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DEVELOPMENT of PROTOTYPE LAPAROSCOPIC GRASPER with HAPTIC FEEDBACK

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Abstract*— The introduction of robot-assisted surgery into the operating room has revolutionized the medical field. These systems not only have the advantages of traditional minimally invasive surgery (MIS), such as reduced patient trauma and recovery time, lower morbidity, and lower health care costs, but they also eliminate surgeon tremor, reduce the effects of surgeon fatigue, and incorporate the ability to perform remote surgical procedures. However, current robotic surgical systems, such as the Da Vinci™ Surgical System, lack the capability of providing force feedback to the surgeon that is present in conventional surgery. Therefore, this lack of force feedback presents excellent developmental opportunities for surgeons and engineers to create novel surgical tools and methods to incorporate force feedback capabilities into these robotic surgical systems. The goal of this research is to restore force feedback capability to the surgeon in robot-assisted surgery through a haptic interaction experience involving force feedback from the surgical site using our novel teleoperation platform. This project will summarize our research including: 1)The Laparoscopic tool will be mounted over robotic arm.2)The Laparoscopic grasper can be integrated with force feedback system and tactile system.3)Incorporation of master slave technique in prototype model.4)The sensors will be used to transmit force data to slave controller and then transmitted wirelessly to master controller which then controlled by servo motor(force feedback device.5)Opening and closing process of Laparoscopic grasper is controlled by servo motor.

***Keywords*— Haptic feedback, Laparoscopic grasper, force feedback, teleoperation**

I. INTRODUCTION

This paper describes a laparoscopic tool which is mounted over robotics arm. It has 2-DOF, Laparoscopic grasper(3-DOF)which we are going to make is used to grasping the tissue with an integrated force feedback system .The system uses servo motor, flexi force sensors at the jaw of the laparoscopic grasper to detect tissue property and strain gauge force sensor at the shaft of laparoscopic tool to detect and measure tool tissue interaction force. The tactile system is integrated into a modified laparoscopic grasper such that forces at the grasper tips and tool tissue interaction force of each direction are felt by the both hands of the surgeon. Flexi-force sensors and strain gauge sensors transmit force data to slave controller then it is transmitted wirelessly to the master controller, which then control the servo motor (force feedback device). In this system opening and closing process of a laparoscopic grasper is controlled by a servo motor. It is wirelessly controlled by a surgeon from master side.

What is Laparoscopic Surgery?

Laparoscopic surgery is a revolutionary technique. It is minimally invasive, i.e., the surgery is performed with instruments inserted through small incisions (less than 10 mm in diameter) rather than by making a large incision to expose the operation site. The main advantage of this technique is the reduced trauma to healthy tissue, which is the leading cause of post-operative pain and long hospital stay of the patient. The hospital stay and rest periods, and therefore the procedure’s cost, are significantly reduced with minimally invasive surgery, at the expense of more difficult techniques performed by the surgeon.

Why Laparoscopy?

1. Minimize blood loss
2. Minimize post-operative pain
3. Expedite recovery time
4. Less risk of complications

Laparoscopic Grasper:

Is nothing but a grasping jaw with force sensors that have the ability to measure the grasping forces in three directions, namely Fx, Fy, and Fz.

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II. Literature Review

[1] In this paper, we present our results on design, development, and testing of an automated laparoscopic grasper that can provide tri-directional force feedback. Our design addresses the challenges mentioned above and focuses on the direct measurement of the tool/tissue interaction forces. In addition to grasping tissues, the sensors also allow the grasper to be used as a probe for probing soft-tissues. Through probing tissue or an organ surface, a surgeon can diagnose a localized area and then immediately grasp and manipulate the area without having to change tools or loose track of the diagnosed area. This paper will discuss: (1) design and development of the laparoscopic grasper, and (2) evaluation of the laparoscopic grasper in characterizing artificial tissues.

[2] In this paper, a dexterous, pressure-sensing laparoscopic grasper has the potential to enhance laparoscopic surgery by providing the manipulation capabilities associated with open surgery to minimally invasive laparoscopic procedures. While graspers are ideally natural extensions of the surgeon's hand in manipulating tissue, currently available tools significantly diminish the tactile feedback the surgeon receives. Hence, enhanced tactile feedback and grasping ability are important. Tissue trauma due to excessive grasp force is a frequent occurrence, and was the initial motivation for starting this project. Excessive force can damage tissue due to tissue ischemia when blood flow is cut off, or due to mechanical injury. Current graspers also have an unequal pressure distribution across their grasper surfaces since the grasper jaws possess only angular motion similar to that of crocodile jaws. Tissue grasped in the region of the jaws closer to the shaft inevitably experiences a higher pressure than tissue grasped at the tip of the jaws.
On the other hand, the primary purpose of a laparoscopic grasper is its ability to grasp tissue. Currently available graspers have a tendency to push tissue out of the grasper jaws as they close, due to their non-parallel closing motion. This makes grasping tissue difficult. As a result, tissue can get damaged from repeated attempts to grasp it. Finally, surgeons which use current graspers for extended periods of time are often subject to hand strain injuries due to handle design. We therefore decided to design a laparoscopic grasper with force feedback in the handle and a more dexterous grasping mechanism. This grasper is accurate and easier to use than a conventional grasper, and the handle is designed with human factors in mind.

[3] The technology development for minimally invasive surgery (MIS) allowed surgeons to perform surgery without directly using their hands in the operation sites. A few years later, the progress of robotic technology led to the first use of robots in the operating rooms. At present, recent advances in robotic technology have made the use of minimally invasive robotic surgery (MIRS) systems commonplace. By comparison with traditional surgical techniques, MIRS have significant advantages for both patients and surgeons. Due to these significant advantages, MIS and especially MIRS are growing fast and this growth is anticipated to expand over the next decades. However, despite the superiorities of MIS and MIRS over traditional open surgery techniques, there are a few unsolved shortcomings involved in MIS and MIRS. One of the important shortcomings is the lack of haptic (force and tactile) feedback to surgeons. For instance, the da Vinci Surgical System (Intuitive Surgical, Inc., Sunnyvale, CA), which is one of the widespread MIRS systems, does not provide the surgeon with haptic feedback during tissue manipulation. Such haptic feedback is sensory feedback that results from kinesthetic or
tactile feedback, while surgical instruments are interacting with tissues. Providing tactile feedback to the surgeon in MIS and MIRS, like palpation during open surgical procedures, helps the surgeon to characterize the contact tissues, to investigate anatomical structures of tissues, and to distinguish between different types of tissues. Such different types of tissues can be an abnormal tissue (e.g., a tumorous lump), an artery, a vein, a ureter, etc. surrounded with background tissues. In addition, tactile feedback from the interaction between surgical instruments and tissues allow the surgeons to apply appropriate interacting forces to avoid tissue damage during tissue manipulations. Generally, providing such feedback to the surgeons leads to better performance in MIS and MIRS. It is experimentally proved that providing tactile feedback reduces grasping force in MIRS performed by the da Vinci. Consequently, the development of a tactile sensor with the capability of measuring the force and the distributed tactile information is crucial to mimic the perception of the surgeon's fingertips in MIS and MIRS systems.

[4] In this paper, the goal of the design is to add a two DOF wrist to extend the four DOF available through the fulcrum, and therefore give enough dexterity to perform complex skills, especially suturing and knot tying, in the minimally invasive setting. The slave must be small enough to fit through incisions typically 10 mm wide, but also able to apply forces large enough to manipulate tissue and suture. It must have sufficient workspace to span significant regions in the abdominal cavity and suture at almost arbitrary orientations, yet have a wrist short enough in length to work in constrained spaces. System bandwidth should permit natural motions by the surgeon and haptic feedback with sufficient fidelity. Of course, the system must be safe to be used inside a patient. Performance goals in the design of the millirobot are given in Table I.1 these values are estimated for a suturing task, force and movement requirements for driving a needle through tissue and tying a knot. The diameter of the instrument is chosen to fit the standard 10 and 15 mm diameter trocars. It is preferable not to have larger diameters as it causes greater 1 Courtesy of Endorobotics Inc. TABLE I PERFORMANCE GOALS FOR THE MILLIROBOT damage to healthy tissue. It is not necessary to go smaller than 10 mm for laparoscopic surgery as there are other instruments,for example staplers, that require a 10 mm

trocar. The wristto-gripper length is determined by the clearance between the abdominal wall and the key organs when the abdomen is pressurized. Torque and force requirements are estimated from measurements on instruments performing suturing in an open surgical setting. A 270 of roll rotation is required for driving the needle through tissue in a single movement without regrabbing it. 90 of wrist flexion with 360 of gross rotation is necessary for suturing at the desired orientations. The bandwidth requirement is set to accommodate the bandwidth of intentional hand movements.

[5] In this paper, the complete system is mainly composed of two units. Body-mounted ViKY robot positioned on a patient. ViKY control unit. (a) ViKY system console, (b) autoclavable robotic camera holder, (c) safety foot pedal for voice control, and (d) foot pedal without voice control.1) The scope holder by itself: It has 3 DOF, each of them being actuated by autoclavable motor. This specific architecture allows that each of these 3DOFexactly corresponds to a given direction in the image frame (left/right, up/down, zoom in/out). This avoids a complex geometric and cinematic robot model for deriving motor commands from directional information obtained in the images, which is an obvious advantage for the visual servoing task addressed in this paper. 2) A control unit integrating motor drivers and software for scope holder control. One command mode is achieved by plugging a multidirectional footswitch to the control unit. Vocal command is an alternative choice for scope holder control. A wireless microphone and a voice recognition engine are used in this case. For instrument tracking, video output from the camera is digitalized by a video acquisition card installed in the control unit. The control unit allows the surgeon to easily redefine the amplitude of the movements if required, and contains a person-specific voice-recognition training module.

III.METHODS OF CONTROLLING OF OPERATION TOOL

a) Haptic feedback:

Haptics generally describes touch feedback, which may include kinesthetic (force) and cutaneous (tactile) feedback. In manual minimally invasive surgery (MIS), surgeons feel the interaction of the instrument with the patient via a long shaft, which eliminates tactile cues and masks force cues. Some studies have linked the lack of significant haptic feedback in MIS to increased intraoperative injury. In teleoperated robot-assisted minimally invasive surgery (RMIS), all natural haptic feedback is eliminated because the surgeon no longer manipulates the instrument directly. The lack of effective haptic feedback is often reported by surgeons and robotics researchers alike to be major limitation tocurrent RMIS systems.

b) Force feedback:

Force feedback improves the performance of telerobotic systems by providing a feeling of telepresence. In a system with perfect transparency, the force that the user feels when he moves the master manipulator is equal to the force he would feel if he were directly manipulating the environment. The main factors preventing perfect transparency in teleoperation include transmission delay, device friction, and device mass.

c) Tactile feedback:

The goal of tactile sensing in RMIS can be to detect local mechanical properties of tissue such as compliance, viscosity, and surface texture – all indications of the health of the tissue – or to obtain information that be used directly for feedback to a human operator, such as pressure distribution or deformation over a contact area.

IV.IMPLEMENTATION

A conventional laparoscopic grasper (manufactured by Ethicon) has been retrofitted with two strain gages on the handle and a position sensor to record the normal force exerted on the tissue by the jaws and the displacement of the jaws. However, in order to use an instrumented laparoscopic grasper in a robotic surgical system, automated actuation of the jaws is necessary. Therefore, our research focused next on the development of an automated laparoscopic grasper with force measuring capability through a calibration to the applied motor current; thus, requiring no force sensors on the tool. Additionally, the jaws were designed to be modular and replaceable with cutting or dissecting jaws. The next generation of our automated laparoscopic grasper involved the addition of force sensors for direct force measurement at the jaws and two additional degrees of force measurement for a total of three (normal, lateral, and longitudinal). Also, piezoresistive and resistive force sensors were incorporated into the jaw design for accurate measurement of the tool-tissue interaction forces at the jaw. Finally, the current generation of our automated laparoscopic grasper has incorporated the previous tri-directional force measurement capability in a compact, modular design for use in a clinical setting.

Conventional laparoscopic grasper with force measurement capability

For our initial prototype of a laparoscopic grasper with force feedback for minimally invasive surgery, we used a isposable laparoscopic grasper manufactured by Ethicon, Inc. The laparoscopic grasper was modified for testing purposes through the addition of two strain gages and a position sensor on the active handle of the tool. These modifications to the grasper created sensing capabilities for the characterization of tissue during grasping and palpation tasks; however, the functionality of the grasper was preserved as employed in MIS procedures.

Design and Development

The standard laparoscopic grasper consists of a 38cm rod with a 5mm diameter shaft that contains a jaw mechanism at one end and an active handle at the other end. The active handle rotates about an axis to actuate an internal rod that translates along the length of the tool shaft to control the opening and the closing of the jaws. This instrument is used for grasping, palpation, and dissection of tissues within the body.

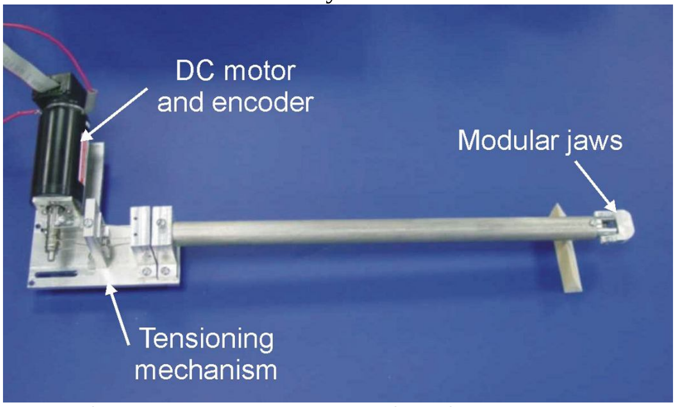

Fig. 1 :Prototype of the laparoscopic grasper with force feedback measurement capability.

Our initial prototype has been designed as a laparoscopic grasper; therefore, the end-effector consists of two serrated jaws to facilitate grasping (see Fig. 1). The jaws were similar to those found on conventional laparoscopic grasper with a few modifications. The grasping area on each jaw is approximately 0.25 square inches. This represents an increase in contact area of approximately 5 times over conventional tools. In subsequent versions of this prototype, the contact area was scaled down to a comparable value with currently used jaws. The jaws have also been designed with a quick-change feature.

V. RESULT

Our robotic surgical system incorporated a modular laparoscopic grasper. The laparoscopic grasper incorporates a normal grasping force sensor in one of the jaw of the tool and four strain gages located on the shaft of the tool for measurement of the surgical manipulation forces and the grasper is mounted on the end-effector of the robot arm in this system. The robot arm is a serial manipulator with joints, in our system. The haptic device is utilized as the master controller of the robot arm and laparoscopic grasper and also provides force feedback of the surgical forces to the operator of the system as measured by the grasper.

VI. CONCLUSIONS

In this paper, a laparoscopic tool consisting of force feedback system has been proposed and mounted on the surgical robotic arm. The system allowed surgeon to grasp tissues using the surgical robotic arm and feel the pressure levels at the hands of the surgeon that corresponds to force applied to the laparoscopic grasper with the servomotor attached to master control jig. The electro surgical tissue cutting mechanism with modification in feedback control can be in corporate in the same arrangement as a future work.

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