Tactile feedback without direct touch: an achievement for robotically working heart surgeons?

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Abstract

For the improvement of telemanipulated operations haptic feedback is implemented into a realistic experimental robotic surgical platform. The importance and acceptation of force-feedback for robotic heart surgeons is evaluated. The study intended basic surgical and cardiac surgical procedures. Knot tying, breaking suture material and detection of arteriosclerosis had to be performed in a defined cycle with double blinding. The goal of these experiments was to examine claims about necessity of force feedback for robot-assisted surgical procedures in cardiac surgery. We present an approach of evaluating haptic feedback with a novel robotic system for minimally invasive and endoscopic surgery. The performance of certain surgical challenges while knot-tying will profit from this feature. Experiments have shown that haptic feedback can be employed to prevent the surgeon from potentially harmful tissue defects and breaking of suture material.

1 Introduction

The introduction of telemanipulator systems into cardiac surgery enables the heart surgeon to perform sophisticated minimally invasive and endoscopic procedures with high precision under stereoscopic view. At present the commercially available robotic surgical systems do not dispose of force feedback for the operating surgeon. The lack of haptic (force or tactile) feedback causes damage of tissue and bending or breaking of suture material [1]. For further improvement of telemanipulated systems we implemented haptic into a realistic experimental platform [2] and evaluated force-feedback for robotic heart surgery. We provide a robotic scenario which offers the surgeon an impression very similar to usual and open procedures with high immersion. It enables the surgeon to feel for arteriosclerosis in coronary vessels, to tie surgical knots with delicate suture material and to feel the break of suture material. The aim of this study was to analyse the presence of haptic feedback in typical cardiac surgical procedures for the safety of the patients and for the quality in endoscopic procedures.

2 Material and Methods

2.1 Robotic system with force feedback

The robotic system we built up consists of two surgical manipulators, which are controlled by two PHANTOM® input devices, and a third robot, which carries the stereoscopic camera.

Each manipulator is composed of a KUKA KR 6/2 robot that bears a surgical instrument of Intuitive Surgical® (see **figure 1**). The KUKA robot disposes of six degrees of freedom. The surgical instruments provide three degrees of freedom. A micro-gripper at the distal end of the shaft can be rotated and the adaptation of pitch and yaw angles is possible. Since the shaft of the surgical instrument is made of carbon fibre, force sensors have to be very sensitive and reliable. Therefore strain gauge sensors are applied at the distal end of the instrument's shaft near the gripper in order to display the real forces during operation.

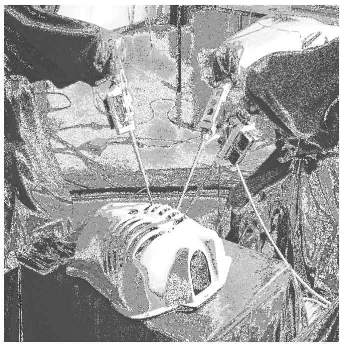

Figure 1 Surgical robotic system with haptic feedback

The signals from the sensors are amplified and transmitted via CAN-bus to a PC system. Since reading of direct sensor is associated with noise a smoothing filter is applied in order to stabilize the results.
The surgeon controls the position and orientation of the manipulators with two PHANTOM® devices. It provides enough space to perform surgical procedures. A stylus pen equipped with a switch is used to open and close the micro-grippers. One outstanding feature of the PHANTOM® devices is their capability of displaying forces to the user. Forces are fed back by small servomotors incorporated in the device.

2.2 Subjects and surgical tasks of haptic evaluation

The human subjects of this study included 25 surgeons within the Clinic for Cardiovascular Surgery in the German Heart Center at the Technical University of Munich in different levels of surgical training and age. The study intended basic surgical and cardiac surgical procedures (see **figure 2**). Knot tying, breaking suture material and detection of arteriosclerosis had to be performed in a defined cycle with double blinding. These tasks imply at least basic knowledge in surgical principles. The participants dealt with three different levels of haptic feedback: no haptic, actually fed back forces and enhanced force feedback.

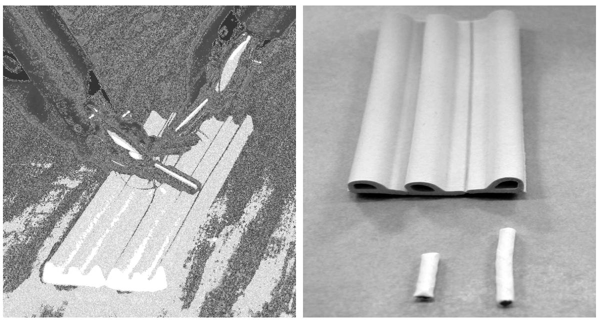

Figure 2 Surgical knot tying and the detection of stenosis

The critical flicker fusion frequency (CFF) was measured analyzing the progression of fatigue during the evaluationduring the experiment in between three blocks of tasks using three different degrees of haptic.

3 Results

The disruption of suture material and injuries to the tissue occur less with haptic feedback for the surgeon. The amount of the applied forces while manipulating decreases with haptic feedback.. The surgeon's subjective sensation of safeness and confidence while manipulating with implemented haptic feedback is enhanced versus non-haptic environment. The decrease of visual stress is detected with haptic versus non-haptic conditions in this setup. The surgeons could classify the different levels of haptic while working and identify the schematically ordered sequence of force feedback in the three main tasks. The impression of telepresence in this experimental surgical setup is significantly higher under increasing haptic feedback.

4 Conclusion

The goal of these experiments was to examine claims about necessity of force feedback for robot-assisted surgical procedures in cardiac surgery. We present a novel approach of a robotic system for minimally invasive and endoscopic surgery. The main purposes of the system are evaluation of force feedback and machine learning. The performance of certain surgical tasks like knot-tying will profit from this feature. Experiments have shown that haptic feedback can be employed to prevent the surgeon from potentially harmful mistakes. Tension of thread material and tissue parts can be measured and displayed in order to restrict force application to tolerable amplitude. For the future clinical use the perfection is planned by improving the set-up of the instruments and by incorporating these results of the evaluation into the control software. A simulation environment is designed for modelling haptic interaction with a tissue model. This can be applied for offline evaluation of critical tasks. In our experimental set-up we are able to demonstrate that the surgical procedure in robotic heart surgery is safer, quicker and gentler for the patient and more comfortable for the surgeon using force feedback.

Acknowledgment

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5 Literature

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