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# Development of an inheritance assist system for experienced operation skill by using a haptic function of PHANToM

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***Abstract:*** Recently, various kinds of medical issues have been reported such as lacks of doctors and/or nurses, medical mistakes, and escalation of medical costs. On the other hand, medical quality and doctor's skill are required to be enhanced. Then, virtual surgical simulator has been developed and used in inexperienced doctors' training. However virtual training simulators provide the training opportunities for doctors to practice cutting and/or sewing against virtual organ by them. In order to maintain and enhance medical quality the experience doctors had constructed, it is required to provide an environment where inexperienced doctors can learn the skills of experienced doctors. This study proposes a training factor that helps to take over experienced operation skills to inexperienced doctors. In order to make this training factor, we have to develop a skill recording system that can store the operation data as supervised data, and and reproduce the stored data on a surgical simulator. A trainee intuitively learns the other doctor's skill. In this paper, a recording system based on a haptic device is presented. Some experimental results where a subject tries to manipulate a mock surgical forceps according to the supervised data are discussed.

**Keywords:** *Virtual reality, Mechanical modelling, Surgical simulator, and Computer aided system.*

## 1. **Introduction**

Both surgical skills and medical expertises of experienced doctors have to be taken over next generation. It has been reported that the number of doctor is gradually decreasing, meanwhile the number of cases of diagnosis errors and treatment failures have been increasing. Against them, inexperienced doctor and residences have been required to have high quality medical treatment skills and accurate diagnostic skills. Recently, surgical simulator or surgical planning assist system have been developed based on collaboration of between virtual reality technique and haptic technologies[1][2][3]. Most of the reported surgical simulator enables doctors to practice the skills of cutting and sewing virtual organs. In this virtual environment trainees can practice surgical skills without concerns about the patient's physical load and surgical risks. The effect of training simulator increases by operation is infrequent. For example, considering a case of that patient's vitality level is low and/or significant preparation for operation is essential and so on, experienced doctors perform the operation and inexperienced doctors devote to assist the operating surgeon. Therefore surgical opportunities for inexperienced doctors are not enough as the operation skills needed in operation are more difficult. Then a training simulator including a training factor that enables to teach various experienced skills to trainee has some possibilities to become one of solutions for the current medical issues.

This study aims to construct a training factor that enables trainee to intuitively learn the skills of experienced doctors and to apply this factor to a simple operation technique. In this paper, some fundamental studies about recording operation data as supervised data and the effect of reproducing the supervised data on training on a surgical simulator. A simple surgical knife operation is subjected in our fundamental research. Ideas of recording function and reproducing function are described in the following sections, and experimental results for this simple operation are discussed.

## 2. Concepts

Considering doctors' manipulation of forceps for patient's organ during operation, the doctors operate the forceps according to not only visual information but also force information of operation target. Not only for doctors, we are doing same things even in our daily life, for example window cleaning. We wipe out the window by using a dust cloth, where we make visual feedback and force feedback in ourselves and control our hand force against the dust on the window by obeying these feedback loops.

When a doctor cuts the body surface by using a knife forceps depending on the previously determined surgical plan, he/she controls both of forceps's position, posture, force, and moment. In other words, cutting operation is performed by the feelings of organ's stiffness, elasticity, and viscosity transmitted via the forceps to doctor's fingertip. Then a lack of force feedback functions for tele-robot surgical system, for example Da Vinch, Zeus, etc., is assumed as one of the significant problems of tele robotics surgical system [5]. Doctors wear globes in operation. Their tactile sensibility is prevented by wearing globes but they can recognize the differences of organs' elasticises. For example, cardiovascular surgeons determine the region of left ventricular by the basis of feelings of cardiac muscle palpation [4].

### 3. Method

In this chapter, two basic functions of our system are presented. A recording function by the basis of function of a haptic device PHANToM Premium is firstly described, where operation data will be stored in the computer memory as a supervised data. Next is a reproducing function. This function is composed of a haptic control function of PHANToM Premium. The system structure we have developed is composed of a PC and HANToM Premium. The PC is running on Windows XP and its development environment is Visual C++ 2005.

### 3.1 Recording function

PHANToM Premium is one of commercially available haptic devices. It can detect its end effecter's position and posture in three dimension. Force feedback function is effect on the three axis direction, where *Fx*, *Fy*, and *Fz* are controllable. We employ this haptic device as human interface in order to record operation data in this study, where a pen type end effecter is used as a mock device of knife forceps. Then time variation data of forceps is recorded, where *x(t)*, *y(t)*, and *z(t)* are stored in the computer memory.

### 3.2 Reproducting function

The recorded data, $x_r(t)$, $y_r(t)$, and $z_r(t)$, based on the recording function is used as supervised data for trainee, and is used the target data of force control of PHANTom. This force control assists the operation of trainee.

In the force control system of PHANToM, HD library can make PHANToM output force by the settings of parameters in the programming code. Its control frequency is approximately 1000Hz, complete real-time processing might be prevented due to process for graphical application or resident programs of Windows Operation System. A simple PID control method is employed in this system. Equation (1) is a control low for force control in respect to x-axis direction.

Each axis direction's control low are established as well as equation (1), where; $Fx$ shows output force, $K_p$, $K_d$, $K_i$ are proportional, differential, and integral feedback gains respectively. $x_r$ is a variable of target coordinate and $x$ is for current x-axis coordinate variable. We are coding this PID control low with empirically adjusting each feedback gains.

$$F_x = K_p(x_r - x) + K_d(-\dot{x}) + Ki\int (x_r - x)dt \qquad (1)$$

### 3.3 Virtual organ model

As mentioned above, a doctor operates a surgical forceps depending on the feelings of patient's organ, so a virtual organ based on a dynamic model has to be build.

Co-author who is cardiovasuclar surgeon desires an application of this study for cardiovascular surgical field. Therefore, a virtual aorta model has been developed in our laboratory [6]. However, rigorous simulation model for aorta is not requested in our current step. So, a cylindrical dynamic model imitating shape of aorta has been constructed.

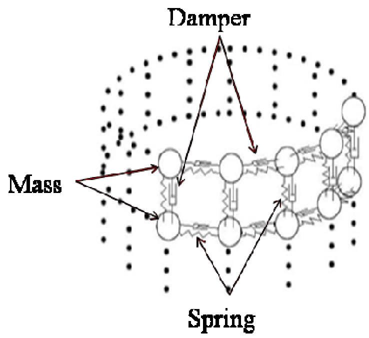



Fig. 1 A scheme of the cylindrical dynamic model based on spring network system

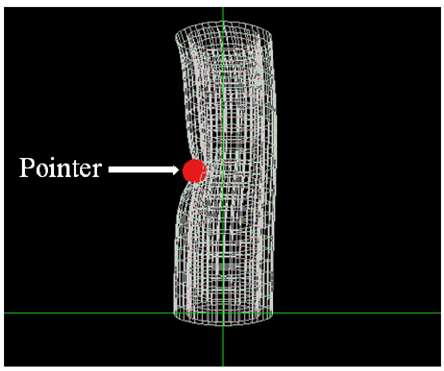



Fig. 2 A graphical model of the bilayed dynamic model

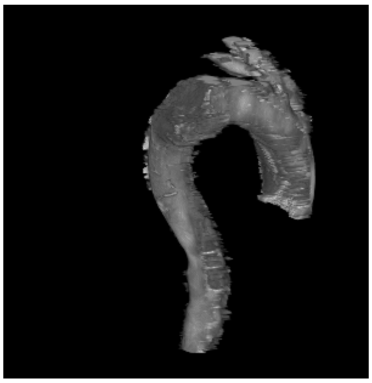


Fig. 3 A volume model of patient's aorta rendered with OpenGL Volumizer

Fig. 1 shows a schematic diagram of the cylindrical dynamic model based on mass-spring network model. Because aortic tissue construct both inner wall and outer wall, so two cylindrical dynamic models are arranged as like as a bilayer film. All of mass of these two layers are connected with springs and dampers in order to make this virtual model have aortal thickness. Fig. 2 is a graphical model of the virtual organ used in this study. This is drawn by using OpenGL. The accurate shape of aorta is going to be interpolated with patient three dimensional computer tomography data. The co-author has been tried to extract the volume data of aorta from patient's computer tomography.

Fig. 3 is a volume model, where OpenGL Volumizer rendered this graphical model by the basis of the volume data derived a patient's computer tomography data. We would like to extract three dimensional coordinates of aorta from this model in future.

## 4. Experiment

### 4.1 Recording experiment

As mentioned above, a simple knife operation is used as a basic operation in this study. Then, the three

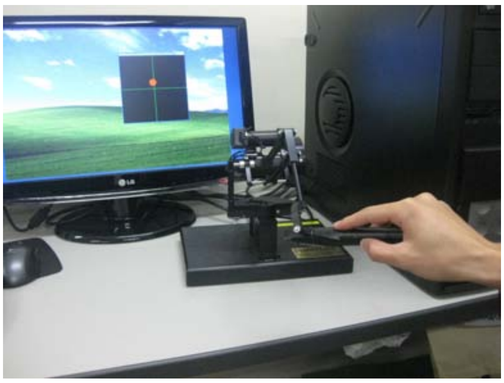
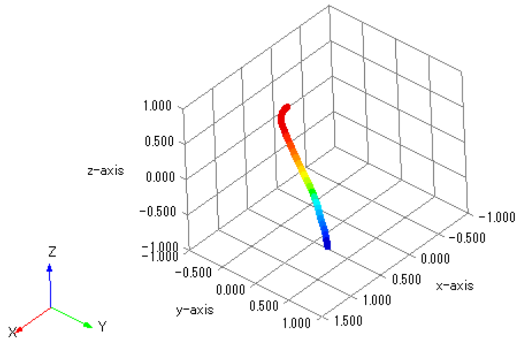


Fig. 4 Experimental scene of operating PHANToM Premium A




(a) line

Fig. 5 Recorded supervised data

dimensional coordinates of the edge of PHANToM end-effecter are stored in the computer memory and are saved in a file. This paper introduced a virtual organ model in section 3.3, however this experiment uses no virtual organ model. Because we have to mount a function that judges the contact between the surface of cylindrical dynamic model and a pointer which is controlled by the trainee via PHANoM in order to use our dynamic model as a virtual organ model. Fig. 4 shows a scene of experiment for recording operation data, where a laboratory student performed like that a doctor cut an organ with knife forceps. The obtained data are shown in Fig. 5 by using Graph-R. The data starts at red color and moves to blue color.

### 4.2 Reproducing experiment

In this experiment, we implemented experiments under two different conditions. The first condition is that the computer gives subjects only visual information. The supervised data is drawn as a point moving according to the recorded data. Total four subjects tried to trace the supervised data. After five times trials, we evaluate the experimental data by using mean square method.

Next condition is that both visual information and force information are given. The force information is just a force assist instructed from the force control of PHANToM.

## 5. Result and discussion

The experimental results implemented under the first condition are shown in Table 1. And the experimental results for the second condition are shown in Table 2. Each table are indicating the evaluation results based on applying mean square method to between the supervised data and subject's operation data. All subject tried five times under same experimental condition. These results clearly show most subjects were getting skilful by the

Table 1 Experimental result for the first condition

| | Subject A | | | Subject B | | | Subject C | | | Subject D | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Exp. I | x | y | z | x | y | z | x | y | z | x | y | z |
| 1 | 30.38 | 30.72 | 55.54 | 42.40 | 113.18 | 137.54 | 52.36 | 140.90 | 15.36 | 17.64 | 364.57 | 1028.12 |
| 2 | 13.04 | 26.43 | 30.07 | 13.93 | 8.21 | 200.49 | 2.44 | 106.34 | 390.42 | 109.96 | 727.46 | 1512.75 |
| 3 | 20.30 | 21.05 | 26.04 | 23.93 | 155.13 | 263.00 | 19.09 | 77.25 | 445.77 | 5.72 | 233.63 | 1410.12 |
| 4 | 16.91 | 5.57 | 42.72 | 23.28 | 105.81 | 249.94 | 36.32 | 180.63 | 495.83 | 10.85 | 93.78 | 143.24 |
| 5 | 8.31 | 17.01 | 99.54 | 15.68 | 58.84 | 198.50 | 45.29 | 70.59 | 783.55 | 10.90 | 14.14 | 20.75 |

Table 2 Experimental result for the second condition

| | Subject A | | | Subject B | | | Subject C | | | Subject D | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Exp. II | x | y | z | x | y | z | x | y | z | x | y | z |
| 1 | 5.44 | 0.84 | 28.63 | 7.97 | 1.23 | 86.93 | 133.82 | 80.08 | 179.61 | 5.72 | 14.90 | 6.91 |
| 2 | 0.48 | 6.45 | 61.17 | 9.59 | 15.15 | 20.23 | 59.57 | 101.29 | 218.50 | 8.60 | 8.60 | 6.39 |
| 3 | 5.28 | 25.23 | 64.50 | 4.10 | 5.07 | 53.52 | 56.18 | 99.13 | 264.14 | 5.18 | 5.18 | 1.89 |
| 4 | 1.31 | 10.57 | 68.95 | 3.36 | 7.06 | 26.01 | 31.10 | 135.73 | 346.60 | 10.19 | 10.19 | 1.57 |
| 5 | 3.03 | 8.40 | 48.38 | 3.78 | 5.46 | 19.41 | 36.37 | 148.51 | 399.47 | 2.07 | 2.07 | 1.60 |

number of times progress regardless of conditions. And the results of experiment II are entirely better than that of experiment I due to assistance of force control.

Because it was difficult to create a sense of depth in the virtual environment, most of subjects were not able to get good result in respect to z-axis against the other axis direction. Realistic shape of forceps is necessary to make the virtual training environment more practice. Then, the evaluation criterion about posture of forceps can be added. In this experiment we adopted a simple operation like a doctor cuts the body surface as the supervised data. To make it possible to apply the reproducing function for other operation skill such as sewing a blood vessel, not only a virtual forceps model but also torque control function of a haptic device is requested. Constructions of a virtual forceps model and the contact model between the virtual forceps model and the dynamic model are our future work.

## 6. Conclusions

This paper described the technical factors of new training factor that helps to inherit the surgical skills of experienced doctors to inexperienced doctors and/or residents. Though the supervised data was a simple operation and there were no dynamic model in experimental environment, the results under the second condition showed the force assist function has an effect for operation training.

For the next step, we firstly improve the virtual environment where a virtual forceps model will be built and the dynamic model will be added. In order to embed the dynamic model, realistics of virtual model makes the training sysmte more plastic. So we are planning to apply OpenGL Volumizer to volume rendering the vitual organ model. Then, the computation speed and imaging speed of GPGPU would be helpful. The integration of the development environments for the haptic device, OpenGL Volumizer, and GPGPU are neccesary.

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