

Training System for Puncture Operation Force Adjustment in Hemodialysis

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Abstract: The study deals with a training system for the force adjustment in puncture operation for university students in clinical engineering. It is known in hemodialysis treatment that high level of accuracy is required including the force, angle and needle tracks when inserting a needle into the blood vessel, while it is difficult to master the complex technique within a limited university time with fewer exercises. For the reason, we construct a training system on PC having the ability of insertion force response, quantitative operation effect evaluation and good repeatability. The students experience operation in such a vivid environment with real-timely evaluation. The effectiveness of system was proved with questionnaire on students.

Keywords: Computer Training System, Skill Science, Clinical Engineer, Support to operations

1. Introduction

With the progress in computer science and technology, computer-supported education/training systems have obtained increasing attention (Watanabe, et al., 2010). Similarly in clinical engineering, the development of training systems with the most advanced computer technology has been taken into account (Sueda, 2010). A clinical engineer faces a wide range of tasks including operations of multiple medical machines, and the management and maintenance of them. To fulfill the tasks requires complex techniques and rich expertise. However, it is very difficult to get such a large sum of knowledge, skill and experience within the limited university time in which students are always with less operation practice and particularly for frequent trouble-shooting.

In order to solve the above problems, we have carried out a series of studies for construction of teaching/training systems with highly simulated medical operations (Kanehira, et al., 2010). For obtaining higher training efficiency towards the final goal of such a training system with low cost, rich experiences and repeatability, we proposed in this study one for clinical engineers using the up-to-now knowledge from our sequential researches (Kanehira, et al., 2014). In addition to conventional e-learning for general knowledge, special attention was paid to the practical operation on medical machines (Kanehira, et al., 2016).

The conventional e-learning focuses mainly on theoretical knowledge like that in textbook, with less attention paid to how to operate the practical medical machines. The knowledge from textbook are not as good as those obtained from rich experience (empirical knowledge), body movements (embodies knowledge), and tacit knowledge (Suwa, 2009). Therefore, we are focusing the research on the operation training with the physicality in the field of skill science.

We chose a training system for puncture operating force in hemodialysis. It is considered that such a system must be with operating force response capability in hemodialysis. The system was constructed on a VR (virtual reality) environment in such a way that puncture operation drills with force feedback senses can be repeatedly achieved without the use of real machine or on a real human body. In more detail, an arm model with clinical puncture needle capable of force sensitivity was constructed using the Phantom force-feedback device. Operation exercise can be repeated in the VR training environment.

2. Hemodialysis and Dialysis Puncture Technique

Hemodialysis is the operation to take out the dirty blood from a patient with disabled kidney, to purify it through a dialyzer and to put the clean blood back to his body. Each operation normally takes four hours, and the operation must be repeated every 2 days. The operation starts with a “puncture” operation, by holding a needle and stinging into the blood vessel. The puncture operation must be repeated two times for each treatment, including one needle sting to take out the blood from vessel and another to return it to vessel by putting needles into the special shunts put earlier in the blood vessel. The needle should be stung precisely into the shunts at a proper angle under a difficult condition that blood vessels are structurally complex and visually hidden underneath the skin. Therefore, a puncture operation is always more difficult and dangerous compared with normal injections. Furthermore, an erroneous puncture operation may result in accidents such as heavy bleeding. The puncture is one of the most important techniques for hemodialysis.

Undoubtedly, punctures with high levels of precision are required for such operation. However, it is impossible to allow students to do practical puncture on patients during clinical training. As the result, it can be imagined how anxious and uneasy the student may be when he faces a patient for the first time. However, there has not yet been such a training system up to the present time upon our best knowledge. In order to solve the above problems, we proposed the following training system for “puncture” operation for hemodialysis.

3. Puncture Technique Training System

We developed an early version of the system for teaching of insertion angle and track, which was not satisfactory as it did not provide force feedback during insertion. Therefore, we pay attention mainly on the force feedback ability and repeatability of the system which represents the operation sense or feeling of the operator and the training efficiency. In more detail, the training system was constructed as a Virtual Reality (VR) environment on PC. The device “PHANTOM Omni” (Sensable Technology Inc./ OpenHapticsToolkit) was used to provide force feed-back. A VR arm model was formed, and the reaction force from the experienced clinical engineers was input as teaching standard. The improved system thus possesses the ability of operation sense, insertion angle and direction, and so on. The system was used in training our students, and the effect was confirmed with questionnaire.

For an easy understanding of the insertion angle and distance in VR most like that in real operation, a simple arm model with skin, inner vessel and outer vessel of three layers was constructed, each of which was with force resistance. The size and force resistance of vessels were made changeable in response to the gender, age of difference people. It is required to provide teaching standard data in the system. For this purpose, operations from several experienced clinical engineers were recorded, analyzed and quantified as training standard index. The force resistance of 0.3N, 0.2-0.6N, and 0.4Nf was set for the skin force resistance, inner vessel and out vessel, respectively.

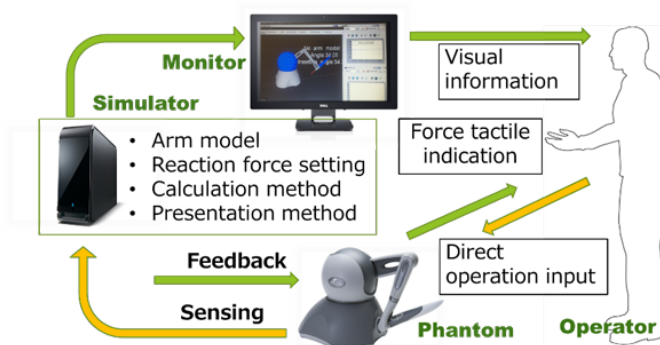


Figure 1. Configuration of the puncture training system

The Ubuntu suitable for ROS (Robot Operation System) was used as the OS for Phantom. The configuration and flowchart for operation and information were shown in Fig.1. When using this system, the students are requested to view first the electronic text of the flow chat of how to do the

puncture operation. Then, they do puncture exercise on PC using Phantom device. The Phantom provide force feed-back by force resistance, and the insertion angle was displayed by numerical value and graph. Whether or not the insertion reach the upper layer will be indicated by words and color so the students can confirm their operation easily (Fig.2). They do repeated exercise to improve their skills while confirming the distance, angle, force, etc. during the exercise.

We evaluated the system with 16 participants at our university, including one teacher, 11 male students and 4 female students. A questionnaire was done upon them after finishing the use of our training system. Such questions as “have you experienced puncture with the system”, “do you wish to use the system before going to clinical”, were set and a 5-stage evaluation was asked for their answers. The teacher tell that he did experience the real puncture sense with the training system, and 90% of the students gave positive evaluation answers.



Figure 2. Experience on puncture operation sense of touch

4. Conclusion

This study deals with the teaching/training of the force adjustment in puncture operation for the clinical engineering university students. It is known in hemodialysis treatment when inserting a needle into the blood vessel of a patient, high level of accuracy is required including the force, angle and needle tracks. For such the reason, we construct a training system on PC with force feed-back device, quantitative evaluation and repeatability. The students experience the operation in such a vivid environment, evaluated from the PC and correct their mistakes real-timely. The effectiveness of training was proved with the answers from the trained students.

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