Development of an inheritance assist system for experiencing operation skills by using a haptic function of PHANToM

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Abstract At present, several commercially available surgical simulators have been used in advanced medical facilities, and most of them provide a self-learning environment for trainees who are young doctors and/or residents. Therefore, we assume that inexperienced doctors have to inherit the veteran skills of experienced doctors because the lack of doctors and nurses is one of the most serious medical issues. This article proposes a training function on a surgical simulator system which enables trainees to sense the feelings of experienced surgeons while operating. The inheritance assistance function we are constructing might be of help in compensating for the lack of experience of young doctors and be more effective than the present system. The inheritance assistance function makes it possible to record the operational data of experienced doctors, and to reproduce this data in a training scene for young trainees. Then young doctors could practice their own skills by intuitively referencing the recorded advisory data in a surgical simulator. In order to accomplish the purpose of this study, we have constructed a fundamental system. A simple virtual object based on a dynamic model reacts in terms of visualization and force against the manipulation of virtual forceps via a haptic device, PHANToM. Several laboratory students of the experimental subject were challenged to obtain training with the system developed. This article describes the system and discusses the results and future work.

Key words Virtual reality · Haptic device · Skill inheritance · Surgical simulator · SN system

1 Introduction

At present, several medical problems such as the lack of doctors and nurses, medical errors, and the escalation of medical costs have been reported. In particular, in step with the aging of the population, the number of patients who need to receive various kinds of advanced medical treatment is increasing. In order to maintain and improve the current level of medical quality, doctors have been required to have a high standard of medical treatment skills and accurate diagnostic skills regardless of their experience. A surgical training simulator is one of the solutions to one recent medical issue, so that trainee doctors can obtain training opportunities without concerns about the patient’s physical stress, the risk of medical error, and the various kinds of cost necessary for animal experiments. These days, various kinds of simulators have been developed according to the type of operation, and are used in advanced medical facilities. The main purpose of the conventional surgical simulator is to give inexperienced doctors a self-learning opportunity regardless of duty hours. However, it is difficult for trainee doctors to get the operational feelings of skillful doctors even they practice in the presence of teaching doctors.

We assume that a training function that gives the operational feelings of skillful doctors intuitively would make a conventional training simulator more practical. We therefore propose a function that records operational data when an experienced doctor performs on a surgical simulator, and reproduces the recorded operational data in the training of inexperienced doctors. This function will make it possible for trainees to learn operational skills more intuitively than by using conventional simulators. We are carrying out basic research for the development of an inheritance assistance function for operational skills. A simple virtual training system has been developed and used by several subjects,
and the experimental results and some discussions are given.

## 2 Concept

Considering the manipulation of forceps by a surgeon on a patient during an operation, it is clear that surgeons control the position, posture, and force of the forceps based not only on visual information, but also on force information obtained via the forceps. This feedback mechanism of human behavior is applied not only to doctors, but also to ordinary people. We all receive visual feedback and force feedback ourselves when we do any daily work. A cutting operation with a scalpel is one simple operational skill, but the differences in an operating surgeons’ experience appear in the conditions of the incision. Surgeons manipulate forceps by reference to the feelings of an organ’s stiffness, elasticity, and viscosity transmitted through the forceps to the fingertips, so inexperienced doctors do not know how to homologize the manipulation of forceps to the varying feelings while cutting a patient’s skin. Incidentally, the lack of force feedback that transmits the feelings to the surgeon’s fingertips in tele-surgical robotic systems such as Da Vinch, Zeus, etc., has been considered as one of the most significant problems. Doctors need to wear gloves during an operation because of the danger of infection and hence their tactile sensibility is limited by wearing gloves, but they can still recognize differences in an organs’ elasticity. For example, cardiovascular surgeons determine the region of the left ventricular on the basis of the feeling of cardiac muscle palpation in left ventricular plasty. Therefore, we assume that a trainee needs the forceps in a surgical simulator whose position, posture, and velocity are controlled according to the recorded operational data obtained by an experienced surgeon.

## 3 Method

The purpose of this study was to investigate the effectiveness of the inheritance assistance function by using a haptic device. First we established a virtual object which deforms and mechanically reacts against the manipulation of a haptic device. The PHANToM Premium is employed as the haptic device in this study, since it is one of the commercially available haptic devices and has the function to detect the position of its end effector and to control the force in three dimensions. By using its force feedback function based on the PID control law, the inheritance assistance function we have proposed is realized. The system structure for our fundamental research is composed of a PC running on Windows XP, and its development environment is Visual C++ 2005.

### 3.1 Virtual environment construction

The requirements for the virtual object are that it should react against the manipulation of PHANToM with respect to visualization and force without a time-delay. A spring damper network system is commonly used as a dynamic model in order to achieve these requirements. This study also applied a spring damper network system for the construction of a virtual object, where a Voigt model with a spring and damper arranged in parallel is used.

In order to simplify the mechanism of the dynamic model, we decided to combine two different models. One model is used only to calculate the reaction force, and the other one is to express the deformation of the virtual object. Figure 1a shows a schematic diagram of the dynamic model for the computation of the reaction force. This lattice-shaped model is patched on the base model which expresses the deformation of the virtual object, as shown in Fig. 1b, and moves on the surface of the basic model corresponding to the manipulation of PHANToM. The base model is composed of a three-layer structure of a large size lattice-shaped dynamic model. Each mass point is connected with a Voigt model-based element.

This structure can be applied to the shape of a patient’s organ taken from medical images by realigning the coordinates of the mass points according to the shape of the patient’s organ, and can compute the continuous reaction force according to the manipulation of PHANToM. Figure 2 shows an execution screen in this study, where the shape of the virtual model is completely flat, as in Fig. 1b. The visco-elastic parameters are empirically determined to make the output of PHANToM closer to the feeling of human skin.

### 3.2 Assistance function

The training is to repeatedly go over the trajectory that an advisory doctor has previously performed. The difficulties of going over a trajectory which is drawn by a human are in containing individual biological rhythms. Of course, the