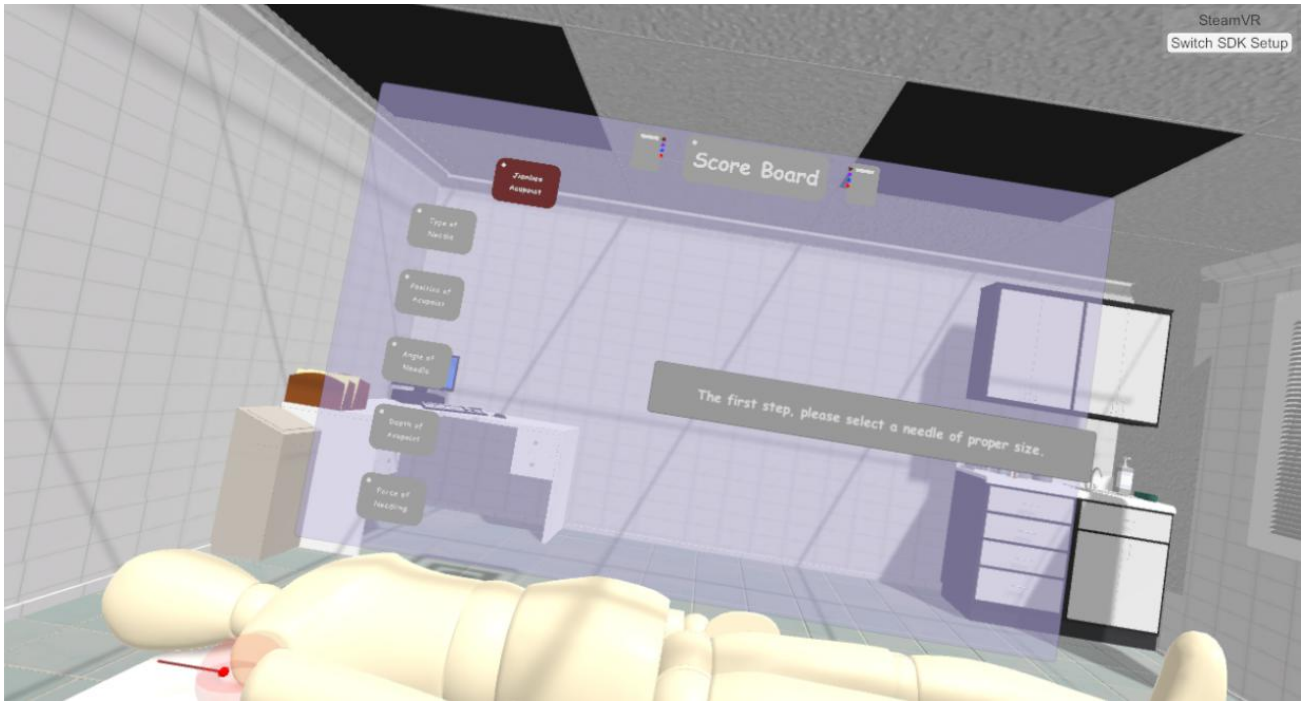


Figure 4-10 The hint animation of the acupoint.

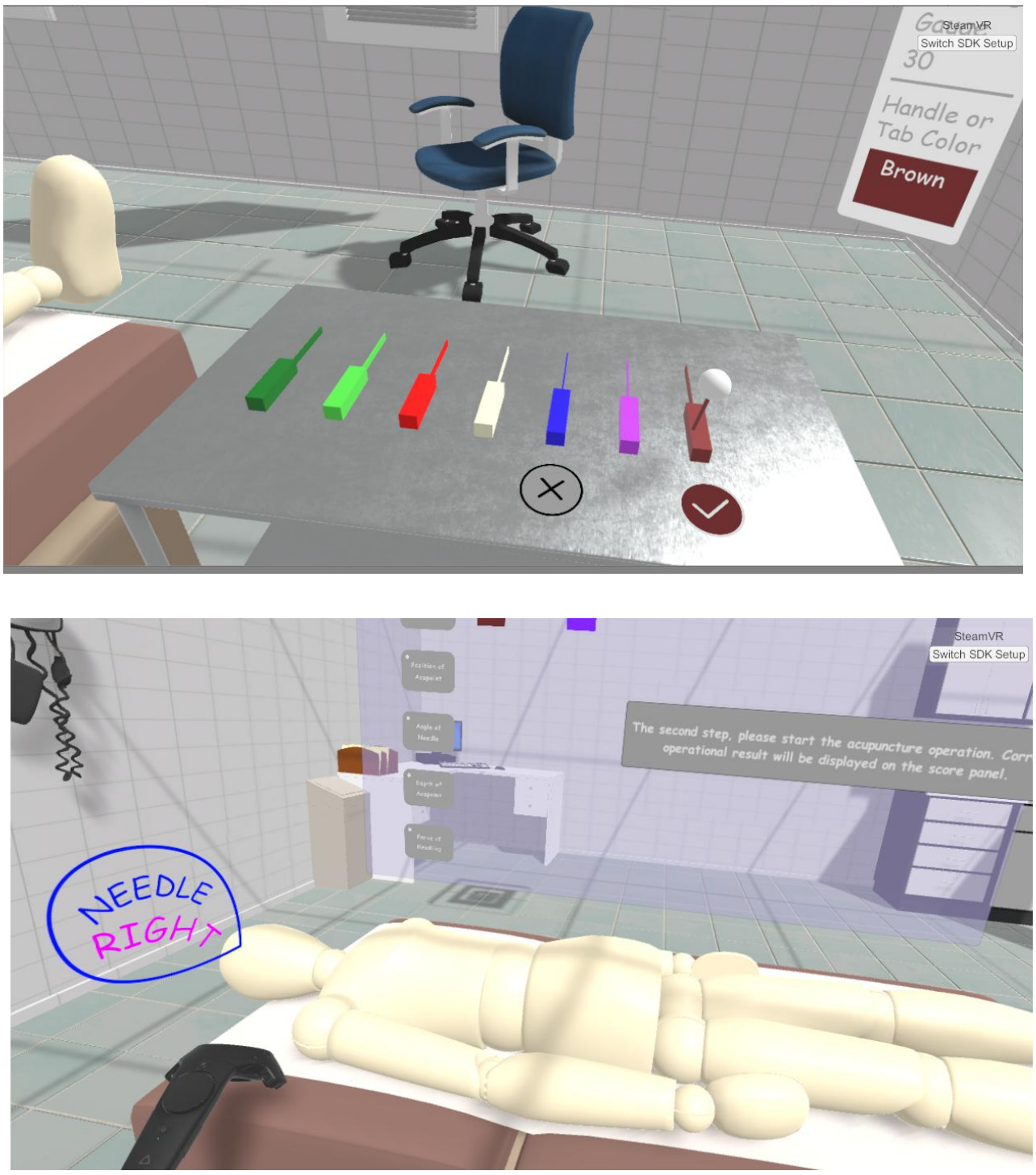


Figure 4-11 The choosing needle operation and feedback.

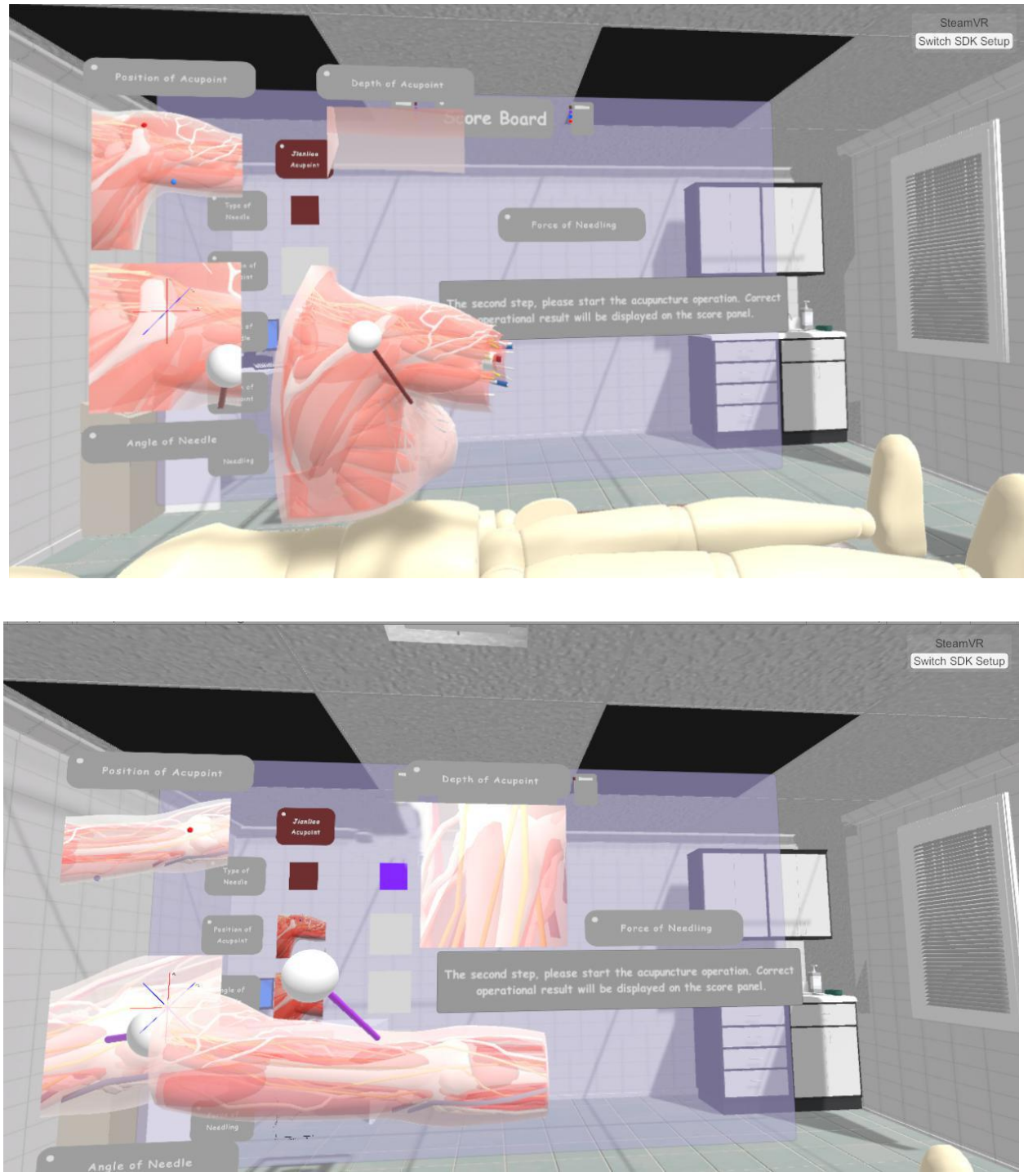


Figure 4-12 The concurrent operation and feedback about the needling

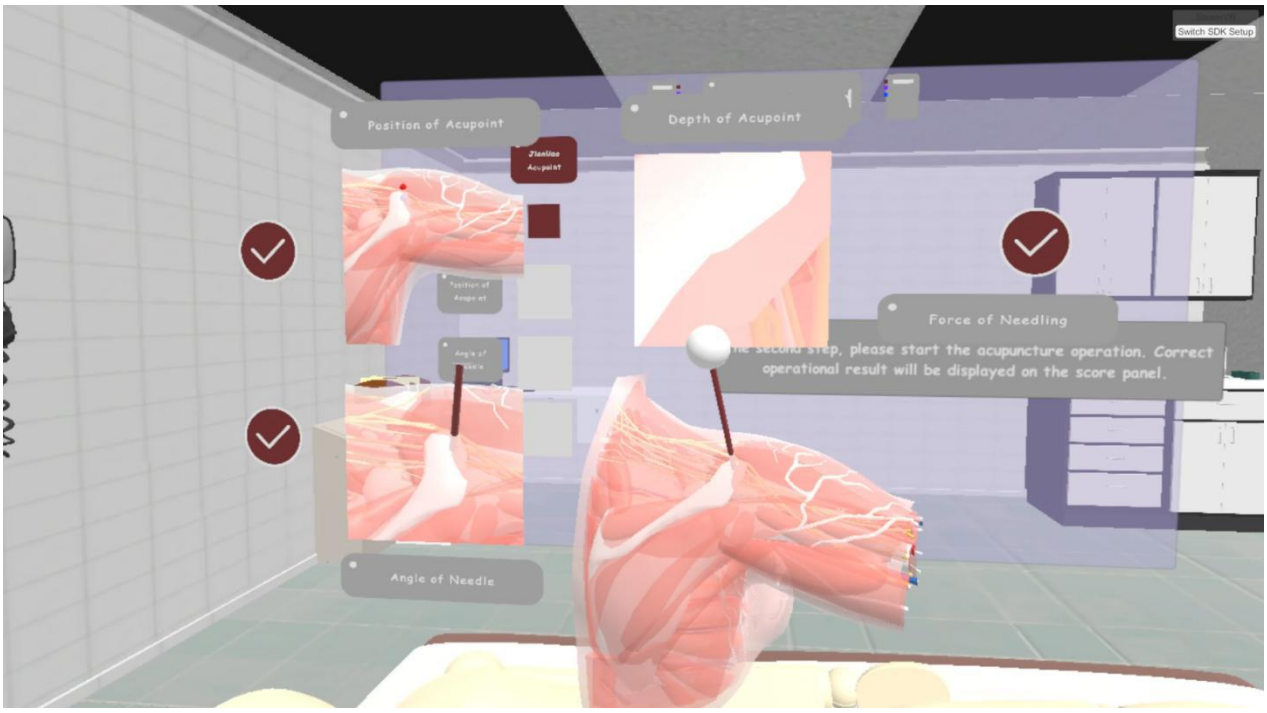


Figure 4-13 The real-time judgment with the operation (right label)

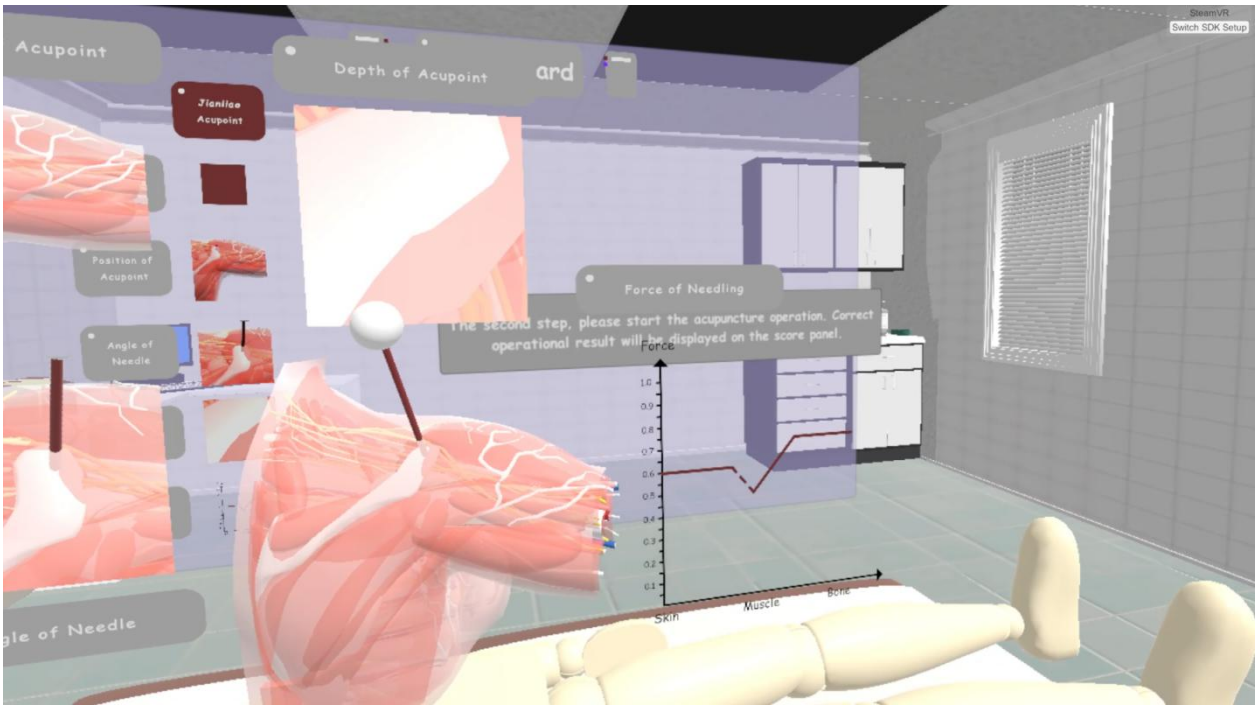
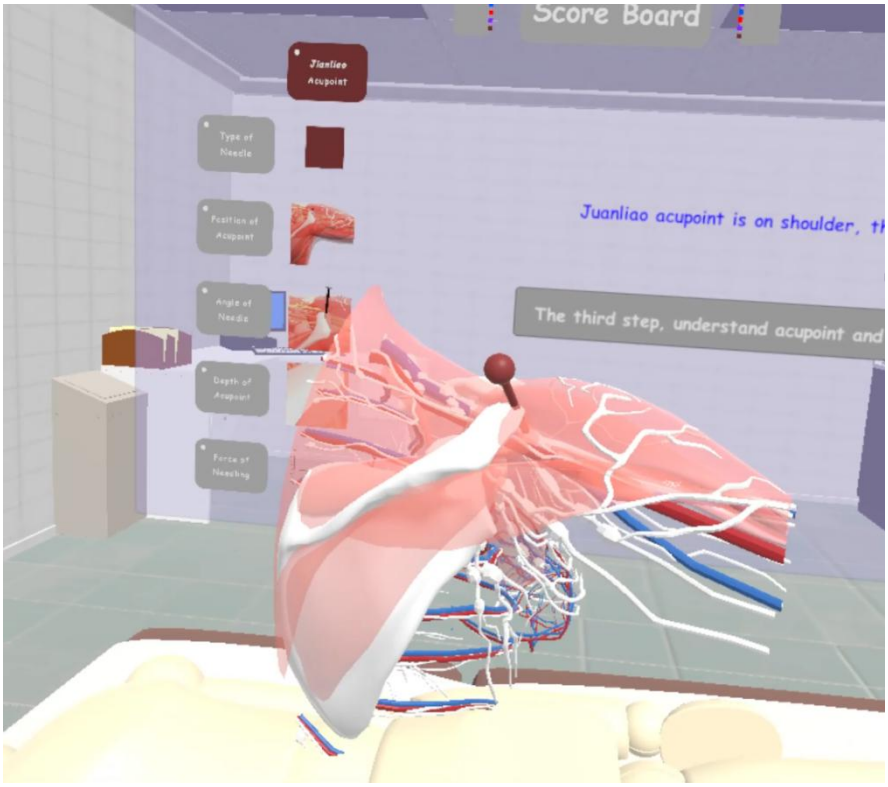


Figure 4-14 The force chart of the needling.

4.2.3 Terminal Needling Results

The user can record the needling result, when he or she achieves the total right labels, by pressing the Button2 on the haptic device. And the results will be shown on the scoreboard. Figure 4-15. Moreover, the anatomical animation will be shown to tell the user the correct operation and the relationship between the anatomy and acupuncture. Figure 4-16. After that, the user will see the running of the main meridian channels to remit the disease. Figure 4-17. Finally, the user can send the terminal results to the professional acupuncturist to get the expert evaluation and feedback. Figure 4-18.

Figure 4-15 The terminal results are shown on the scoreboard.



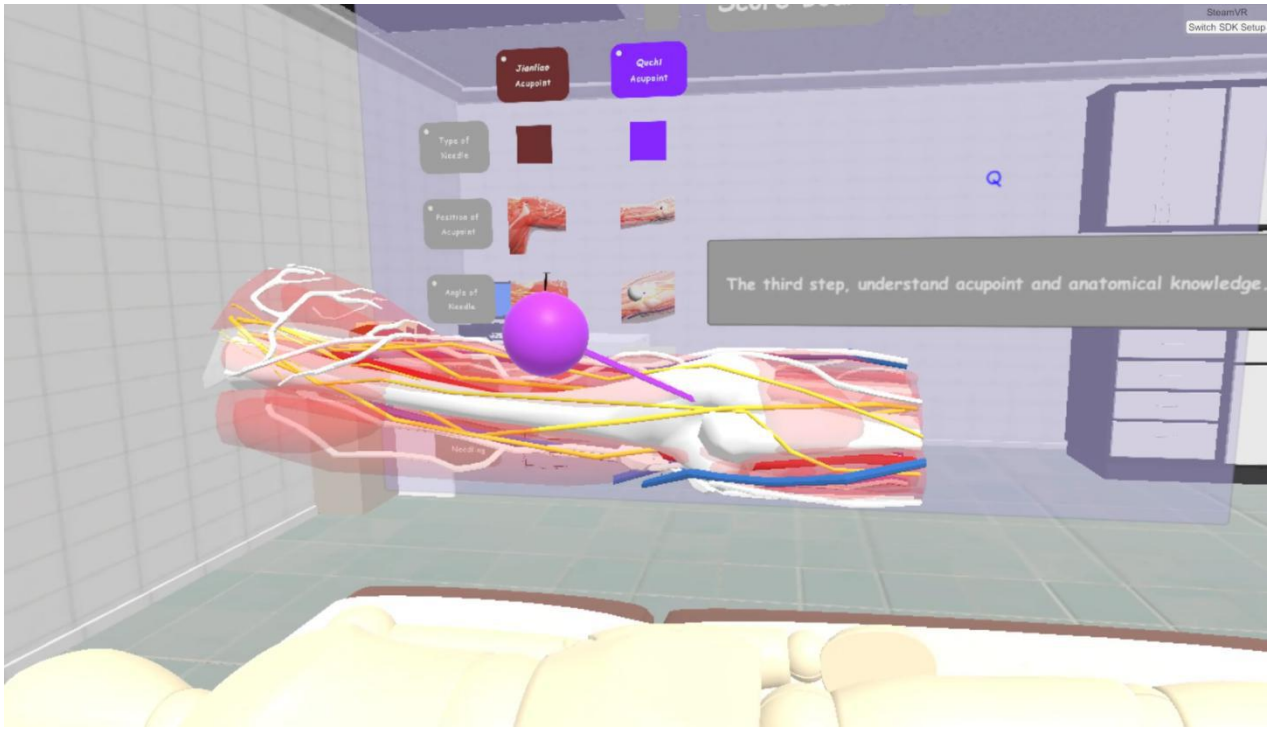


Figure 4-16 The correct needling and anatomical animation.

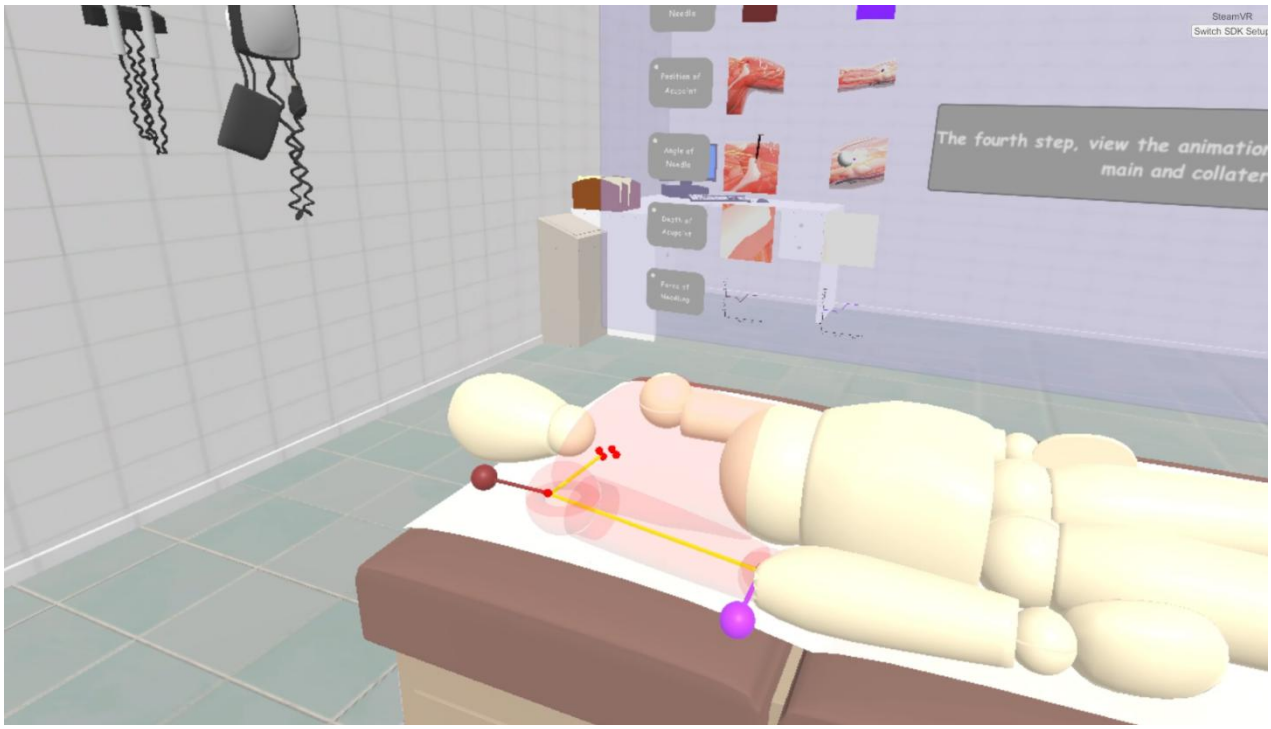


Figure 4-17 The main meridian channels to remit the disease.

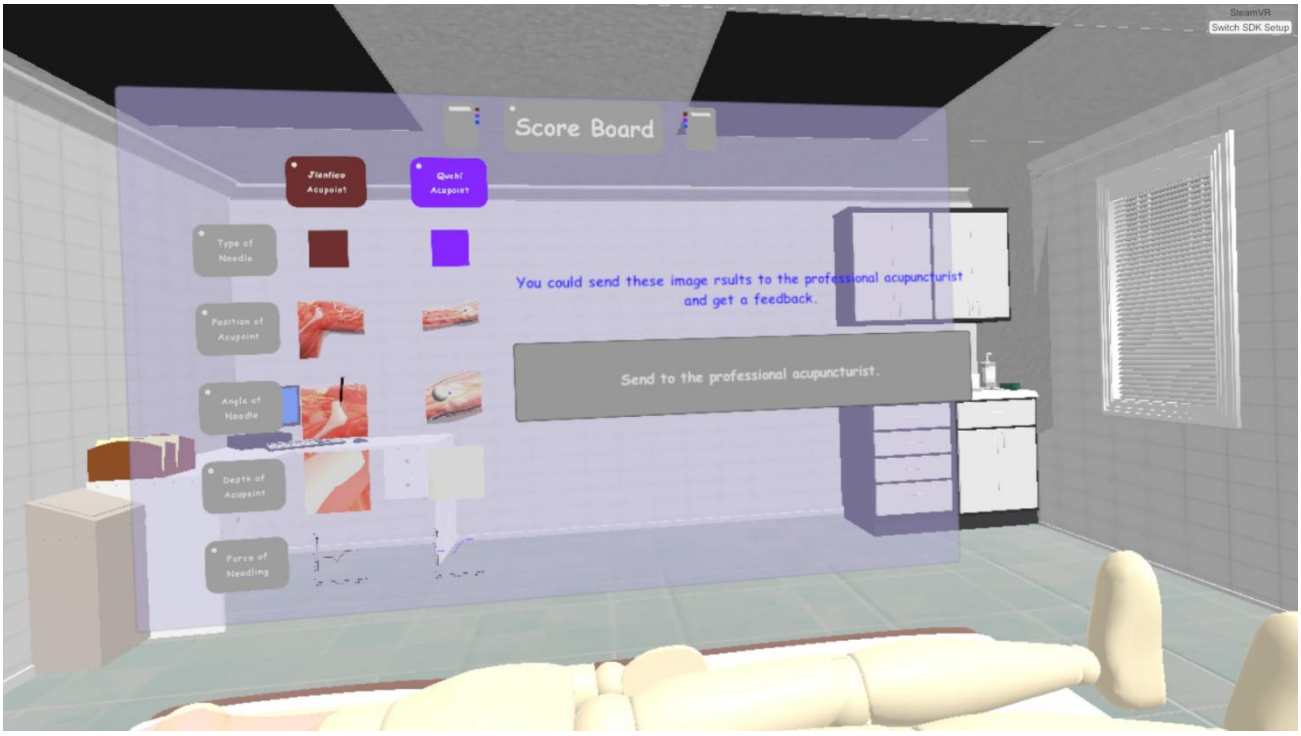


Figure 4-18 Send the terminal images to the professional acupuncturist.

4.2.4 Acupuncture and Anatomy Learning

The user can learn the knowledge of acupuncture and anatomy by the introduction interface (Chapter 4.2.1), the audio tip (Figure 4-19), the acupoint hint (Chapter 4.2.2 Figure 4-10), the anatomical animation(Chapter 4.2.3 Figure 4-16) and the running of main meridian channels (Chapter 4.2.3 Figure 4-17).

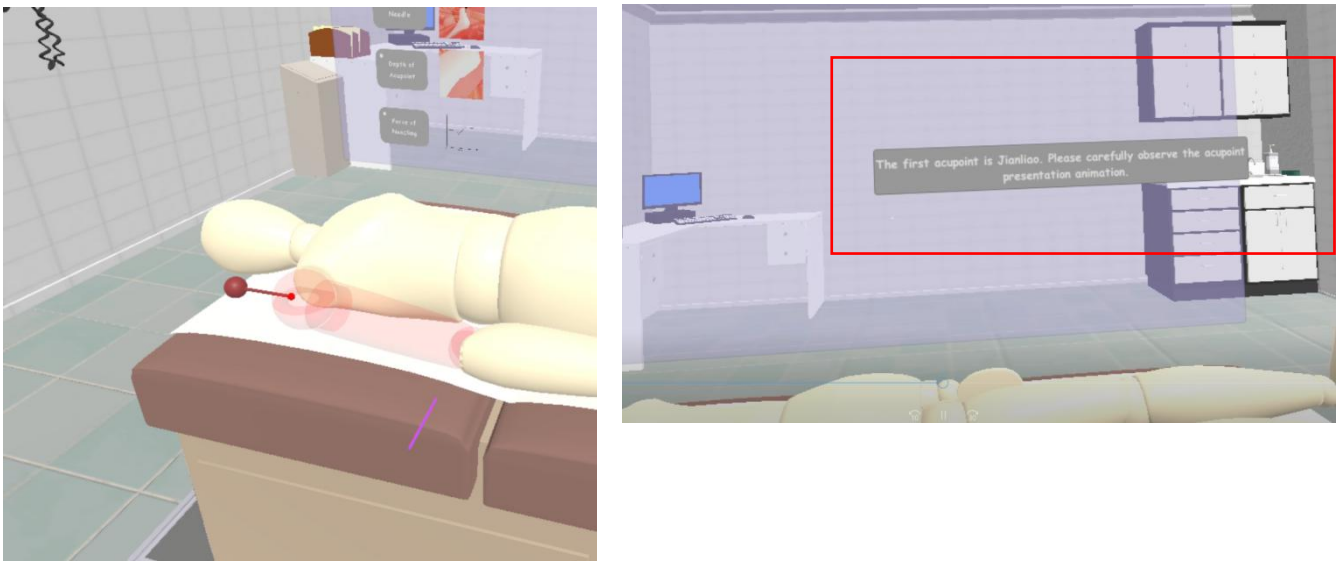


Figure 4-19 The audio tip of the steps in the acupuncture training.

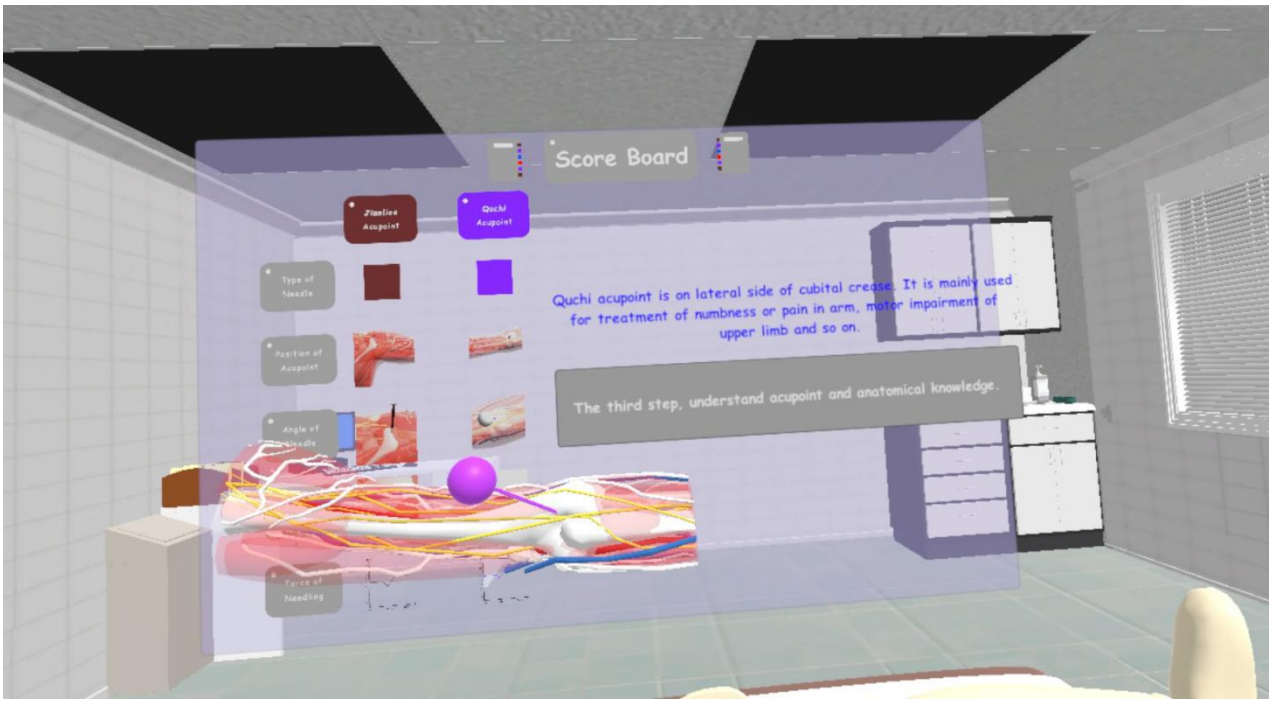
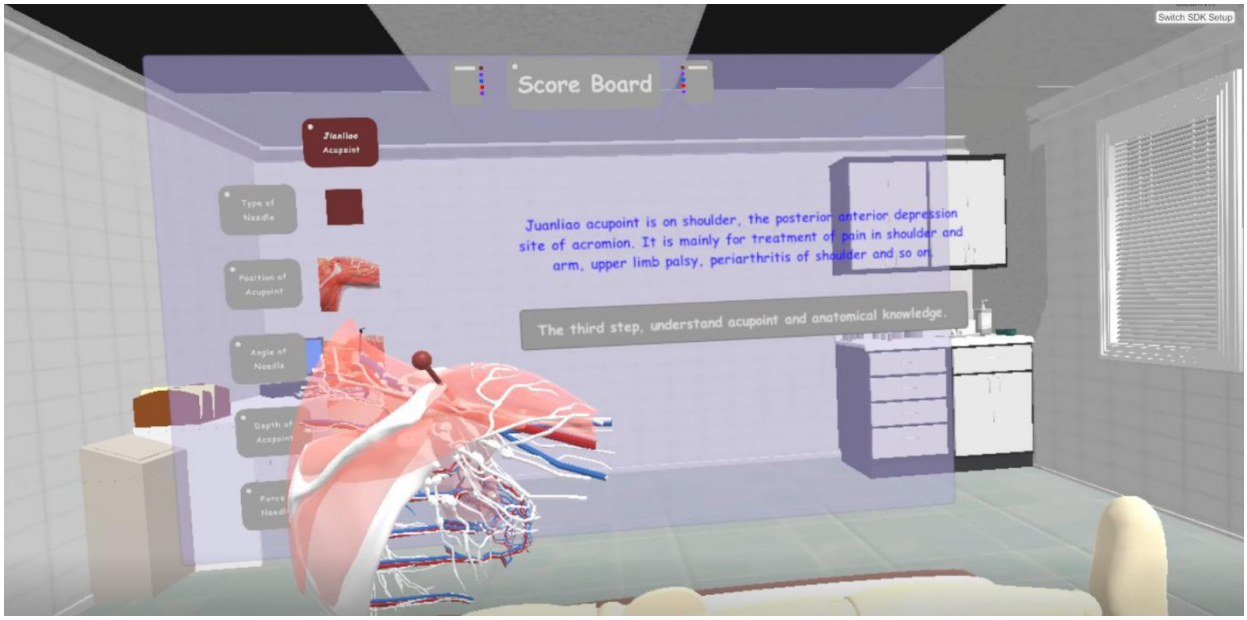


Figure 4-19-1 The audio tip of the introduction of the acupoint.

4.2.5 Languages System

The user can choose a suitable language to do the training. Figures 4-20, 4-21.



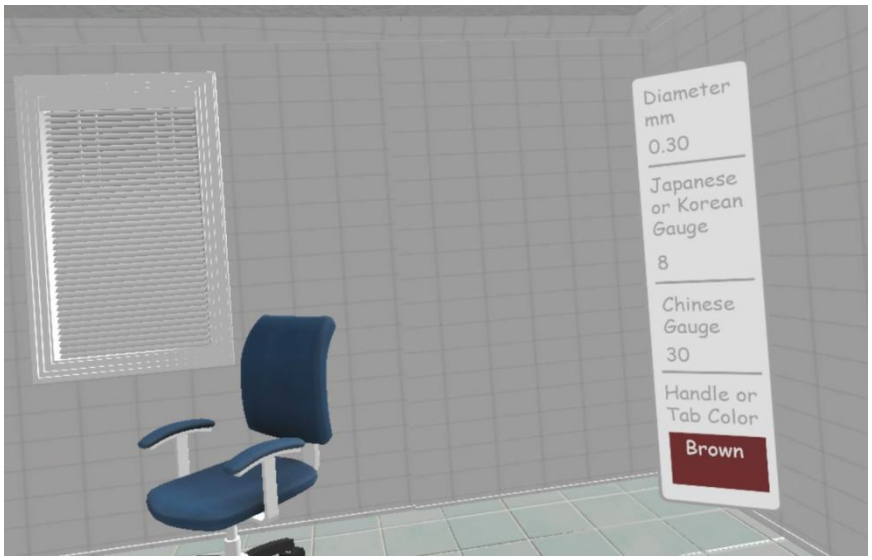


Figure 4- 20 The English System

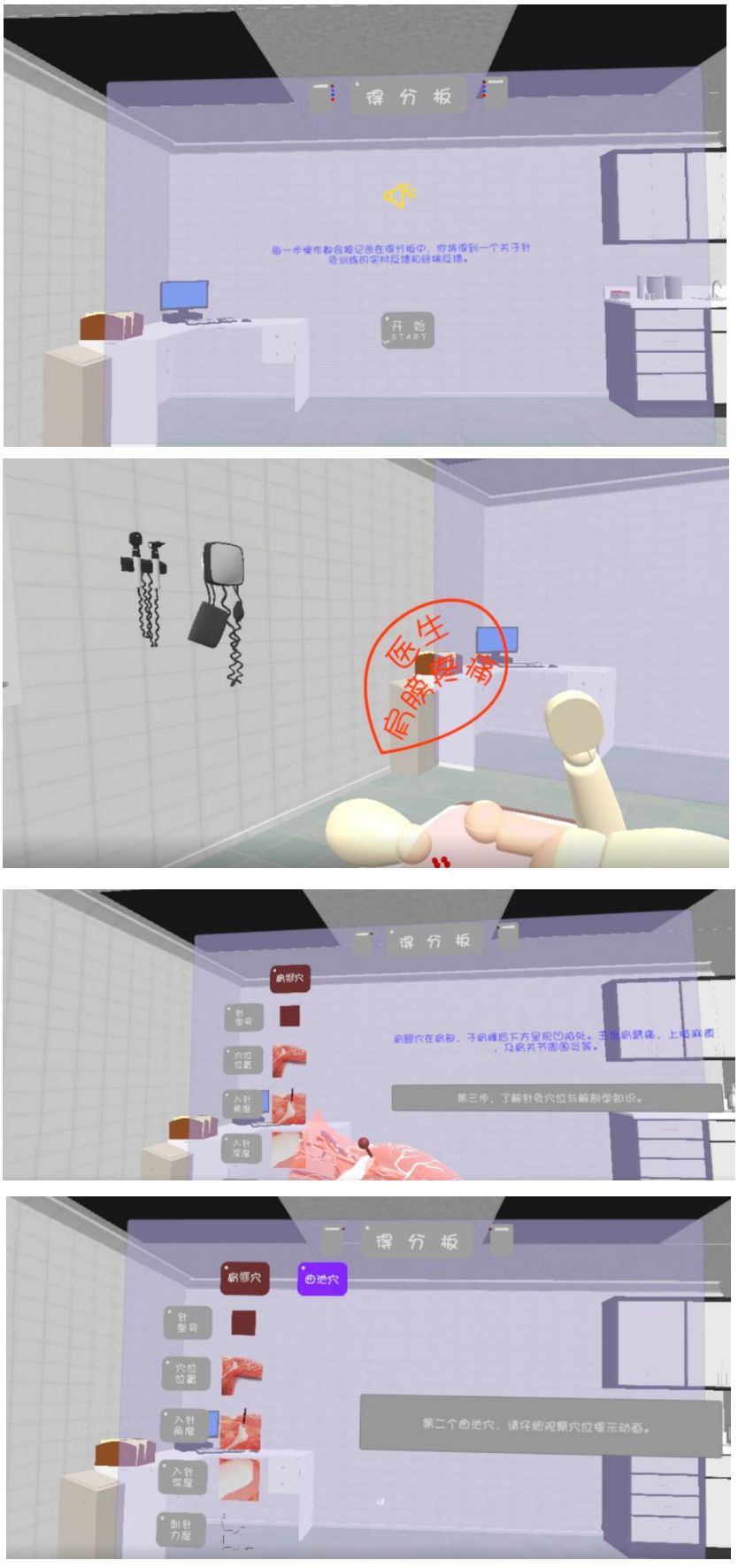


Figure 4- 21 The Chinese System

5 Evaluation

5.1 Introduction

It is necessary to test the application with the two groups of participants to access the usefulness and integrity of the feedback platform in the acupuncture. Participants will operate the whole application through HTC Vive and the haptic device. The initial hypothesis for testing is expecting the accurate acupuncture feedback can be achieved and the knowledge of acupuncture can be delivered. However, overall the application should be received well by all participants with the minor calibration to make the app more professional and competent.

5.2 Methods

5.2.1 Participants

A total of 10 people took part in the testing, eight students, and two acupuncturists. Two groups of participants were defined. The first group was composed of GSA students from the various courses. The second group was professional acupuncturists from the acupuncture stores in the UK. The acupuncturists would calibrate the parameter of haptics to make the haptic feedback realistically, and they completed questionnaires. It was worth highlighting that students paid more attention to the understanding and learning the knowledge of acupuncture, and the professional acupuncturists took part in the calibration of the haptic properties.

5.2.2 Experimental Set-up

The testing used the HTC Vive, Phantom Omni, and the suitable PC. During the experiment, the participants were sitting at the desk and wore the VR headset to connect with the virtual environment. Also, the haptic device was used to test the force feedback. Figure 5-1 The testing situation.

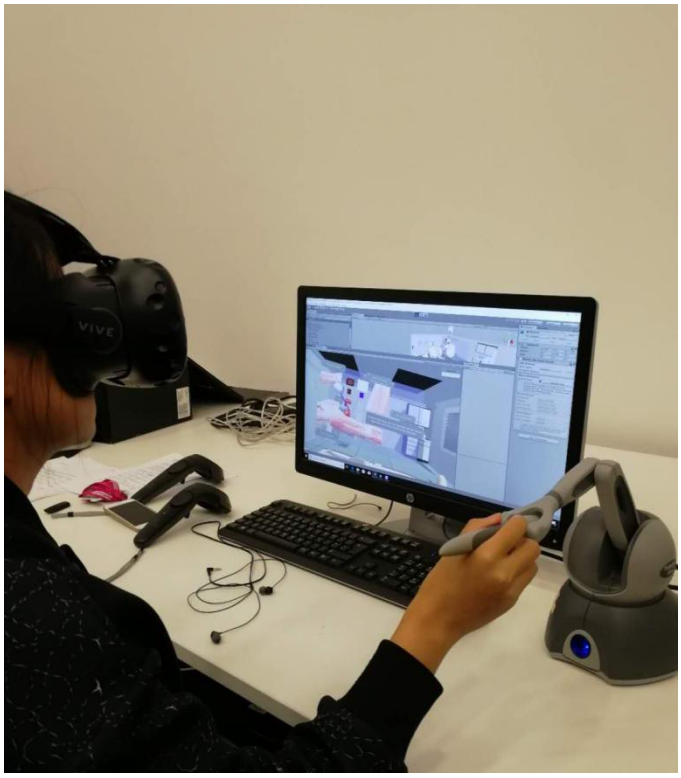


Figure 5-1 The testing situation

5.2.3 Procedures

5.2.3.1 Testing by the Professional Acupuncturist

Two professional acupuncturists were from the acupuncture stores in the UK, Shizhen Chinese Medicine Store and Chinese Medicine Centre 2000.

Firstly, the acupuncturist was placed in front of the PC with the VR headset and the haptic device positioned on the desk in front of them. At the beginning of the application, they watched the introduction animation to analysis the validity of the

information.

Secondly, entering into the acupuncture training centre, the information of the real-time training feedback was measured carefully.

Thirdly, the acupuncturist was asked to analyze the validity about the acupoint hint information and the anatomical animation. The acupuncturist would test the application from the professional, accurate and available angle to analysis the advantage and disadvantage of the application.

Finally, the acupuncturists would calibrate the haptic feedback in the acupuncture training. So they would help the application become more realistic and accurate.

5.2.3.2 Testing by the GSA Students

Universal testing aimed to evaluate the stability and usefulness of the application as the users did not have the previous acupuncture knowledge. Multi-angle evaluations would be obtained because the testing students were from the various courses in GSA. The users could do the review of the total application expression, delivering the knowledge of acupuncture, as well as what the students think could be developed into the application.

The students were also the essential participants in the testing because the application had an aim to deliver the knowledge of acupuncture to the next generation. Exploring the methods for spreading the acupuncture knowledge is meaningful.

5.2.3.3 Data Analysis

After testing the application, questionnaires were implemented by students and acupuncturists. Students were given the standard survey, and the acupuncturists had the professional one (as seen in Appendix 1).

Also, the questionnaire outcomes and data analysis were illustrated clearly in Chapter 5.3.2

5.3 Results

5.3.1 Calibration

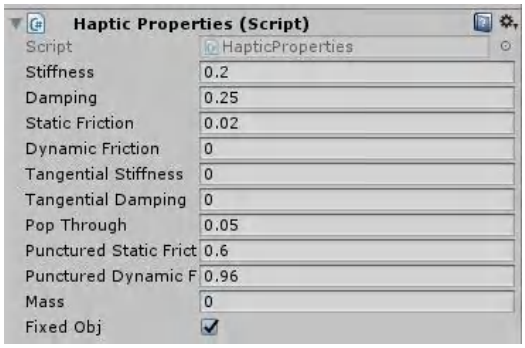


Figure 5-2 The needling feedback force across the skin.

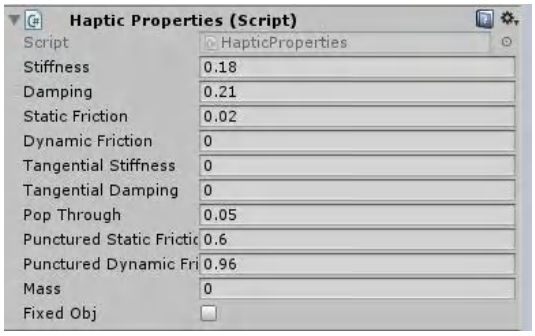


Figure 5-3 The needling feedback force across the muscle.

Above figures show the calibration of haptic properties, which adjusted by the acupuncturists.

5.3.2 Questionnaire Outcomes and Data Analysis

Firstly, the following charts show the students' understanding of acupuncture in standard questionnaires for GSA students. Charts 5-1, 5-2, 5-3, 5-4.

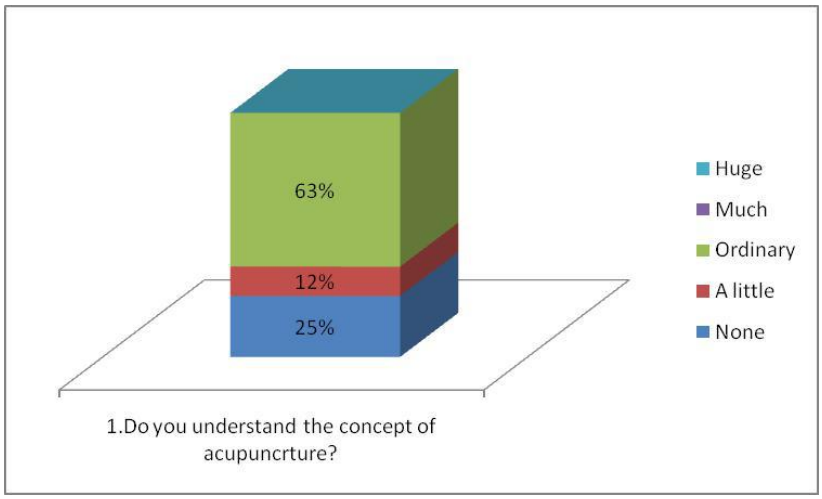


Chart 5-1 The understanding of the concept about the acupuncture for students.

The chart shows the students' original understanding of the acupuncture, and the most students have the collective knowledge about the acupuncture. However, they do not have the specific relevant understanding about acupuncture.

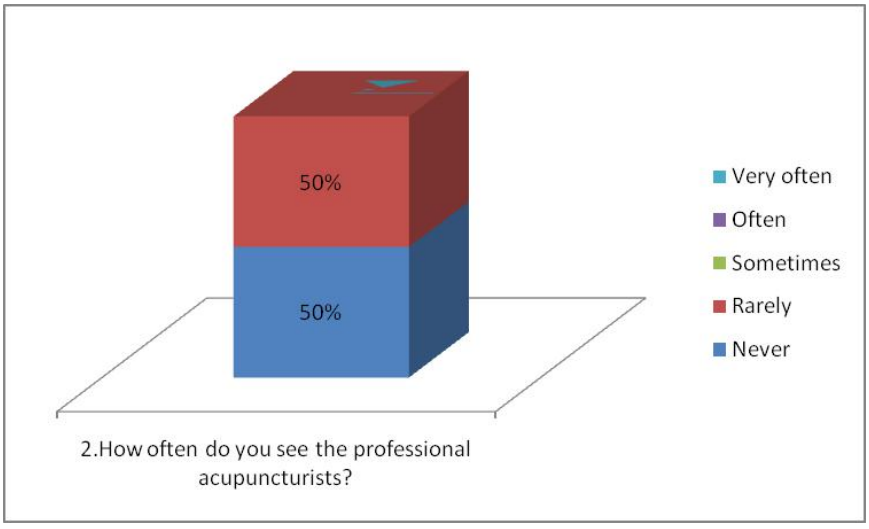


Chart 5-2 The frequency of seeing the professional acupuncturist.

The chart shows the frequency of seeing the professional acupuncturist. It shows that acupuncture is an unpopular method for the young generation to do the treatment or health-care.

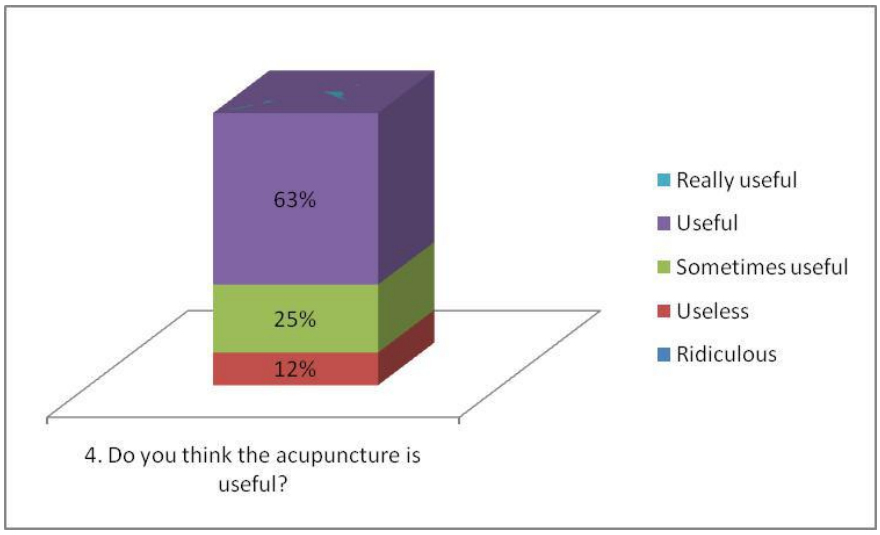


Chart 5-3 The reliability of the acupuncture.

The chart shows more than half students still think the acupuncture is useful. It means in the young generation, although they do not choose the acupuncture to do treatment, they still have the attitude of trust to the ancient art.

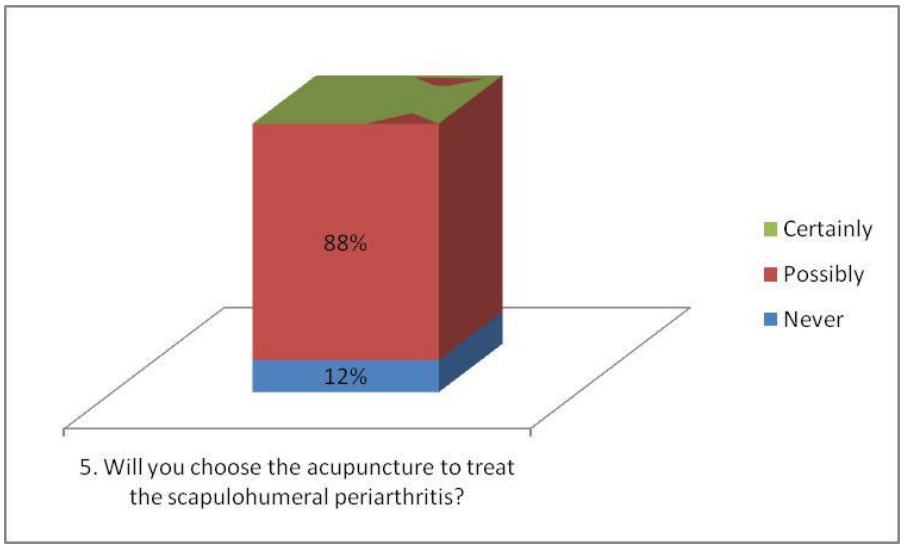


Chart 5-4 Choose the acupuncture to treat the scapulohumeral periarthritis.

The chart shows a significant proportion of students will choose the acupuncture to treat the scapulohumeral periarthritis. It means they believe acupuncture will relieve periarthritis of the shoulder.

Overall, the series of questions are prepared for the students, and it is a survey about the understanding of the acupuncture in the young generation. Most students have the curiosity about the knowledge of acupuncture and believe acupuncture has been used to alleviate certain diseases and do health-care.

Secondly, about understanding the knowledge of acupuncture in the application, it has three levels of comments. Table 5-1. Different numbers represent different levels of comments.

No	Not clearly	Yes
1	2	3

Table 5-1 Different levels of comments about the understanding of acupuncture knowledge in the application.

First of all, according to the responses from GSA students, Table 5-2 shows the results from eight students about the learning elements in the application.

A	B	C	D	E	F	G	H	I
	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
1	1	2	2	1	3	3	3	2
2	3	3	3	2	1	3	2	2
3	2	3	3	3	1	2	2	3
4	3	3	2	3	3	2	2	2
5	2	3	3	2	2	3	3	2
6	3	3	2	3	3	2	2	3
7	3	3	3	3	2	3	3	2
8	3	3	2	3	2	2	3	2
Average	2.5	2.875	2.5	2.5	2.125	2.5	2.5	2.25
STD	0.755929	0.353553	0.534522	0.755929	0.834523	0.534522	0.534522	0.46291

Table 5-2 The data statistics for the understanding of the knowledge in acupuncture from eight students.

Also, Chart 5-5 represents the mean values and standard deviation error bars for these eight questions which asked the participants to rate the learning results about the knowledge of acupuncture in the application.

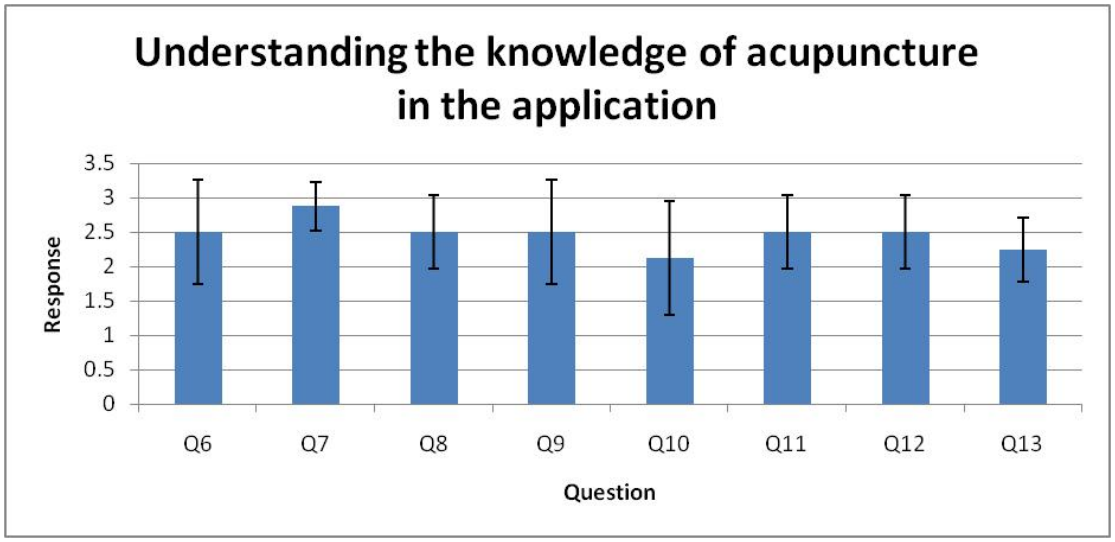


Chart 5-5 Mean value and error bars for questions testing the learning outcomes about the knowledge of acupuncture from eight students.

Moreover, Table 5-3 and Chart 5-6 show the results of the learning outcomes of the knowledge in acupuncture from the acupuncturists.

	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
1	2	3	3	2	2	3	3	2
2	3	3	2	3	2	3	3	3
Average	2.5	3	2.5	2.5	2	3	3	2.5
STD	0.707107	0	0.707107	0.707107	0.57735	0	0	0.707107

Table 5-3 The data statistics for the understanding of the knowledge in acupuncture from two acupuncturists.

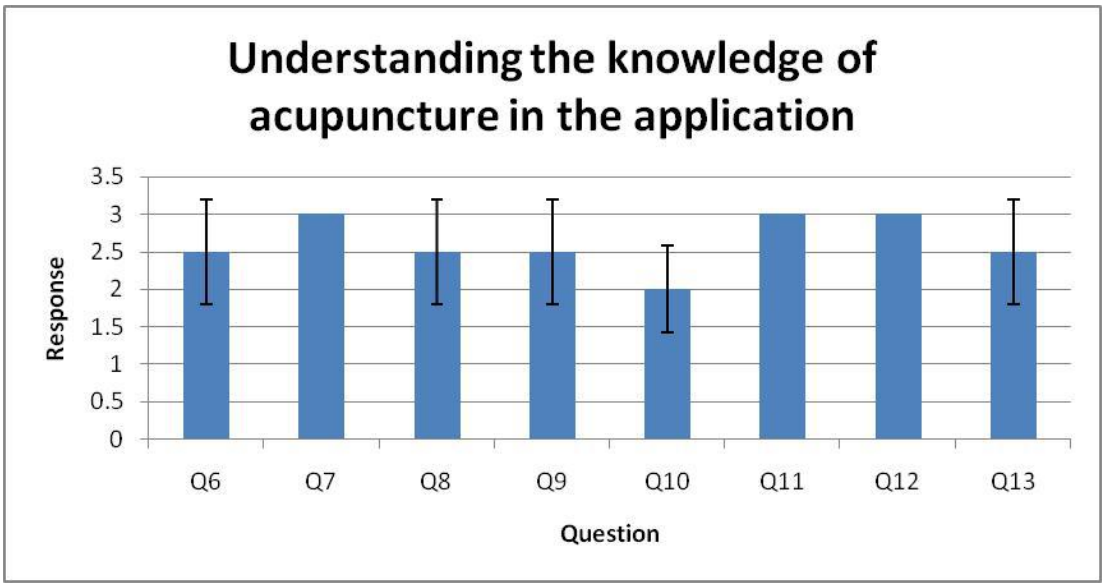


Chart 5-6 Mean value and error bars for questions testing the learning outcomes about the knowledge of acupuncture from two acupuncturists.

From these charts, participants comment the application can deliver the knowledge of acupuncture, except the effect of each acupoint (Question 10) is not very clear in the learning.

Thirdly, participants test the effective learning feedback of the acupuncture.

In the chart, the number indicates the different level of agreement. Table 5-4

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Table 5-4 shows the number means different level of agreement.

In this part, eight students implement the standard questionnaires (Questions 14-21), and the acupuncturists are asked the professional surveys (Question 14-23). Table 5-5 shows the data analysis of the accurate feedback system of acupuncture training from the total participants. Chart 5-7 shows the mean value and error bars about the participants' comments.

	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23
1	3	3	2	3	3	5	3	3		
2	5	3	3	3	3	4	3	4		
3	4	2	2	2	3	3	2	4		
4	5	4	3	2	2	4	4	4		
5	4	4	2	2	3	4	4	4		
6	4	4	2	3	2	4	4	5		
7	4	3	3	3	3	4	3	4		
8	4	4	3	3	2	4	4	5		
9_expert	5	4	3	2	3	4	4	4	4	4
10_expert	4	4	3	3	3	5	4	4	3	4
Average	4.2	3.5	2.6	2.6	2.7	4.1	3.5	4.1	3.5	4
STD	0.632456	0.707107	0.516398	0.516398	0.483046	0.567646	0.707107	0.567646	0.707107	0

Table 5-5 The data analysis of the accurate feedback system.

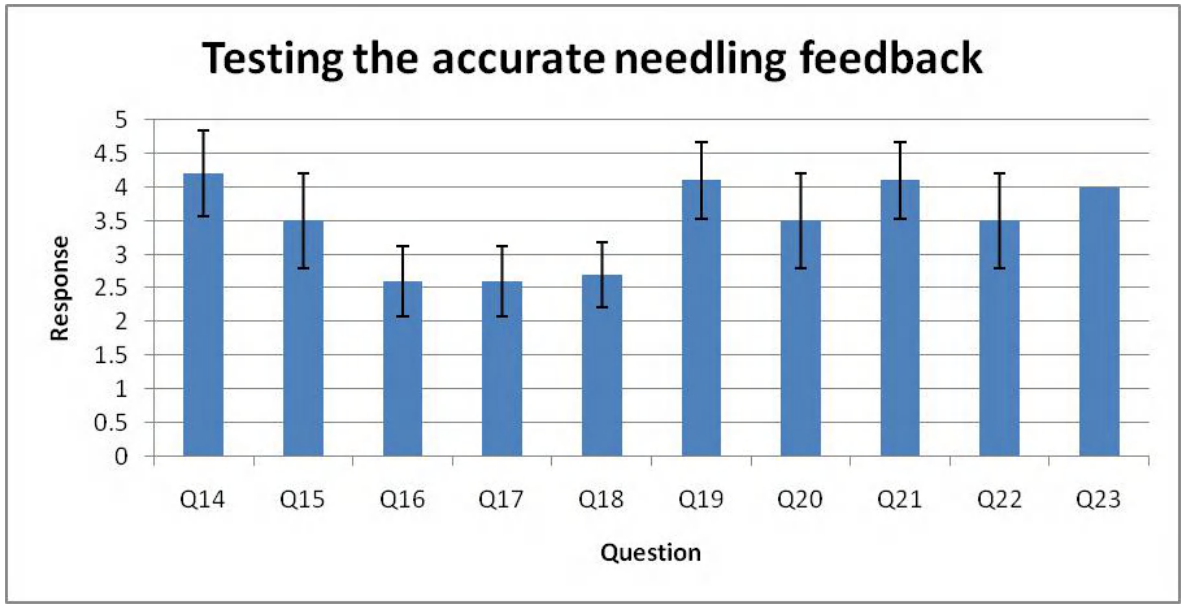


Chart 5-7 Mean value and error bars about the comments of needling feedback system.

According to the above charts, the information feedback about the weakness of the feedback in the angel of needling (Q 16), the depth of needling (Q17) and the force of needling (Q 18). In the Q16, $\bar{\mathbf{x}}$ = 2.6, $\boldsymbol{\sigma}$ = 0.51; in the Q17, $\bar{\mathbf{x}}$ = 2.6, $\boldsymbol{\sigma}$ = 0.51; in the Q18, $\bar{\mathbf{x}}$ = 2.7, $\boldsymbol{\sigma}$ = 0.48. It means in these three aspects, and the comments level is in the middle. Calibration of the feedback system is essential in the further development.

Fourthly, participants evaluate the immersion and visualisation in the virtual environment (Questions 22-26 in students' questionnaires or Questions 24-28 in acupuncturists' questionnaires).

	Q22	Q23	Q24	Q25	Q26
1	3	2	3	5	2
2	3	4	4	4	3
3	4	4	3	5	2
4	4	2	3	5	3
5	3	4	4	4	4
6	3	4	3	4	2
7	3	2	5	4	3
8	4	3	3	4	4
9_expert	4	3	3	5	3
10_expert	4	4	4	4	4
Average	3.5	3.2	3.5	4.4	3
STD	0.527046	0.918937	0.707107	0.516398	0.816497

Table 5-6 The data statistics about the comments in the feeling of the virtual environment.

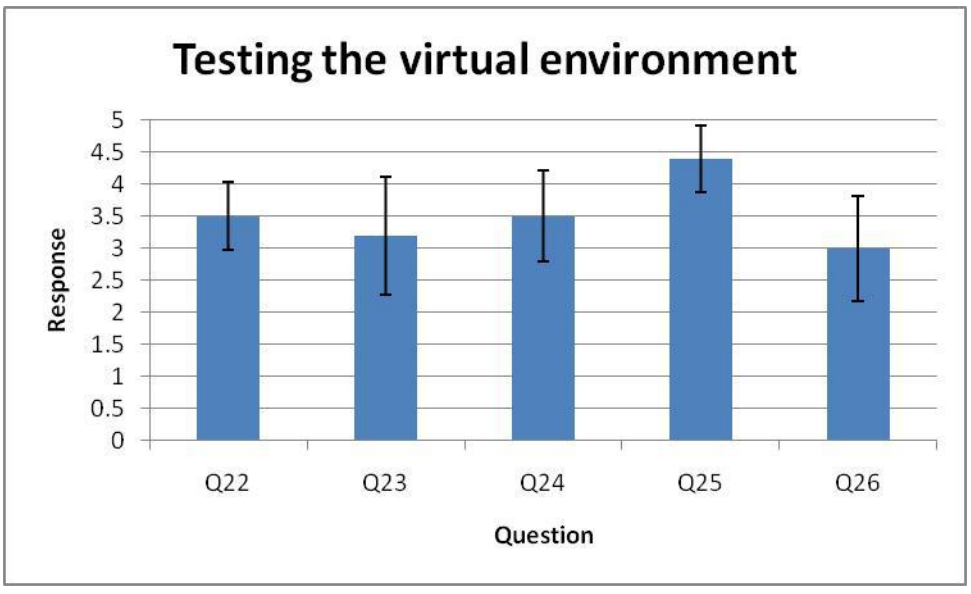


Chart 5-8 Mean value and error bars about the comments of immersion and visualization.

Fifthly, the evaluation of the application from participants (Questions 27-29 in students' questionnaires or Questions 29-31 in acupuncturists' questionnaires).

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	Q27	Q28	Q29
1	4	3	4
2	5	4	4
3	4	3	5
4	5	4	5
5	5	4	5
6	4	4	4
7	5	4	5
8	5	3	5
9_expert	4	4	5
10_expert	5	4	5
Average	4.6	3.7	4.7
STD	0.516398	0.483046	0.483046

Table 5-7 The data statistics about the comments of the application.

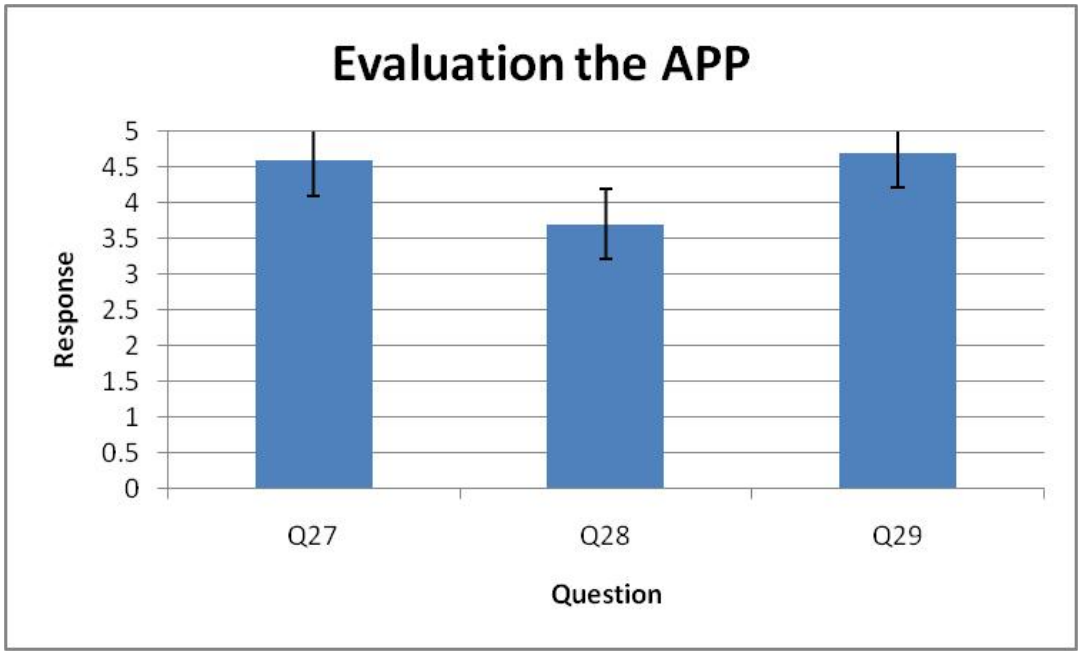

Chart 5-9 Mean value and error bars about the comments of the application.

5.3.3 Results of Evaluation

The vital purpose of testing the application is inviting the professional acupuncturists to provide the practical feedback from the experienced operation. Making an accurate acupuncture feedback platform is the topic of the application. Thus the precision of the realistic feedback in acupuncture is the essential requirement.

From the testing and data analysis, the results of the evaluation can be shown the below.

1. For the young students, acupuncture is an unfamiliar field, the most of them never went to see the professional acupuncturists before, and they did not understand the knowledge of acupuncture, thus, in this situation, delivering the understanding of acupuncture to the youth is a subject worth exploring.

2. Form the Charts 5-10 and 5-12, participants comment that the application can help them learn the knowledge of acupuncture in the process of operation, but the detailed knowledge is not highlighted and transparent, such as the effect of each acupoint (`x = 2, σ = 0.57).

3. In the testing of the accuracy of acupuncture feedback, acupuncturists rate the method of standardizing feedback highly. However, the precision needs to calibrate further.

4. The interaction in the virtual environment and the usefulness of the application have a favorable reception (Q25 `x =4.4 , σ = 0.51, Q28 `x = 3.7, σ = 0.48). Also, all participants comment the application is a breakthrough in the method of learning and training acupuncture (Q29 `x = 4.7, σ = 0.48).

5.4 Conclusion of Evaluation

Firstly, the acupuncturists have already refined the parameter of haptic device close to the practical needling. However, due to a large amount of variation between every patient, it is hard to set the feedback parameter accurately. In other words, the accurate feedback for each step of needling is impossible.

Secondly, the information about acupuncture and anatomy will be checked to deliver the rationale and knowledge of acupuncture effectively and correctly by the acupuncturists.

Thirdly, the students evaluate the application as an appropriate learning tool. It can spread the information and theory of acupuncture to the young generation logically and visually. Nearly every participant thinks the APP is a new teaching attempt to explore transmitting the acupuncture and exercising the needling. However, the weakness of the application is also mentioned in the testing, such as the occlusion problem between multiple interfaces.

To conclude, the acupuncturists comment that the application can be adapted to beginning teaching for the acupuncture. It is an important method to make the beginner understand the position of acupoint and experience the haptic feedback. Moreover, the virtual training also can prepare the real professional needling. However, because the treatment of acupuncture is connecting with the patients' feeling strictly, the virtual needling training cannot replace the actual exercising.

6 Discussion and Conclusion

6.1 Discussions

6.1.1 Discussion of Development Process

The process of developing the application has a most successful outcome. Overall, the development process can be divided into the following steps.

1. Set the acupuncture topic, and draw the storyboard to do the brainstorm. It is a useful method to make the design idea logically.

2. Functional designing. The application needs to be implemented by various functions. In the project, the primary functions are achieving the interaction in the virtual environment and learning to understand and script the Haptic Plugin.

3. Make the prototype of the application. The prototype includes establishing the virtual environment and scripting the interaction and functions.

4. Combine the HTC Vive and haptic device to develop the application further.

Furthermore, some questions are still confused me in the development, firstly, the haptic camera and VR camera cannot arrange synchronously, so the virtual environment sometimes will change and rotate the position. It means if I turn a PC to run the application, I will re-fix the total environment again possibly. Secondly, the controller of HTC Vive and the haptic device need to be used in the same application, and sometimes when the user immerses in the virtual environment, he or she can not find the haptic device through the VR headset. These are the hardware and developing problems, which can be improved in the future refinement.

6.1.2 Discussion of Immersion

Generally speaking, for immersion in the virtual environment, participants comment

that they feel present in the virtual environment. The acupuncturists also think the virtual environment can cultivate an ability of the hand-eye coordination, and the ability is essential for the medical students. Therefore, the immersion provides a potential method to train the students.

Moreover, the testers also find the audio system can help them immersing better - a method for establishing the training environment. The audio introduction can attract them to pay attention to the information in the process of training.

However, it still has some problems with the immersion. Firstly, the feedback system is the core function to make an accurate needling platform. The results of the concurrent and terminal feedback will be shown on Canvas, and it will generate the numerous interfaces. The multiple interacted interfaces can occlude the sight line of the testers partly. Therefore, the re-organizing of the interface in the virtual environment is a modified part of the application. Secondly, two participants meet the breaking off bug in the haptic plugin, that is the problem to break the immersion. The participants can not experience the application smoothly. Furthermore, the haptic device is lost in the virtual environment (when wearing the VR headset), it means changing the equipment from the controller to the haptics is difficult in the virtual environment.

6.1.3 Discussion of Potential for Learning

Overall, as a learning tool, the students and acupuncturists all think the application will aid their learning. It can be discussed in the following parts.

Firstly, considering the immersion of the virtual environment, it will help the user establish a visualization learning environment. The user will be like to reflect in the realistic setting and experience the training adequately. Besides, the user will experience the friendly and comfortable interaction in the virtual environment. The synthetic world is not static but responds to the user's input (gesture, verbal command, etc.). It defines a key feature of virtual reality, which is real-time interactivity (Grigore C. Burdea, 2003). In the application, the user can respond to the different inputs to achieve real-time interactivity. Furthermore, the environment also will provide an interacted feedback to the user, such as the animation about the result of choosing needles.

Secondly, all participants agreed the application can be used to deliver the knowledge of acupuncture and anatomy. On the one hand, the App will spread the knowledge to the students without significant foundation by the vivid and visual introduction video and the anatomical animation. On the other hand, the application explains the acupuncture knowledge, it is useful for the beginners of the acupuncture. The application can be used as a universal learning product, as well as a professional acupuncture training tool, because of the direct information communication and feedback.

Thirdly, combining with the virtual display, the haptic technology can be used for people to train some skills, which need the hand-eye coordination (Maharashtra, 2015). The training of acupuncture needs to improve the ability of the hand-eye coordination, so the application for making the haptic feedback platform is meaningful. The acupuncturists comment that although the parameter of the feedback is not quite accurate, the App has already come up with the effective training methods, and the measuring standard of the needling feedback. It will serve as a basis to consummate the perfect feedback platform in the training of acupuncture.

To conclude, the application can not only help to deliver the knowledge of acupuncture to the youth no educational limited, but also make the first acupuncture students train the needling.

6.2 Limitations

6.2.1 Suggestions by the Students and Acupuncturists

Suggestions by the Students and Acupuncturists
The acupuncturists focus on each feedback for the needling, they think the angle of needling is uncontrollable and inflexible, and the depth of needling needs to label it more clearly. Besides, the students comment that the multi-layer interface needs to be optimized better.

6.2.2 Technology Limitations

1. The breaking off bug in the haptic plugin when running the application.

2. The haptic camera and VR camera cannot arrange synchronously, so the virtual environment sometimes will change and rotate the position. It means if I turn a PC to run the application, I will re-fix the total environment again possibly.

6.3 Conclusion

The study has provided an application prototype for making an accurate acupuncture feedback platform in the virtual teaching environment. Combining with the VR and Phantom Omni, the application has the feature of immersion and real-time feedback, and it is proved to provide the more beneficial teaching and training environment.

The study improved the development of the haptic feedback skills, the usefulness for delivering the rationale and knowledge of acupuncture and anatomy to the next generation and the training feedback of the application has been proved effective and meaningful for the acupuncture students in the early stage of learning.

The application establishes the knowledge introduction interface, which can help the user with little acupuncture knowledge understand the knowledge of acupuncture through vivid and interacted images, or make the beginners of the acupuncture learn the acupuncture and anatomical knowledge point systematically. And this outcome is proved eminent through the testing.

The development of the application has allowed for the professional acupuncturists' simulation operation of the periarthritis of shoulder. Although the application has the disadvantage now, the suggestions from the professional acupuncturists are important for the implementing in the future development.

Overall, the acupuncturists think the application is essential for effective teaching and training for acupuncture. For the acupuncture students, it provides a simulated needling training repeatedly. For the professional acupuncturists, it offers an opportunity to plan the acupuncture operation before the actual needling. The

delivering of the knowledge in the acupuncture, and the measuring standard of the acupuncture feedback are rated highly, but the accuracy of needling needs to be realistic. Finally, the hardware limitations sometimes can reduce the smoothness and immersion of the application.

6.4 Future Development

Firstly, form the comments in the evaluation, because of the individual difference, the parameter of feedback in the acupuncture training is not accurate, it is an estimated value from the experiences of acupuncturists. The application is a prototype to establish the feedback platform in virtual acupuncture teaching and training. Thus, connecting with the right feedback database could improve the accuracy of acupuncture, and achieve the definite feeling from penetrating different tissues.

Furthermore, the application could have the acupuncture operation data integrated at any point. It would allow the users to train the latest operation repeatedly, reducing any risks posed by the actual training. Also, at the last step of the application, if the recorded operation results could be emailed to the professional acupuncturists veritably, the students will exercise the acupuncture operation in the absence of acupuncturists.

In the future, further testing can also help improve and verify the further development of the application. The prototype has been developed successfully, and the application has the potential to include more accurate feedback system, and the overall and latest training operation modes.

Reference

Biocca, F., 1992. *Communication Within Virtual Reality: Creating a Space for Research. Journal of Communication*. 42-4. 5-22. Available at: http://www.mindlab.org/images/d/DOC687.pdf [Accessed 2006]

Basdogan, C., Srinivasan, M.A., 2001. *Virtual environments for medical training: graphical and haptic simulation of laparoscopic common bile duct exploration. IEEE/ASME Transactions on Mechatronics*. 269-285. DOI: 10.1109/3516.951365

Bradley, P., 2006. *The history of simulation in medical education and possible future directions. Medical Education*. 40:254-262. DOI: 10.111/J.1365-2929.2006.02394.x

Byrne. C.M., 1993. *Virtual Reality and education. Chapter 9 - Summer Students in Virtual Reality: A Pilot Study on Educational Applications of Virtual Reality Technology.* Available at: https://www.sciencedirect.com/science/article/pii/B9780127450452500192 [Accessed 1993]

Burdea, G., Coiffet, P., 2003. *Virtual Reality Technology.* 2th ed. Wiley-IEEE Press. 464. Available at: https://www.wiley.com [Accessed 2003]

Claude, G., 2005. *Encyclopedia of Human Computer Interaction*. London: Idea Group Reference, 17033. Available at: http://www.eurospanonline.com [Accessed 2006]

Coles, T.R., Meglan, D., John, N.W., 2011. *The Role of Haptics in Medical Training Simulator:A Survey of the State of the Art. IEEE Consumer Electronics Society. IEEE Computer Society. IEEE Robotics & Automation Society*. 51-66. DOI: 10.1109/TOH.2010.19

Deshpanda, C.S., 2015. *The Study of Haptics in Medical Training Simulation. International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)*. 4-5. Available at: http://ijarcet.org/wp-content/uploads/IJARCET-VOL-4-ISSUE-5-2488-2491.pdf

[Accessed 2015]

Eisenberg, D., Kaptchuk, J., et al., 2002. *Acupuncture: Theory, Efficacy, and Practice*. 136: 374-383. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.886.5313&rep=rep1&type=pdf [Accessed 2002]

Hannaford, B., Okamura, A.M., 2008. *Haptics. Springer Handbook of Robotics.* 719-739. DOI 10.1007/978-3-540-30301-5_31

Hoffman, H.M., et al., 1995. *Virtual Reality Meets Medical Education.* Netherlands: IOS Press.130. Available at: https://books.google.co.uk/books [Accessed 1995]

Han, H., Wang, P., Chen, X., Gao, X., 2016. *Learning method of self-evaluation and mutual-evaluation for practical teaching of Acupuncture and Moxibustion Technique curriculum: application and exploration*. 36(8). 877-879. DOI: 10.13703/j.02555-2930.2016.08.027

Heng P.A., Wong, T.T., et al., 2006. *A Haptic Needle Manipulation Simulator for Chinese Acupuncture Learning and Training*. *International Journal of Image and Graphics.* 205-230

Heng P.A., Wong, T.T., et al., 2006. I*ntelligent Inferencing and Haptic Simulation for Chinese Acupuncture Learning and Training*. *IEEE TRANSACTIONS ON INFORMATION TECHNOLOGY IN BIOMEDICINE.* 10-1

Jung, Eun-Young., Park, D.K., Lee, Y.H., et al., 2011. *Evaluation of practical exercises using an intravenous simulator incorporating virtual reality and haptics device technologies. Nurse Education Today.* 32-4. 458-463

Jiang, Y.C., Jiang, J., et al., 2016. *Virtual reality of acupuncture manipulation in digital virtual human. Chinese Journal of Tissue Engineering Research.* 20(44):6643-6648.DOI: 10.3969/j.issn.2095-4344.2016.44.015

Kong, Jian., Gollub, R., Huang, T., et al., 2007. *Acupuncture De qi, from Qualitative History to Quantitative Measurement. The Journal of Alternative and Complementary Medicine*. 13-9. DOI: 10.1089/abm.2007.0524

Kuhn, C., Hubner, M., Krumm, H.G., et al., 2009. *The Karlsruhe Endoscopic Surgery Trainer as an example for virtual reality in medical education*. 122-125. DOI: 10.3109/13645709709152715

Laurel, B., Mountford, S.J., 1990. *The Art of Human-Computer Interface Design.* Available at: https://dl.acm.org/citation.cfm?id=575201 [Accessed 2018]

Lee, I.S., Wallraven, C., et al., 2014. *Haptic Simulation for Acupuncture Needle Manipulation. THE JOURNAL OF ALTERNATIVE AND COMPLEMENTARY MEDICINE.* 654-660. DOI: 10.1089/acm.2013.0475

Massie, T.H., Salisbury, J.K., 1994. T*he PHANTOM Haptic Interface: A Device for Probing Virtual Objects.* SensAble Technologies: ASME Paper. Available at: https://cn.3dsystems.com/scanners-haptics [Accessed 1994]

Ma, K., 2017. DECEMBER 2000 VOL 18. *Acupuncture: Its Place in the History of Chinese Medicine.* Available at: http://aim.bmj.com/content/acupmed/18/2/88.full.pdf?sid=5aed504f-2d26-4b25-9c6f-0a8bcfb779bb [Accessed 16 Sep 2017]

Mazuryk, T., Gervautz, M., 1999. *Virtual Reality History, Application, Technology and Future.* Available at: https://www.researchgate.net/publication [Accessed 1999]

Mousesette, C., 2012. *Simple Haptics. Sketching Perspectives for the Design of Haptic Interactions.* Available at: http://umu.diva-portal.org [Accessed 2012]

Smaldino, S.E., Russell J.D., Heinich, R., Molenda, M., 2008. *Instructional Technology and Media for Learning.* 12th ed. Available at: https://www.pearsonhighered.com/assets/preface/0/1/3/4/0134287487.pdf

Steuer, J., 1992. *Defining Virtual Reality: Dimensions Determining Telepresence*. Journal of Communication. 42,4. 73

Siciliano, B., Khatib, O., 2016. *Springer Handbook of Robotics*. 2th ed. *Springer Nature*. DOI: 10.1007/978-3-319-32552-1

Sherman, W.R., Craig, A.B., 2002. *Understanding Virtual Reality: Interface, Application, and Design.* Available at:
www.mkp.com [Accessed 2002]

Tsuei J.J., 1996. *The sciences of acupuncture-theory and practice*. *IEEE Engineering in Medicine and Biology Society.* 52-57. DOI: 10.1109/51.499758

Appendix 1 - Questionnaires

Participant Questionnaire:

* Only the professional acupuncturist received this document

Making a Haptic Acupuncture Teaching Platform in Virtual Reality

MSc in Serious Games and Virtual Reality

Researcher: Boyu Xu

The questionnaire is designed to test the content and usefulness of the application. This includes validating the operation and visualisation of the application, and evaluation it. You will put forward the suggestions to improve the further development of the application.

You will be asked questions about the following 4 areas.

1. Understanding the knowledge of acupuncture.
2. Testing the accurate operation feedback of acupuncture.
3. Testing the immersion and visualisation in the virtual environment.
4. Further development of the application in the virtual environment.

Understanding the knowledge of acupuncture

Please circle below if any of the following elements you find them in the application:

For example: *Yes* *No* *Not clearly*

6.The concept of acupuncture.

Yes No *Not clearly*

7.The concept of scapulohumeral periarthritis.

Yes No *Not clearly*

8.The concept of main meridian channels.

Yes No *Not clearly*

9.The position of each acupoint.

Yes No *Not clearly*

10.The effect of each acupoint.

Yes No *Not clearly*

11.The hint of acupuncture operation.

Yes No *Not clearly*

12.The knowledge of anatomy.

Yes No *Not clearly*

13.The relationship between anatomy and acupuncture.

Yes No *Not clearly*

Other comments:

Testing the effective learning feedback of acupuncture

Please circle below if you agree it.

14.You could achieve a clear feedback about **the type of needles**.

Strongly disagree Disagree Neutral Agree Strongly agree

15.You could achieve a clear feedback about **the position of the acupoint**.

Strongly disagree Disagree Neutral Agree Strongly agree

16.You could achieve a clear feedback about **the angle of needling**.

Strongly disagree Disagree Neutral Agree Strongly agree

17.You could achieve a clear feedback of **the depth of needling**.

Strongly disagree Disagree Neutral Agree Strongly agree

18.You could achieve a clear feedback of **the force of needling**.

Strongly disagree Disagree Neutral Agree Strongly agree

19.You could **record the accurate operation** each step.

Strongly disagree Disagree Neutral Agree Strongly agree

20.You could achieve **a clear evaluation of each acupoint**.

Strongly disagree Disagree Neutral Agree Strongly agree

21.You could achieve **a clear evaluation of the whole operation training**.

Strongly disagree Disagree Neutral Agree Strongly agree

22.You could learn **the accurate anatomical knowledge** in the application.

Strongly disagree Disagree Neutral Agree Strongly agree

23.You could learn **the accurate acupuncture knowledge** in the application.

Strongly disagree Disagree Neutral Agree Strongly agree

Other comments:

Testing the immersion and visualisation in the virtual environment

Please circle below if you agree it.

24.You could feel **comfortable and friendly** in the process of testing the application.

Strongly disagree Disagree Neutral Agree Strongly agree

25.The **scale of objects** in the virtual environment are realistic.

Strongly disagree Disagree Neutral Agree Strongly agree

26.You feel you are **in the virtual environment**.

Strongly disagree Disagree Neutral Agree Strongly agree

27.You feel you are making the **interaction** with the objects.

Strongly disagree Disagree Neutral Agree Strongly agree

28.You could run the application smoothly.

Strongly disagree Disagree Neutral Agree Strongly agree

Other comments:

The evaluation of the application

29.You could l**earn the knowledge of acupuncture and anatomy** in the application.

Strongly disagree Disagree Neutral Agree Strongly agree

30.You think the application is **useful** for students who want to learn the acupuncture operation to treat the scapulohumeral periarthritis

Strongly disagree Disagree Neutral Agree Strongly agree

31.You think the application is **a new try** in the teaching of learning and training acupuncture.

Strongly disagree Disagree Neutral Agree Strongly agree

Please answer the questions below to comment your thoughts. This will help to develop the application further before the submission date.

1. What did you like most about the application?

2. What did you dislike most about the application?

3. Were there any problems about the application?

4. Please write down the additional suggestions for further development.

Participant Questionnaire:

* Only the student received this document

Making a Haptic Acupuncture Teaching Platform in Virtual Reality

MSc in Serious Games and Virtual Reality

Researcher: Boyu Xu

The questionnaire is designed to test the content and usefulness of the application. This includes validating the operation and visualisation of the application, and evaluation it. You will put forward the suggestions to improve the further development of the application.

You will be asked questions about the following 5 areas.

1. People's understanding of acupuncture.
2. The knowledge of acupuncture in the application.
3. Testing the effective learning feedback of acupuncture.
4. Testing the immersion and visualisation in the virtual environment.
5. Further development of the application in the virtual environment.

People's understanding of acupuncture

Please circle below if you agree it.

For example: How often do you see the professional acupuncturist?

Never Rarely Sometimes Often Very often

1. Do you understand the concept of acupuncture?

None A little Ordinary Much Huge

2. How often do you see the professional acupuncturist?

Never Rarely Sometimes Often Very often

3. Why do you see the professional acupuncturist?

Have a fever Massage Body pain (like shoulder pain) other_____

4. Do you think the acupuncture is useful?

Ridiculous Useless Sometimes useful Useful Really useful

5. Will you choose the acupuncture to treat the scapulohumeral periarthritis?

Never Possibly Certainly

Other comments:

Understanding the knowledge of acupuncture

Please circle below if any of the following elements you find them in the application:

For example: *Yes* *No* *Not clearly*

6. The concept of acupuncture.

Yes No *Not clearly*

7. The concept of scapulohumeral periarthritis.

Yes No *Not clearly*

8. The concept of main meridian channels.

Yes No *Not clearly*

9. The position of each acupoint.

Yes No *Not clearly*

10. The effect of each acupoint.

Yes No *Not clearly*

11. The hint of acupuncture operation.

Yes No *Not clearly*

12. The knowledge of anatomy.

Yes No *Not clearly*

13. The relationship between anatomy and acupuncture.

Yes No *Not clearly*

Other comments:

Testing the effective learning feedback of acupuncture

Please circle below if you agree it.

14. You could achieve a clear feedback about **the type of needles**.

Strongly disagree Disagree Neutral Agree Strongly agree

15. You could achieve a clear feedback about **the position of the acupoint**.

Strongly disagree Disagree Neutral Agree Strongly agree

16. You could achieve a clear feedback about **the angle of needling**.

Strongly disagree Disagree Neutral Agree Strongly agree

17. You could achieve a clear feedback of **the depth of needling**.

Strongly disagree Disagree Neutral Agree Strongly agree

18. You could achieve a clear feedback of **the force of needling**.

Strongly disagree Disagree Neutral Agree Strongly agree

19. You could **record the accurate operation** each step.

Strongly disagree Disagree Neutral Agree Strongly agree

20. You could achieve **a clear evaluation of each acupoint**.

Strongly disagree Disagree Neutral Agree Strongly agree

21. You could achieve **a clear evaluation of the whole operation training**.

Strongly disagree Disagree Neutral Agree Strongly agree

Other comments:

Testing the immersion and visualisation in the virtual environment

Please circle below if you agree it.

22. You could feel **comfortable and friendly** in the process of testing the application.

Strongly disagree Disagree Neutral Agree Strongly agree

23. The **scale of objects** in the virtual environment are realistic.

Strongly disagree Disagree Neutral Agree Strongly agree

24. You feel you are **in the virtual environment**.

Strongly disagree Disagree Neutral Agree Strongly agree

25. You feel you are making the **interaction** with the objects.

Strongly disagree Disagree Neutral Agree Strongly agree

26. You could run the application smoothly.

Strongly disagree Disagree Neutral Agree Strongly agree

Other comments:

The evaluation of the application

27. You could l**earn the knowledge of acupuncture and anatomy** in the application.

Strongly disagree Disagree Neutral Agree Strongly agree

28. You think the application is **useful** for students who want to learn the acupuncture operation to treat the scapulohumeral periarthritis

Strongly disagree Disagree Neutral Agree Strongly agree

29. You think the application is **a new try** in the teaching of learning and training acupuncture.

Strongly disagree Disagree Neutral Agree Strongly agree

Please answer the questions below to comment your thoughts. This will help to develop the application further before the submission date.

1. What did you like most about the application?

5. What did you dislike most about the application?

6. Were there any problems about the application?

7. Please write down the additional suggestions for further development.

Appendix 2 - Introduction Video

Acupuncture Introduction.mp4.mp4