Roboterunterstützte Herzchirurgie: Einführung automatischer Operationssequenzen in einem experimentellen System

Towards robotic heart surgery: Introduction of autonomous procedures into an experimental surgical telemanipulator system

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Introduction

The introduction of telemanipulator systems into cardiac surgery enabled to perform minimally invasive procedures with high precision and stereoscopic view. For further improvement and especially for inclusion of autonomous action sequences, implementation of force-feedback is necessary. The aim of our study was to provide a robotic scenario giving the surgeon an impression very similar to open procedures (high immersion) and to enable autonomous surgical knot tying with delicate suture material.

Materials and Methods

Similar to other systems, our setup comprises an operatorside master console for in-output and a patient-side robotic manipulator that directly interacts with the operating environment. Position and orientation of the manipulators are controlled by two PHANToM devices (Fig. 1). providing a full 6 dof input, while force feedback is restricted to three translational directions. The user controls a stylus pen equipped with a switch used to open and close the micro-grippers. Forces are fed back by servo motors incorporated in the device. They are used to steer the stylus pen in a certain direction creating the impression of forces, while the user is holding the pen at a certain posture. The force sensors were applied directly on the shaft of the instrument. Since the shaft of the surgical instrument is made of carbon fibre, force sensors have to be very sensitive and reliable. Therefore we decided to apply strain gauge sensors, which are employed for industrial force registration. As shown in Fig. 2, the sensor gauges are applied at the distal end of the instrument's shaft, i.e. near the gripper. At the top of Fig. 2, the perpendicular arrangement of strain gauges as full bridges is demonstrated. One full bridge of sensors is used for each direction. Signals from the sensors are amplified and transmitted via CAN-bus to a PC system.

As sensor readings are blurred with noise, we have applied digital filters to stabilize the results. Knowing the position and orientation of the instruments, we can transform occurring forces back to the coordinate system of the PHANToM devices. For the introduction of an autonomous surgical knot, trajectories and forces during a knot performed by a surgeon were recorded and reproduced by the system by methods of skill-transfer.

Results

The user has the impression of direct haptic immersion, while the system records forces during any time of a given task. Using the data recorded, the system was able to perform autonomous knot tying with delicate surgical material without breaking the thread or the needles. Fig. 3 shows the amount of forces during successful tying of several knots.

Conclusion

In our experimental set-up, we were able to demonstrate for the first time, that autonomous surgical knot tying is possible using stereoscopic view and force feedback. Further investigations will evaluate the usefulness of haptic informations on procedures performed by a human teleoperator.