Report on Tactile Feedback System for Da Vinci Robot

ENME808M

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Introduction:

Robotic surgery leads to increase in the range of motion, improved vision and higher precision as compared to the standard procedures. Another key area where robotic surgery excels would be the in the minimally invasive surgeries. They can operate with smaller incisions being made in the human body leading to faster recovery and quicker discharge time from the hospital. The da Vinci robotic system has brought minimally invasive surgery to more than 3 million patients worldwide.

Background:

The Da Vinci Robotic System is a human controlled robot that allows the surgeon's hand movements to be translated into smaller, precise movements of tiny instruments inside the patient's body. The surgeon is always a 100% in control of the robot. One thing to note here is that the da Vinci surgical robotic system only provides minimal force feedback. It is very restrictive and only occurs when the robotic tools collide with other rigid structures. The robot does not prevent damage to soft tissues or breaking of sutures inherently.

Figure 1 An overview of the Da Vinci Robot

Visual information is usually enough for most procedures; but, the addition of tactile information may enable surgeons to "feel" tissue better, more optimally work with sutures, better identify pathology cases. Haptic feedback may also decrease the learning curve associated with the learning of robotic surgery.

Approach:

The paper this report is based on describes a tactile feedback system with a silicone-based pneumatic balloon as the actuator, a piezoresistive force sensor, and a pneumatic control system that translates forces at the sensor (on the gripper) to pressures in the actuator (at master control side). The system has been attached on the da Vinci surgical robotic system and allows forces at the robotic end-effectors to be felt by the fingers of operator.

Actuator:

Actuators arrays were developed to provide pneumatic pressure stimuli to the fingers using hemispherical silicone balloons. The actuator arrays were designed specifically for mounting on the master controls of the da Vinci robotic surgical. The actuator arrays are comprised of a macro molded polydimethylsiloxane substrate housing pneumatic channels and a thin film silicone membrane. The presence of the actuator array gives the ability to provide spatial orientation of the object at the operator's fingers.

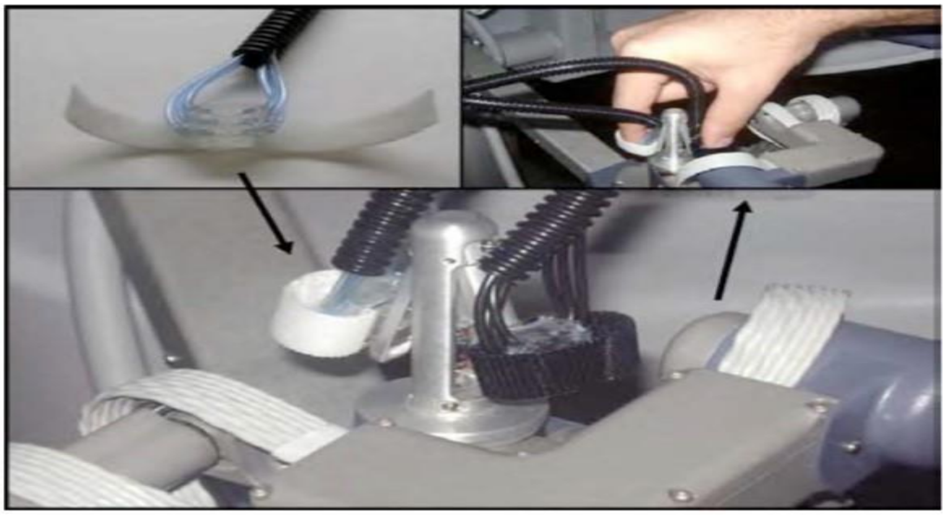

Figure 2 Pneumatic actuator on the Master console

Sensor:

Piezoresistive force sensors were mounted directly onto the end-effectors of the da Vinci robotic surgical system. Piezoresistive force sensors 'Tekscan FlexiForce' were selected for mounting onto the Cadiere tools (Type of gripper used).

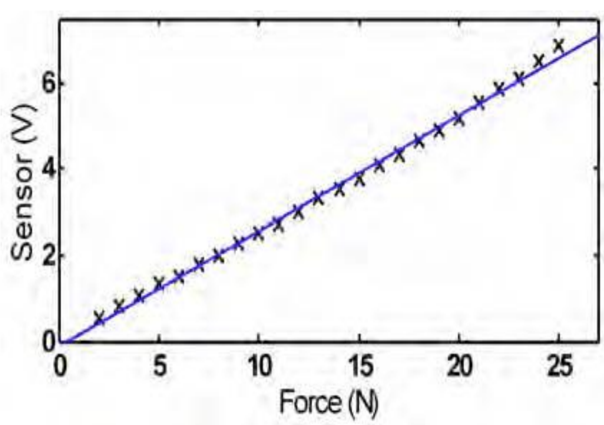

Figure 3 Voltage output according to variation of force

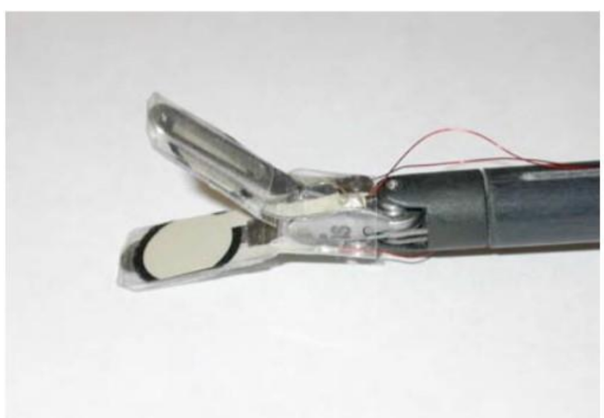

Figure 4 Force sensor mounted on the gripper

Control system:

The control system processes the sensor resistances into voltages, calculates the level of balloon inflation for each input resistance, and generates the control output signals to the pressure regulators for desired inflation pressures into the balloons.

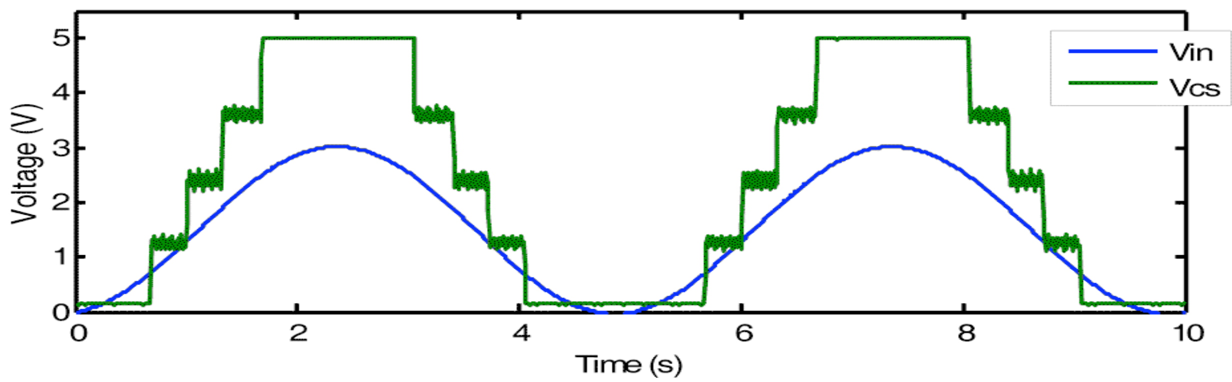

Figure 5 Input from the sensor (Blue) and output from the control system (Green)

The control system was connected to the pneumatic system, sensor, and actuator. The feedback system allowed users to 'feel' five discrete force levels applied by the robotic end-effectors when grasping objects with the master controls using their fingers.

Evaluation:

Figure 6 The robot being operated on a pressure sensitive film

A pressure-indicating film was attached to a rectangular neoprene strip and used to estimate grasping forces both with and without tactile feedback. Four subjects, including one novice, one surgical resident, one laparoscopic minimally invasive surgery fellow, and one robotic surgery expert, participated in a grasping test using the pressure sensitive film. Actuator arrays were mounted on the da Vinci master control at each subject’s dominant hand, and force sensors were mounted on both tips of the corresponding grasper.

Conclusion:

Figure 7 Pressure film showing test results for no feedback condition (Top) and using tactile feedback (Bottom)

For all the test subjects, a greater number of marks with higher color intensity was present in the films that were grasped without tactile feedback. Fewer, lighter marks appeared on the films when tactile feedback was used to grasp the film, thereby, indicating that less force was applied by all subjects when the tactile feedback system was active. Which shows that tactile feedback may prove beneficial to robotic surgery by allowing the surgeon to more optimally apply forces to tissues and sutures during surgery.

References:

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