FORCE ACQUISITION ON SURGICAL INSTRUMENTS FOR VIRTUAL REALITY SURGICAL TRAINING SYSTEM

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***Abstract*— Surgical training is needed for novice surgeons or medical students to get used to surgical instruments and to practice their skills in order to control and manipulate the surgical tools before a real operation on patients. In surgical education, virtual reality (VR) simulation is a new alternative approach for surgeons to learn and determine their level of capability. This study is to introduce force acquisition on surgical instruments that can obtain real force data at human/tool interface. The measuring surgical instruments are developed for two types of operators which are human and robot. The information of force applied by operators on their instruments during cutting pig's meat is capable of being database for realistic force feedback VR simulation. Moreover, the system is a part of virtual reality surgical training system project which the system can provide accurate force feedback to user.**

Keywords - Haptics, Surgical Simulator, Virtual Reality, Simulation

I. INTRODUCTION

Surgical training is needed for novice surgeons or medical students to get used to surgical instruments and to practice their skills in order to control and manipulate these tools before they operate on patients. Training for novice surgeon, which is called hands-on workshop, is often set up in short period of time by the experienced surgeon. It requires not only experienced surgeon to give beginner surgeon advice, but also a set of tools to be used for performing such functions as cutting, dissecting or suturing.

There are many methods of training nowadays. Training on laboratory animals is commonly used by practice on pork, dog, or goat. Before novice surgeons do operation with real patient, they should pass operating in same procedures with laboratory animals. It is the one way to avoid involving with patient, however, there are a few issues that have to be concerned, it is the cost of animal and another is sterilization that means any animal have to be fed with proper method and be ensured that they are sterile. For training on cadaver there is some limitation about the number of cadavers which is not enough for medical students. Another weakness of cadaver is that its properties can be changed if it is not properly kept. Currently, training in simulator becomes popular and being another alternative for training. Simulators can replace conventional training either on human patients or on animal.

Haptics is the technology to let human operator undergo and create touch sensation by force feedback. Haptic technology can improve the sensation performance of operator in simulated environment by means of attempt to generate a sensation that the operator is interacting with a real environment. Haptic rendering is the process of computing the force required by contact with virtual objects in virtual environments. This computed force is based on measurement on the user's motion. There are many steps to formulate in the process of haptic rendering (Fig.1). Although the most of applications that haptic technology is integrated into are for entertainment, haptic virtual environment applications for training of medical procedures have also been created in the last decade [1, 2].

Virtual reality (VR) is a three-dimensional computer-generated database in which a person can interact as he or she is in imaginary place. The application of this technology is shown in surgical training for reducing risk to patients during training and increasing trainee's opportunity to practice. Another advantage of VR simulation is that it can measure technical skill by software programming while traditional surgical training program relies on subjective assessment of operative skill. Nevertheless, some VR surgical training system cannot afford realism of sensation due to lack of proper force feedback, so trainee cannot perceive physical objects like real ones in conventional training. The main goal of our work is to develop virtual reality surgical training system which can provide accurate force feedback. However, because there are many stages in our work, one part of this system which is force acquisition is presented in this paper [3, 4].

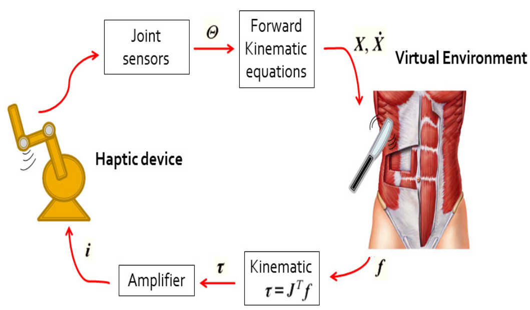

Figure 1.Schematic diagram of haptic rendering.

II. APPROACH

Overall system consists of four parts that are related to each other.

A. *Force Acquisition*

The most important component to fulfill the system with realistic force feedback is to obtain real forces applied by users on instruments during surgery. Force acquisition is a procedure to acquire force data measured at the human/tool interface (Fig.2) [5-7]. More details of this part are described in this paper.

B. *Virtual Reality (VR) Simulation*

Virtual reality (VR) is a technology that allows a person to interact with three-dimensional database in real time. In surgical education VR simulation proposes surgeons new way to teach and determine their level of capability before they operate on patients. Also VR simulation allows trainees to repeat same procedure several times.

C. *Haptic Device with Attached Surgical Instrument*

Haptic device is mechanical device that mediate communication between a user and a computer. Haptic device allows the user to touch, feel and manipulate three-dimensional objects in virtual environments and tele-operated systems. However, the significant aspect for VR simulation in surgical education is to provide three-dimensional virtual environments that user can interface easily with, while it still keeps the specific appearance and the feeling of surgical instrument. To maintain those features, it is need to attach the actual surgical instrument handle to haptic device. There are a wide variety of haptic devices available for purchase, such as, the Phantom Omni device from SensAble Technologies. It is designed to have the special stylus adapter kit that can be used to attach a variety of devices to the standard stylus.

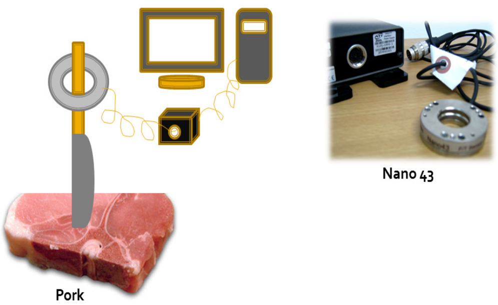

Figure 2. Concept of force acquisition.

D. *Haptic Rendering*

Haptic rendering is the process of computing the force required by contact with virtual objects in virtual environments. This computed force is based on measurement on the user's motion. There are many steps to formulate in the process of haptic rendering. One of these steps is force calculation which is the step after the contact between the haptic interaction point (HIP) and virtual object is occurred. For simple virtual environment force calculation is commonly computed by using the simple model, such as, the spring model (Hooke's Law). For our system the force data which is acquired from the measurement on real human/tool interface is applied to be databases for force calculation step. It is believed that the acquired force from measurement can provide more realistic feedback to user than the computed force from mechanical model when it is applied to haptic rendering.

III. FORCE ACQUISITION

A. *Design on The Measuring Surgical Instrument*

Scalpel (surgical knife) which is common surgical instrument is selected to be prototype of our concept. To acquire force data measured at the human/tool interface, a force sensor (ATI model-Nano43 DAQ transducer) is mounted into scalpel called the measuring surgical instrument. The force sensor is capable of measuring three components of force (F_x, F_y, F_z) and three components of torque (T_x, T_y, T_z) in the Cartesian frame. The force/torque data is sampled by using computer with a 16 bit NI PCI-6220 DAQ card (National Instruments). In addition, a LabVIEW (National Instruments) application is developed incorporating a user interface for acquiring visualizing the force/torque data in real-time. Two types of experiment by using different kind of operator are set up to compare a result: by manual and by robot.

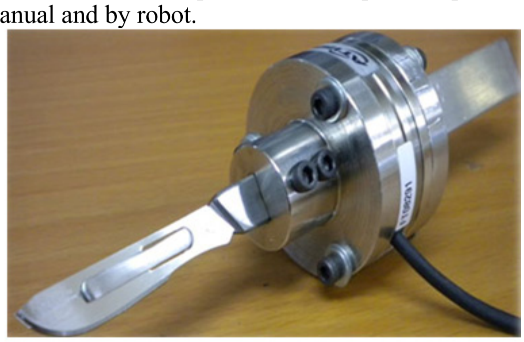

Figure 3. The measuring surgical instrument by manual

.For the manual experiment the scalpel is modified to have an adapter to attach the force sensor (Fig.3). And also for the robot experiment the adapter to mount force sensor into the Motoman HP3 robot is developed (Fig.4).

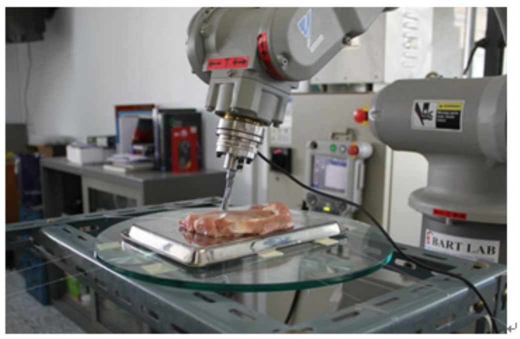

Figure 4. The measuring surgical instrument by robot

B. Experimental System Setup

Experimental system is created in order to obtain real force. The experiment is set up by testing a cutting of three layers of pork: skin, muscle, and fat layer with the measuring surgical instrument. There are two types in this experiment which are the manual cutting and the robot cutting. The information from this experiment is concerned only in force along x-axis according to the movement direction of surgical instrument that is set in the experiment. Step of experiment is shown in Figure 5 to demonstrate all steps of force acquisition.

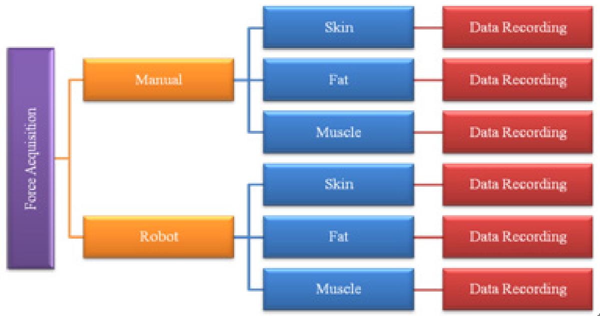

Figure 5. Step of experiment for force acquisition.

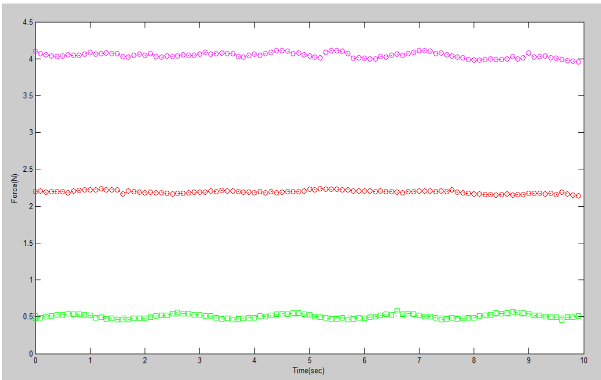

Figure 6. Results from manual cutting

IV. EXPERIMENTAL RESULTS AND ANALYSIS

A. Manual Cutting

Results from manual cutting are shown in Figure 6. This graph represents the relationship between force (Newton) and time (Second). The unit of data from force sensor is voltage. It can be changed to Newton unit by multiplying the constant value 1.8. This graph shows the average of force in three layers of pork which are 4.0456 N for the skin layer, 2.1924 N for the muscle layer, and 0.5066 N for the fat layer. The experiment of cutting by human provides the linear measurement of force. However, because the depth of cutting cannot be measured, so the relationship between the force and the depth in each layer cannot be formulated as well.

B. Robot Cutting

Results from robot cutting are shown in Figure 7. This graph shows the average of force at the depth of cutting at 2.5 mm in each layers of pork which are 4.5349 N for the skin layer, 0.6778 N for the muscle layer, and 0.2941 N for the fat layer. The difference of force value in each layer if compared with the force value of the manual cutting may occur from sliding of pork when the scalpel is touching and cutting on it. In the robot experiment the depth of cutting can be fixed by controller in each layer. The equation of relationship between the force and the depth in each layer can be formulated.

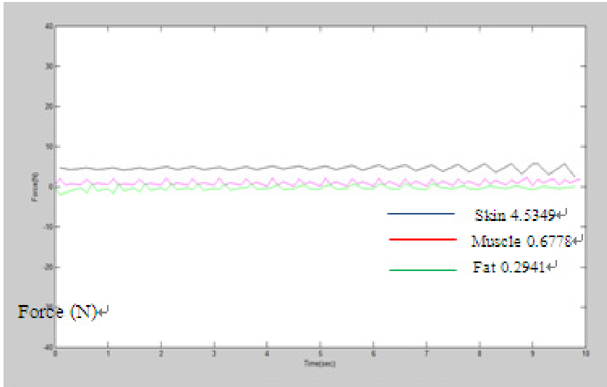

Figure 7. Results from robot cutting

V. CONCLUSION AND FUTURE WORK

The force acquisition on surgical instruments for virtual reality surgical training system was reported. The prototype of this work was developed by modifying surgical knife. Force sensor is mounted into surgical knife to acquire force data at the human/tool interface. The experiment was set up by testing a cutting of three layers of pork: skin, muscle, and fat layer with the measuring surgical instrument. There were two types in this experiment which were the manual cutting and the robot cutting. Both results of cutting showed the different value of force in each layer.

The force acquisition process is a part of virtual reality surgical training system. The main goal of our work is to develop virtual reality surgical training system which can provide accurate force feedback. The future work includes development of virtual reality (VR) simulation for cutting. And for more complicated surgical procedure, such as, laparoscopic surgery the force acquisition experiment can be developed by applying same concept of this work.

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