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FORCE FEED BACK SYSTEM FOR MINIMALLY INVASIVE ROBOTIC SURGERY

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ABSTRACT

Minimally invasive robotic surgery is a technique, in which small incisions are used for surgical access with the aid of robotic systems controlled by a surgeon. In medical surgery, robotic surgery belongs to many studies because of its advantages, such as better enhancing results, reduced recovery time, and more accurate surgical movements. In the conventional Minimally Invasive Robotic systems the surgeon gets only the video feedback from the patient's body, to increase the precision and the accuracy of the surgery a force feedback system is incorporated into the existing system. A master-slave configuration is used for this visual and force feedback system. This helps the surgeon to identify the exact position of the surgical instrument inside the patient's body whether it is bone or soft tissue. If it is a soft tissue then the surgeon will also get the thickness of the tissue. By identifying the exact position of the surgical instrument the surgeon can apply efficient amount of force that is suitable for the tissue. So the presence of the force feedback system will help the surgeon to do the surgery in a more precise manner.

Keywords: robotic surgery; minimally invasive surgery, integrated development environment.

INTRODUCTION

According to medical doctors, the 20th century was the century of surgery. The last century was also the period of huge traumata, due to large incisions, which are necessary to gain access to the operation area. Minimal and micro access techniques are introduced in the 21st century. This technique reduces the patients' trauma dramatically. During the last years several surgery robots developed for experimental or even routine application. Due to the number of advantages such as high precision, use of preoperative planning data and the option of new surgery techniques, such as minimally invasive robotic surgery, the Numbers of clinical applications increases.

The minimally invasive robotic surgery (MIRS) is a technique in which small incisions are used for the surgical access with the aid of robotic system controlled by the specialist. The Minimally invasive robotic surgery is also called endoscopic or keyhole surgery. Minimally invasive robotic surgery is one of the most dynamically developing areas of medical surgeries. Minimally invasive robotic surgery has been used for different surgeries such as cardio surgery, neurosurgery, cholecystectomy, and radiosurgery. In medical science robotic surgery is the subject of many studies because of the advantages offered such as

- Better cosmetic result
- Reduced recovery time
- Precise surgical movements

In conventional minimally invasive robotic surgery systems the video feedback is the only information given to the surgeon from patient's body. From the visual feedback the surgeon will only get the 2D images from the surgical environment it provides the visual properties of the tissues. It will affect the accuracy and precision of the minimally invasive robotic surgery. Because of the following drawbacks:

- Vision is restricted in to 2D video monitoring
- Demands higher precision from the surgeon
- The consequences for the patients may be
    - Internal bleeding
    - Infection and even death

To increase the precision and accuracy of the surgery a force feedback system is incorporated into the existing system. This helps the surgeon to identify the exact position of the surgical instrument inside the patient's body whether it is bone or soft tissue, so the presence of the force feedback system helps the surgeon to do the surgery in more precise manner.

This paper is organized as follows, section II mainly presents the minimally invasive robotic surgery, including visual feedback system in an MIRS followed by force feedback system for a MIRS. Section III principle components. Section IV presents design part, including sensor part for the video and force feedback system, a slave Robotic arm and a controlling software part. The last part is result followed by a conclusion and reference list.

MINIMALLY INVASIVE ROBOTIC SURGERY

Minimally invasive surgery (MIS), is a way of performing surgical procedures by inserting tools through small incisions or natural orifices on the human body. This is a technology developed to accomplish an optimal result for the patient by mainly focusing on the area that is injured and not the surrounding organs, muscles and tissue. The minimally invasive robotic surgery is having several benefits like, the invasion and tissue trauma is minimized to the adjacent tissue and muscles, and the incisions are very small as compared with open surgery so the results is being, the patients recovery time is reduced, the hospital stay gets shorter and the incidence of post-surgical complications and morbidity is reduced. The drawbacks with MIS are that the tactile feedback is reduced or even non-existing, vision is reduced to 2D video monitoring, and the stiff surgical tools gives less degrees of freedom in manipulation than conventional open surgery.

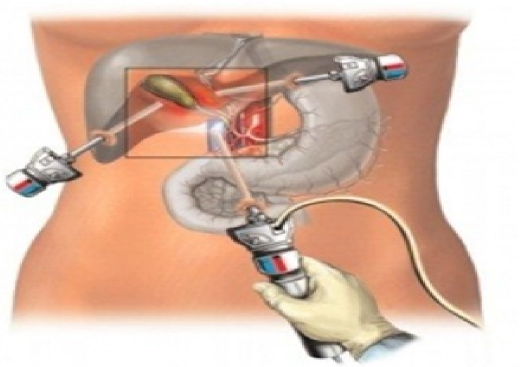

Figure-1. Minimally invasive surgery setup.

The consequences for the patient may be internal bleedings, infections and even death. One group of surgical robot systems is the operated systems where the surgeon performs the surgical procedure indirectly, by controlling a robot which performs the actual operation. Lack of tactile feedback is one of the most significant drawbacks of the existing minimally invasive robotic system. To solve this problem the researchers try to incorporate force feedback to the existing system. Because of the presents of both the feedback systems the surgeon is able to identify the interacting environment of the surgical tool. An advantage appears when introducing virtual forces with the objective of guiding the motions of the operator helping him to complete the task successfully.

Visual Feedback System in a MIRS

Robotic surgery attempts to supplement the performance of the surgeon with a robot, overcoming some of the difficulties encountered with minimally invasive surgery while reducing trauma for the patient. In typical minimally invasive robotic surgery, a robotic end effector passes through a small port in the body to interact with internal tissue. The motion of the robot is controlled by the surgeon, by moving an interface mechanism whose motion is mapped to the robot. A complete robotic surgical system would consist of two interface mechanisms and their corresponding instruments, as well as an endoscopic camera and monitor for visual feedback.

Force Feedback System for MIRS

Force feedback refers to the transmission of object shape or stiffness through the generation of motion or strain in the operator's muscles and joints. This will increase the accuracy and precision of the surgery. Force feedback is widely assumed to enhance performance in robotic surgery. The average force magnitude applied to the tissue is increased at least 50% in the absence of force feedback, and increased the peak force magnitude by at least 100%.

The number of errors that damage tissue increased by over a factor 3. The advanced visual devices sometimes may not be able to identify the Tumours buried under the tissue surface; it can be done by the visual feedback along with the force feedback. The important problem that may result in the surgery because of the absence of force feedback is increasing tissue trauma and the unintentional damage of healthy tissue. So for increasing the precision and accuracy, a force feedback system is incorporated to the current minimally invasive one. The force feedback system is providing the information about the type of tissue to the doctor whether it is soft or hard so that the doctor can apply the exact amount of force required for that particular type of tissue. If it is a soft type of tissue the doctor should know the depth of the tissue before applying the force. Then only the minimally invasive surgery becomes more accurate and precision.

PRINCIPLE COMPONENTS

The aim of the paper is to implement the coordinated movement of the joints of a robotic arm, according to the instructions of the surgeon. The combination of visual feedback and force feedback with a force based automatic thresholding is used to minimize the patient tissue trauma and tissue damage, while the robotic arm performs gripping, suturing, and other movements inside the body. The objective of this paper can be divided into 3 parts:

- A master control unit
- A slave robotic arm
- A force feedback system

The slave system consists of several subsystems. The minimally invasive instruments should be small (diameter less than 10 mm) in order to reduce pain and trauma to a minimum. This sensor data can be used for feedback to increase the quality of immersion of the operator and more intelligent control low of surgical robots. Force measurements can be used to limit the maximum manipulation force and to detect collision between instruments.

The master system has to provide high quality feedback, both force and video. This is necessary to find invisible structures. The surgeon has direct access to the force at the operating area and therefore increases the quality of the operation. The application of high quality 3D vision is strongly recommended to gain depth information. The communication between master and the salve has to be flexible and safe. The slave part will provide the force and video information to the master computer.

The device can be divided into three parts: The master, the slave robotic arm and the feedback system together with the depth information. The master part comprises of a Laptop which provides the position and gripper movement information to the slave robotic arm through USART. The slave robotic arm moves accordingly and receives force and depth information via the force and depth sensors placed at the gripper end. This force and depth information as well as the video input from the slave robotic arm is transferred back to the master controlling part for actuation and tissue identification, also the force information is used to restrict the gripper from applying more than a specific amount of force.

The sensors placed on the gripper end picks the force as well as the depth and camera picks the visual properties of the tissue, both are given to the laptop present in the master part through the USART. The surgeon will take decision according to both the visual and force feedback. Accordingly the force is applied to the different tissues by inverse kinematics through the slave robotic arm.

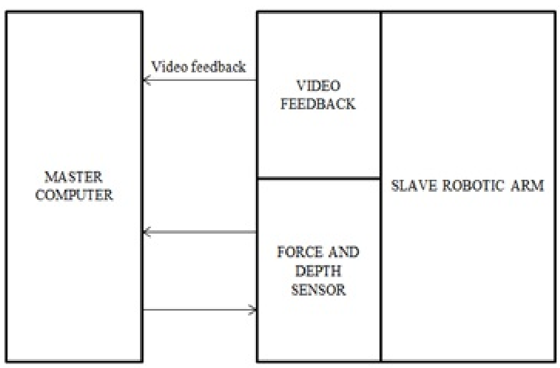

Figure-2. Block diagram.

DESIGN

The components of this paper consist of three parts Master, Slave and feedback. The master part consists of a laptop and an USART connection. The slave part consists of a sensor circuit for force on the tip of the robotic arm end effector. Also a video camera for real time video feedback. And the end effector also consists of a sensor for identifying the depth of the tissue.

Master Control Unit

The master control unit is a laptop, through which the surgeon can view two panels. One is for video feedback and another is for controlling the slave robotic arm by viewing the tissue type and depth. The video camera placed in the end of gripper will send the video of the surgical environment and the force sensor placed in the gripper end will send the force information about the tissue to the microcontroller. The microcontroller will identify the type of tissue according to the program build in it. Both the force feedback and the video feedback is then available to the surgeon through the USART. Then the master control unit is having a control panel through that the surgeon can control the slave robotic arm.

Robotic Arm

In the case of minimally invasive robotic surgery the doctor is doing the surgery through a support of surgical robot. The numbers of surgical robotic arms are used for the same. The robotic arm is used in the minimally invasive surgery for doing the surgery. The force sensors and the camera are placed in the instrument holed by end effecter of the robotic arm. And also the surgeon can control it. The choosing of surgical robot is related to the type of surgery. The slave part consists of a robotic arm. For the purpose of mounting the pressure sensor and applying the inverse kinematics the *OWI* Robotic Arm Edge is used, this is a kit which can be assembled to form the robotic arm.

Figure-3. OWI robotic arm.

Sensor Part

In the conventional Minimally Invasive Robotic Systems the surgeon is only getting the video feedback. The force feedback along is not sufficient for the Robotic Surgery. The video feedback together with the force feedback will increase the precision of the surgery. In this paper we also in corporate a force sensor along with camera. Camera is for getting the surgical environment to the surgeon and also for collecting the physiological characters of the tissues. The camera module used here is a camera transmitter receiver set. Wireless Micro Camera is used here. This is contains a CMOS sensor. The camera transmitter can transmit images wirelessly or it can itself be connected display directly. Through this the surgeon can view the surgical environment.

The force sensor used here is a small force sensitive resistor. Mainly used to identify the type of tissue that is having the contact with surgical instrument tip. There for the sensor is placed in the end of the needle of surgical instrument that is placed in the end effector of the robotic arm. The sensor used in this paper is a Force Sensor 5.08mm. It has 4mm diameter active sensing area. This force sensitive resister will vary its resistance depending on how much pressure is being applied to the sensing area. The harder the force, lower the resistance. An infrared (IR) sensor is used to detect the depth of the tissue in contact with the surgical instrument. This will help the surgeon to identify the depth of the soft tissue through that they can avoid the unwanted pressure on the soft tissue.

Software Part

The tissue identification and the control of the robotic arm is done by the software AVR. The force sensor is placed in the end effector of the robotic arm. Those particular values are amplified and given to the microcontroller that is doing the identification of the soft tissue and the hard tissue. After the identification that value is given to the laptop through the USART connection. According to the tissue identified by the controller, the surgeon can decide the amount of the force, then the robotic arm is controlled according to that force through AVR. Atmel AVR Studio 5 is an integrated development environment used for writing the program in AVR controller. Atmel AVR Studio 5 is the Integrated Development Environment (IDE) for developing and debugging embedded Atmel AVR applications. The AVR Studio 5 IDE gives you a seamless and easy-to-use environment to write, build, and debug your C/C++ and assembler code.

RESULT AND ANALYSIS

Robotic arms available in the market were surveyed and it was decided to use “OWI Robotic Edge” to mount the pressure sensing element and to apply the inverse kinematics force so that precise and easy control of the robotic arm can be achieved. A study on various pressure sensing methods was done and it was decided to use force sensor for the measurement. The measured value is converted and given to the AVR Atmel 32 microcontroller. The program is in built in the microcontroller. Accordingly that will identify the tissue, whether it is soft or hard tissue. Then the tissue type is displayed on the LCD place in the board. An IR sensor is also placed in the end of the surgical instrument. Through that the depth of the tissue can identified. Then the video camera gives the properties of surgical environment to the surgeon. A MATLAB program is used for analyzing and filtering the video feed back part. According to this information’s the surgeon can control the robotic arm section using keyboard.

This will increase the precision and the accuracy of the minimally invasive Robotic Surgery.

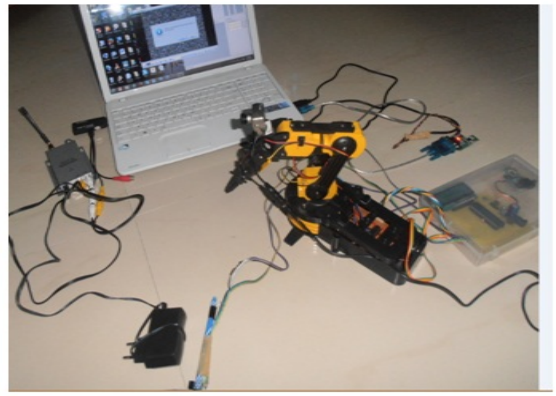

Figure-4. Entire system.

CONCLUSIONS

The minimally invasive robotic surgery is a advancing technology, in which the patient recovery time is very less. In the conventional minimally invasive robotic surgery the surgeon will only get the visual feedback from the patient’s body. This may lead to the unwanted applying of large amount of force to the tissues because of the less precision. The force feedback system along with the visual feedback system will increase the precision and accuracy. Because of the presents of force feedback the surgeon will gets the exact position of the surgical instrument inside the patient’s body whether it is a soft tissue or hard tissue. So that the exact amount of the force can be applied to the tissue according to the different tissues. This will reduce the internal bleeding and infection.

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